

## Overview

The KEMET ESH radial aluminum electrolytic capacitors offer high CV and are designed for high quality, high reliability applications requiring a miniature solution.

## Applications

Typical applications include general purpose coupling, decoupling, bypass, and filtering.

## Benefits

- Suited for high quality, high reliability applications
- High CV
- 2,000 hour operating life
- Operating temperature of up to +105°C
- Case with  $\varnothing D \geq 5$  mm
- Safety vent on the capacitor base



## Part Number System

ESH	107	M	6R3		A	C3	AA
Series	Capacitance Code (pF)	Tolerance	Rated Voltage (VDC)		Electrical Parameters	Size Code	Packaging
Radial Aluminum Electrolytic	First two digits represent significant figures for capacitance values. Last digit specifies the number of zeros to be added.	M = $\pm 20\%$	6R3 = 6.3 010 = 10 016 = 16 025 = 25 035 = 35 050 = 50 063 = 63 100 = 100	160 = 160 200 = 200 250 = 250 350 = 350 400 = 400 420 = 420 450 = 450 500 = 500	A = Standard	See Dimension Table	See Ordering Options Table

## Ordering Options Table

Diameter	Length	Packaging Type	Lead Type	Lead Length (mm)	Lead and Packaging Code
Standard Bulk Packaging Options					
4 – 22	All	Bulk (bag)	Straight	20/15 Minimum	AA
Tape & Reel					
4 – 5	All	Tape & Reel	Formed to 2.5 mm	$H_0 = 16 \pm 0.75$	LA
4 – 8	All	Tape & Reel	2.5 mm lead spacing	$H_0 = 18.5 \pm 0.75$	KA
4 – 8	All	Tape & Reel	Formed to 5 mm	$H_0 = 16 \pm 0.75$	JA
10	≤ 20	Tape & Reel	Straight	$H_0 = 18.5 \pm 0.75$	KA
Ammo Pack					
4 – 8	All	Ammo	Formed to 5 mm	$H_0 = 16 \pm 0.75$	DA
4 – 8	All	Ammo	Straight	$H_0 = 18.5 \pm 0.75$	EA
4 – 5	All	Ammo	Formed to 2.5 mm	$H_0 = 16 \pm 0.75$	FA
10 – 13	All	Ammo	5 mm lead spacing	$H_0 = 18.5 \pm 0.75$	EA
16	All	Ammo	7.5 mm lead spacing	$H_0 = 18.5 \pm 0.75$	EA
18	≤ 25	Ammo	7.5 mm lead spacing	$H_0 = 18.5 \pm 0.75$	EA
Contact KEMET for other lead and packaging options					

## Environmental Compliance

As an environmentally conscious company, KEMET is working continuously with improvements concerning the environmental effects of both our capacitors and their production. In Europe (RoHS Directive) and in some other geographical areas like China, legislation has been put in place to prevent the use of some hazardous materials, such as lead (Pb), in electronic equipment. All products in this catalog are produced to help our customers' obligations to guarantee their products and fulfill these legislative requirements. The only material of concern in our products has been lead (Pb), which has been removed from all designs to fulfill the requirement of containing less than 0.1% of lead in any homogeneous material. KEMET will closely follow any changes in legislation world wide and make any necessary changes in its products, whenever needed.

Some customer segments such as medical, military and automotive electronics may still require the use of lead in electrode coatings. To clarify the situation and distinguish products from each other, a special symbol is used on the packaging labels for RoHS compatible capacitors.

Due to customer requirements, there may appear additional markings such as lead free (LF) or lead-free wires (LFW) on the label.

## Dimensions – Millimeters



Size Code	D		L		P		d		LL+/LL-
	Nominal	Tolerance	Nominal	Tolerance	Nominal	Tolerance	Nominal	Tolerance	Minimum
C3	5.0	±0.5	11.0	+1.5/-0	2.0	±0.5	0.5	Nominal	20/15
E3	6.3	±0.5	11.0	+1.5/-0	2.5	±0.5	0.5	Nominal	20/15
G3	8.0	±0.5	11.0	+1.5/-0	3.5	±0.5	0.6	Nominal	20/15
G4	8.0	±0.5	15.0	+1.5/-0	3.5	±0.5	0.6	Nominal	20/15
G8	8.0	±0.5	16.0	+1.5/-0	3.5	±0.5	0.6	Nominal	20/15
H1	10.0	±0.5	12.0	+1.5/-0	5.0	±0.5	0.6	Nominal	20/15
H9	10.0	±0.5	12.5	+1.5/-0	5.0	±0.5	0.6	Nominal	20/15
H2	10.0	±0.5	15.0	+2.0/-0	5.0	±0.5	0.6	Nominal	20/15
H8	10.0	±0.5	16.0	+2.0/-0	5.0	±0.5	0.6	Nominal	20/15
H4	10.0	±0.5	20.0	+2.0/-0	5.0	±0.5	0.6	Nominal	20/15
L3	13.0	±0.5	20.0	+2.0/-0	5.0	±0.5	0.6	Nominal	20/15
L4	13.0	±0.5	25.0	+2.0/-0	5.0	±0.5	0.6	Nominal	20/15
M7	16.0	±0.5	25.0	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15
M2	16.0	±0.5	32.0	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15
M3	16.0	±0.5	36.0	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15
N5	18.0	±0.5	25.0	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15
N8	18.0	±0.5	30.0	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15
N1	18.0	±0.5	32.0	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15
N2	18.0	±0.5	36.0	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15
N3	18.0	±0.5	40.0	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15
N7	18.0	±0.5	45.0	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15

## Performance Characteristics

Item	Performance Characteristics		
Capacitance Range	1 – 22,000 $\mu$ F	0.47 – 470 $\mu$ F	2.2 – 82 $\mu$ F
Capacitance Tolerance	$\pm$ 20% at 120 Hz/20°C		
Rated Voltage	6.3 – 100 VDC	160 – 450 VDC	500 VDC
Life Test	2,000 hours (see conditions in Test Methods & Performance)		
Operating Temperature	-40°C to +105°C	-25°C to +105°C	-25°C to +105°C
Leakage Current	$I \leq 0.01 CV (\mu A)$ or 3 $\mu A$ , whichever is greater	$I = 0.03 CV (\mu A) + 10 \mu A$	$I = 0.04 CV (\mu A) + 100 \mu A$
C = rated capacitance ( $\mu$ F), V = rated voltage (VDC). Voltage applied for 2 minutes at 20°C.			

## Impedance Z Characteristics at 120 Hz

Rated Voltage (VDC)	6	10	16	25 – 100	160 – 250	350 – 450	400 – 500	400 – 500
Z (-25°C)/Z (20°C)	4	3	2	2	4	4	6	15
Z (-40°C)/Z (20°C)	8	6	4	3	-	-	-	-

## Compensation Factor of Ripple Current (RC) vs. Frequency

Rated Voltage (VDC)	Capacitance Range ( $\mu$ F)	120 Hz	300 Hz	1 kHz	10 kHz
6.3 – 100	1.0 – 68 $\mu$ F	1.00	1.30	1.57	2.00
6.3 – 100	100 – 470 $\mu$ F	1.00	1.23	1.34	1.50
6.3 – 100	471 – 22,000 $\mu$ F	1.00	1.10	1.13	1.15
160 – 450	1.0 – 22,000 $\mu$ F	1.00	1.25	1.40	1.60
500	1.0 – 22,000 $\mu$ F	1.00	1.05	1.10	1.15

## Test Method & Performance

Conditions	Load Life Test	Shelf Life Test
Temperature	105°C	105°C
Test Duration	2,000 hours	1,000 hours
Ripple Current	Maximum ripple current specified at 120 Hz 105°C	No ripple current applied
Voltage	The sum of DC voltage and the peak AC voltage must not exceed the rated voltage of the capacitor	No voltage applied
Performance	<b>The following specifications will be satisfied when the capacitor is restored to 20°C:</b>	
Capacitance Change	Within ±20% of the initial value	
Dissipation Factor	Does not exceed 200% of the specified value	
Leakage Current	Does not exceed specified value	

## Shelf Life

The capacitance, ESR and impedance of a capacitor will not change significantly after extended storage periods, however, the leakage current will very slowly increase.

KEMET's E aluminum electrolytic capacitors should not be stored in high temperatures or where there is a high level of humidity. The suitable storage condition for KEMET's E aluminum electrolytic capacitors is +5 to +35°C and less than 75% in relative humidity. KEMET's E aluminum electrolytic capacitors should not be stored in damp conditions such as water, saltwater spray or oil spray. KEMET's E aluminum electrolytic capacitors should not be stored in an environment full of hazardous gas (hydrogen sulphide, sulphurous acid gas, nitrous acid, chlorine gas, ammonium, etc.) KEMET's E aluminum electrolytic capacitors should not be stored under exposure to ozone, ultraviolet rays or radiation.

**If a capacitor has been stored for more than 18 months under these conditions and it shows increased leakage current, then a treatment by voltage application is recommended.**

## Re-Age (Reforming) Procedure

Apply the rated voltage to the capacitor at room temperature for a period of one hour, or until the leakage current has fallen to a steady value below the specified limit. During re-aging a maximum charging current of twice the specified leakage current or 5 mA, whichever is greater, is suggested.

**Table 1 – Ratings & Part Number Reference**

VDC	VDC Surge Voltage	Rated Capacitance 120 Hz 20°C (µF)	Case Size D x L (mm)	DF 120 Hz 20°C (tan δ %)*	RC 120 Hz 105°C (mA)	LC 20°C 2 minutes (µA)	Part Number
6.3	8	100	5 x 11	26	100	6.3	ESH107M6R3AC3(1)
6.3	8	150	5 x 11	26	120	9.5	ESH157M6R3AC3(1)
6.3	8	220	6.3 x 11	26	165	13.9	ESH227M6R3AE3(1)
6.3	8	330	6.3 x 11	26	200	20.8	ESH337M6R3AE3(1)
6.3	8	470	6.3 x 11	26	230	29.6	ESH477M6R3AE3(1)
6.3	8	470	8 x 11	26	280	29.6	ESH477M6R3AG3(1)
6.3	8	680	8 x 11	26	350	42.8	ESH687M6R3AG3(1)
6.3	8	680	10 x 12	26	320	42.8	ESH687M6R3AH1(1)
6.3	8	1000	8 x 15	26	445	63.0	ESH108M6R3AG4(1)
6.3	8	1000	10 x 12	26	470	63.0	ESH108M6R3AH1(1)
6.3	8	1000	10 x 12.5	26	470	63.0	ESH108M6R3AH9(1)
6.3	8	1500	10 x 15	26	600	94.5	ESH158M6R3AH2(1)
6.3	8	1800	10 x 16	26	600	113.4	ESH188M6R3AH2(1)
6.3	8	2200	10 x 20	26	800	138.6	ESH228M6R3AH4(1)
6.3	8	2200	13 x 20	26	930	138.6	ESH228M6R3AL3(1)
6.3	8	3300	13 x 20	26	1100	207.9	ESH338M6R3AL3(1)
6.3	8	4700	13 x 20	26	1180	296.1	ESH478M6R3AL3(1)
6.3	8	4700	16 x 25	26	1320	296.1	ESH478M6R3AM7(1)
6.3	8	6800	16 x 25	26	1490	428.4	ESH688M6R3AM7(1)
6.3	8	10000	16 x 32	26	1830	630.0	ESH109M6R3AM2(1)
6.3	8	15000	16 x 36	26	2090	945.0	ESH159M6R3AM3(1)
6.3	8	22000	18 x 40	26	2350	1386.0	ESH229M6R3AN3(1)
10	13	47	5 x 11	22	75	4.7	ESH476M010AC3(1)
10	13	68	5 x 11	22	80	6.8	ESH686M010AC3(1)
10	13	100	5 x 11	22	110	10.0	ESH107M010AC3(1)
10	13	150	5 x 11	22	120	15.0	ESH157M010AC3(1)
10	13	150	6 x 11	22	130	15.0	ESH157M010AE3(1)
10	13	220	6.3 x 11	22	180	22.0	ESH227M010AE3(1)
10	13	330	6.3 x 11	22	235	33.0	ESH337M010AE3(1)
10	13	330	8 x 11	22	255	33.0	ESH337M010AG3(1)
10	13	470	6.3 x 11	22	250	47.0	ESH477M010AE3(1)
10	13	470	8 x 11	22	305	47.0	ESH477M010AG3(1)
10	13	680	8 x 11	22	365	68.0	ESH687M010AG3(1)
10	13	680	10 x 12	22	420	68.0	ESH687M010AH1(1)
10	13	680	10 x 12.5	22	420	68.0	ESH687M010AH9(1)
10	13	1000	8 x 15	22	480	100.0	ESH108M010AG4(1)
10	13	1000	10 x 16	22	570	100.0	ESH108M010AH2(1)
10	13	1000	10 x 12.5	22	540	100.0	ESH108M010AH9(1)
10	13	1500	10 x 20	22	800	150.0	ESH158M010AH4(1)
10	13	1800	10 x 20	22	800	180.0	ESH188M010AH4(1)
10	13	2200	10 x 20	22	870	220.0	ESH228M010AH4(1)
10	13	2200	13 x 20	22	1010	220.0	ESH228M010AL3(1)
10	13	3300	13 x 20	22	1100	330.0	ESH338M010AL3(1)
10	13	3300	13 x 25	22	1220	330.0	ESH338M010AL4(1)
10	13	4700	13 x 25	22	1380	470.0	ESH478M010AL4(1)
10	13	4700	16 x 25	22	1410	470.0	ESH478M010AM7(1)
10	13	6800	16 x 32	22	1610	680.0	ESH688M010AM2(1)
10	13	6800	16 x 25	22	1700	680.0	ESH688M010AM7(1)
10	13	10000	16 x 36	22	1950	1000.0	ESH109M010AM3(1)
10	13	10000	18 x 36	22	1980	1000.0	ESH109M010AN2(1)
10	13	15000	18 x 36	22	2180	1500.0	ESH159M010AN2(1)
16	20	33	5 x 11	18	70	5.3	ESH336M016AC3(1)
16	20	47	5 x 11	18	85	7.5	ESH476M016AC3(1)
16	20	68	5 x 11	18	100	10.9	ESH686M016AC3(1)
16	20	100	5 x 11	18	130	16.0	ESH107M016AC3(1)
16	20	100	6 x 11	18	135	16.0	ESH107M016AE3(1)
16	20	150	6.3 x 11	18	175	24.0	ESH157M016AE3(1)
16	20	150	8 x 11	18	180	24.0	ESH157M016AG3(1)
VDC	VDC Surge	Rated Capacitance	Case Size	DF	RC	LC	Part Number

(1) Insert packaging code. See Ordering Options Table for available options.

\* When capacitance exceeds 1,000 µF, the DF value (%) is increased by 2% for every additional 1,000 µF.

**Table 1 – Ratings & Part Number Reference cont.**

VDC	VDC Surge Voltage	Rated Capacitance 120 Hz 20°C (µF)	Case Size D x L (mm)	DF 120 Hz 20°C (tan δ %)*	RC 120 Hz 105°C (mA)	LC 20°C 2 minutes (µA)	Part Number
16	20	220	6.3 x 11	18	220	35.2	ESH227M016AE3(1)
16	20	220	8 x 11	18	235	35.2	ESH227M016AG3(1)
16	20	330	8 x 11	18	280	52.8	ESH337M016AG3(1)
16	20	330	10 x 12	18	285	52.8	ESH337M016AH1(1)
16	20	470	8 x 11	18	375	75.2	ESH477M016AG3(1)
16	20	470	10 x 12	18	395	75.2	ESH477M016AH1(1)
16	20	680	8 x 15	18	450	108.8	ESH687M016AG4(1)
16	20	680	10 x 16	18	530	108.8	ESH687M016AH2(1)
16	20	680	10 x 12.5	18	480	108.8	ESH687M016AH9(1)
16	20	1000	10 x 15	18	640	160.0	ESH108M016AH2(1)
16	20	1500	10 x 20	18	830	240.0	ESH158M016AH4(1)
16	20	1500	13 x 20	18	860	240.0	ESH158M016AL3(1)
16	20	2200	13 x 20	18	1050	352.0	ESH228M016AL3(1)
16	20	3300	13 x 25	18	1250	528.0	ESH338M016AL4(1)
16	20	3300	16 x 25	18	1350	528.0	ESH338M016AM7(1)
16	20	4700	16 x 25	18	1650	752.0	ESH478M016AM7(1)
16	20	6800	16 x 32	18	1900	1088.0	ESH688M016AM2(1)
16	20	6800	18 x 36	18	1790	1088.0	ESH688M016AN2(1)
16	20	10000	18 x 36	18	1900	1600.0	ESH109M016AN2(1)
25	32	22	5 x 11	16	60	5.5	ESH226M025AC3(1)
25	32	33	5 x 11	16	75	8.3	ESH336M025AC3(1)
25	32	47	5 x 11	16	90	11.8	ESH476M025AC3(1)
25	32	68	6.3 x 11	16	125	17.0	ESH686M025AE3(1)
25	32	100	6.3 x 11	16	145	25.0	ESH107M025AE3(1)
25	32	150	8 x 11	16	200	37.5	ESH157M025AG3(1)
25	32	220	8 x 11	16	240	55.0	ESH227M025AG3(1)
25	32	220	10 x 12	16	250	55.0	ESH227M025AH1(1)
25	32	330	8 x 11	16	300	82.5	ESH337M025AG3(1)
25	32	330	10 x 12	16	355	82.5	ESH337M025AH1(1)
25	32	330	10 x 12.5	16	355	82.5	ESH337M025AH9(1)
25	32	470	8 x 15	16	420	117.5	ESH477M025AG4(1)
25	32	470	10 x 16	16	470	117.5	ESH477M025AH2(1)
25	32	470	10 x 12.5	16	440	117.5	ESH477M025AH9(1)
25	32	680	10 x 15	16	560	170.0	ESH687M025AH2(1)
25	32	680	10 x 20	16	650	170.0	ESH687M025AH4(1)
25	32	1000	10 x 20	16	740	250.0	ESH108M025AH4(1)
25	32	1000	13 x 20	16	855	250.0	ESH108M025AL3(1)
25	32	1500	13 x 20	16	920	375.0	ESH158M025AL3(1)
25	32	1500	13 x 25	16	1020	375.0	ESH158M025AL4(1)
25	32	2200	13 x 25	16	1230	550.0	ESH228M025AL4(1)
25	32	2200	16 x 25	16	1230	550.0	ESH228M025AM7(1)
25	32	3300	16 x 32	16	1450	825.0	ESH338M025AM2(1)
25	32	3300	16 x 25	16	1500	825.0	ESH338M025AM7(1)
25	32	4700	16 x 32	16	1800	1175.0	ESH478M025AM2(1)
25	32	4700	18 x 36	16	1690	1175.0	ESH478M025AN2(1)
25	32	6800	18 x 36	16	2050	1700.0	ESH688M025AN2(1)
35	44	10	5 x 11	14	44	3.5	ESH106M035AC3(1)
35	44	15	5 x 11	14	50	5.3	ESH156M035AC3(1)
35	44	22	5 x 11	14	65	7.7	ESH226M035AC3(1)
35	44	33	5 x 11	14	85	11.6	ESH336M035AC3(1)
35	44	47	5 x 11	14	100	16.5	ESH476M035AC3(1)
35	44	68	6.3 x 11	14	130	23.8	ESH686M035AE3(1)
35	44	68	8 x 11	14	130	23.8	ESH686M035AG3(1)
35	44	100	6.3 x 11	14	170	35.0	ESH107M035AE3(1)
35	44	100	8 x 11	14	190	35.0	ESH107M035AG3(1)
35	44	150	8 x 11	14	220	52.5	ESH157M035AG3(1)
35	44	150	10 x 12	14	240	52.5	ESH157M035AH1(1)
VDC	VDC Surge	Rated Capacitance	Case Size	DF	RC	LC	Part Number

(1) Insert packaging code. See Ordering Options Table for available options.

\* When capacitance exceeds 1,000 µF, the DF value (%) is increased by 2% for every additional 1,000 µF.

**Table 1 – Ratings & Part Number Reference cont.**

VDC	VDC Surge Voltage	Rated Capacitance 120 Hz 20°C (µF)	Case Size D x L (mm)	DF 120 Hz 20°C (tan δ %)*	RC 120 Hz 105°C (mA)	LC 20°C 2 minutes (µA)	Part Number
35	44	220	10 x 12.5	14	315	77.0	ESH227M035AH9(1)
35	44	220	8 x 11	14	220	77.0	ESH227M035AG3(1)
35	44	330	10 x 16	14	440	115.5	ESH337M035AH2(1)
35	44	330	10 x 12.5	14	400	115.5	ESH337M035AH9(1)
35	44	470	10 x 15	14	480	164.5	ESH477M035AH2(1)
35	44	470	10 x 20	14	580	164.5	ESH477M035AH4(1)
35	44	680	10 x 20	14	650	238.0	ESH687M035AH4(1)
35	44	680	13 x 20	14	730	238.0	ESH687M035AL3(1)
35	44	1000	13 x 20	14	900	350.0	ESH108M035AL3(1)
35	44	1000	13 x 25	14	995	350.0	ESH108M035AL4(1)
35	44	1500	13 x 25	14	1050	525.0	ESH158M035AL4(1)
35	44	1500	16 x 25	14	1110	525.0	ESH158M035AM7(1)
35	44	2200	16 x 32	14	1450	770.0	ESH228M035AM2(1)
35	44	2200	16 x 25	14	1370	770.0	ESH228M035AM7(1)
35	44	3300	16 x 36	14	1680	1155.0	ESH338M035AM3(1)
35	44	3300	18 x 36	14	1660	1155.0	ESH338M035AN2(1)
35	44	4700	18 x 36	14	1920	1645.0	ESH478M035AN2(1)
50	63	1.0	5 x 11	12	12	3.0	ESH105M050AC3(1)
50	63	2.2	5 x 11	12	18	3.0	ESH225M050AC3(1)
50	63	3.3	5 x 11	12	25	3.0	ESH335M050AC3(1)
50	63	4.7	5 x 11	12	30	3.0	ESH475M050AC3(1)
50	63	6.8	5 x 11	12	30	3.4	ESH685M050AC3(1)
50	63	10	5 x 11	12	50	5.0	ESH106M050AC3(1)
50	63	15	5 x 11	12	50	7.5	ESH156M050AC3(1)
50	63	22	5 x 11	12	75	11.0	ESH226M050AC3(1)
50	63	33	5 x 11	12	95	16.5	ESH336M050AC3(1)
50	63	33	6 x 11	12	105	16.5	ESH336M050AE3(1)
50	63	47	6.3 x 11	12	115	23.5	ESH476M050AE3(1)
50	63	47	8 x 11	12	125	23.5	ESH476M050AG3(1)
50	63	68	8 x 11	12	159	34.0	ESH686M050AG3(1)
50	63	82	8 x 15	12	190	41.0	ESH826M050AG4(1)
50	63	100	8 x 11	12	200	50.0	ESH107M050AG3(1)
50	63	150	10 x 12	12	289	75.0	ESH157M050AH1(1)
50	63	150	10 x 12.5	12	289	75.0	ESH157M050AH9(1)
50	63	220	10 x 15	12	415	110.0	ESH227M050AH2(1)
50	63	220	10 x 12.5	12	360	110.0	ESH227M050AH9(1)
50	63	330	10 x 20	12	535	165.0	ESH337M050AH4(1)
50	63	470	10 x 20	12	630	235.0	ESH477M050AH4(1)
50	63	470	13 x 20	12	730	235.0	ESH477M050AL3(1)
50	63	680	13 x 20	12	800	340.0	ESH687M050AL3(1)
50	63	680	13 x 25	12	860	340.0	ESH687M050AL4(1)
50	63	1000	13 x 25	12	1060	500.0	ESH108M050AL4(1)
50	63	1000	16 x 25	12	1110	500.0	ESH108M050AM7(1)
50	63	1500	16 x 32	12	1350	750.0	ESH158M050AM2(1)
50	63	1500	16 x 25	12	1300	750.0	ESH158M050AM7(1)
50	63	2200	16 x 36	12	1600	1100.0	ESH228M050AM3(1)
50	63	2200	18 x 36	12	1530	1100.0	ESH228M050AN2(1)
50	63	3300	18 x 36	12	1780	1650.0	ESH338M050AN2(1)
63	79	1.0	5 x 11	10	12	3.0	ESH105M063AC3(1)
63	79	2.2	5 x 11	10	20	3.0	ESH225M063AC3(1)
63	79	3.3	5 x 11	10	27	3.0	ESH335M063AC3(1)
63	79	4.7	5 x 11	10	34	3.0	ESH475M063AC3(1)
63	79	6.8	5 x 11	10	37	4.3	ESH685M063AC3(1)
63	79	10	5 x 11	10	55	6.3	ESH106M063AC3(1)
63	79	15	5 x 11	10	65	9.5	ESH156M063AC3(1)
63	79	22	6.3 x 11	10	90	13.9	ESH226M063AE3(1)
63	79	33	6.3 x 11	10	100	20.8	ESH336M063AE3(1)
VDC	VDC Surge	Rated Capacitance	Case Size	DF	RC	LC	Part Number

(1) Insert packaging code. See Ordering Options Table for available options.

\* When capacitance exceeds 1,000 µF, the DF value (%) is increased by 2% for every additional 1,000 µF.



**Table 1 – Ratings & Part Number Reference cont.**

VDC	VDC Surge Voltage	Rated Capacitance 120 Hz 20°C (µF)	Case Size D x L (mm)	DF 120 Hz 20°C (tan δ %)*	RC 120 Hz 105°C (mA)	LC 20°C 2 minutes (µA)	Part Number
63	79	33	8 x 11	10	110	20.8	ESH336M063AG3(1)
63	79	47	8 x 11	10	155	29.6	ESH476M063AG3(1)
63	79	68	10 x 12	10	198	42.8	ESH686M063AH1(1)
63	79	68	10 x 12.5	10	198	42.8	ESH686M063AH9(1)
63	79	100	10 x 12	10	260	63.0	ESH107M063AH1(1)
63	79	100	10 x 12.5	10	260	63.0	ESH107M063AH9(1)
63	79	150	10 x 15	10	330	94.5	ESH157M063AH2(1)
63	79	220	10 x 20	10	465	138.6	ESH227M063AH4(1)
63	79	330	13 x 20	10	650	207.9	ESH337M063AL3(1)
63	79	470	13 x 20	10	700	296.1	ESH477M063AL3(1)
63	79	470	13 x 25	10	800	296.1	ESH477M063AL4(1)
63	79	680	16 x 25	10	1000	428.4	ESH687M063AM7(1)
63	79	1000	16 x 32	10	1200	630.0	ESH108M063AM2(1)
63	79	1500	16 x 36	10	1450	945.0	ESH158M063AM3(1)
63	79	2200	18 x 36	10	1650	1386.0	ESH228M063AN2(1)
100	125	1.0	5 x 11	10	15	3.0	ESH105M100AC3(1)
100	125	2.2	5 x 11	10	22	3.0	ESH225M100AC3(1)
100	125	3.3	5 x 11	10	29	3.3	ESH335M100AC3(1)
100	125	4.7	5 x 11	10	37	4.7	ESH475M100AC3(1)
100	125	6.8	5 x 11	10	46	6.8	ESH685M100AC3(1)
100	125	10	6.3 x 11	10	65	10.0	ESH106M100AE3(1)
100	125	15	6.3 x 11	10	75	15.0	ESH156M100AE3(1)
100	125	15	8 x 11	10	82	15.0	ESH156M100AG3(1)
100	125	22	8 x 11	10	115	22.0	ESH226M100AG3(1)
100	125	33	8 x 11	10	140	33.0	ESH336M100AG3(1)
100	125	33	10 x 12	10	160	33.0	ESH336M100AH1(1)
100	125	47	10 x 16	10	210	47.0	ESH476M100AH2(1)
100	125	47	10 x 12.5	10	185	47.0	ESH476M100AH9(1)
100	125	68	10 x 15	10	240	68.0	ESH686M100AH2(1)
100	125	68	10 x 20	10	241	68.0	ESH686M100AH4(1)
100	125	100	10 x 20	10	305	100.0	ESH107M100AH4(1)
100	125	150	13 x 20	10	370	150.0	ESH157M100AL3(1)
100	125	150	13 x 25	10	414	150.0	ESH157M100AL4(1)
100	125	220	13 x 25	10	520	220.0	ESH227M100AL4(1)
100	125	220	16 x 26	10	590	220.0	ESH227M100AM1(1)
100	125	330	16 x 25	10	720	330.0	ESH337M100AM7(1)
100	125	470	16 x 32	10	875	470.0	ESH477M100AM2(1)
100	125	680	16 x 36	10	1200	680.0	ESH687M100AM3(1)
160	200	1.0	5 x 11	15	17	14.8	ESH105M160AC3(1)
160	200	2.2	6.3 x 11	15	25	20.6	ESH225M160AE3(1)
160	200	3.3	6.3 x 11	15	36	25.8	ESH335M160AE3(1)
160	200	4.7	6.3 x 11	15	43	32.6	ESH475M160AE3(1)
160	200	4.7	8 x 11	15	43	32.6	ESH475M160AG3(1)
160	200	6.8	8 x 11	15	54	42.6	ESH685M160AG3(1)
160	200	10	8 x 11	15	70	58.0	ESH106M160AG3(1)
160	200	10	10 x 12	15	70	58.0	ESH106M160AH1(1)
160	200	15	10 x 16	15	90	82.0	ESH156M160AH2(1)
160	200	15	10 x 12.5	15	90	82.0	ESH156M160AH9(1)
160	200	22	10 x 15	15	115	115.6	ESH226M160AH2(1)
160	200	22	10 x 20	15	130	115.6	ESH226M160AH4(1)
160	200	33	10 x 20	15	160	168.4	ESH336M160AH4(1)
160	200	33	13 x 20	15	180	168.4	ESH336M160AL3(1)
160	200	47	10 x 20	15	195	235.6	ESH476M160AH4(1)
160	200	47	13 x 25	15	250	235.6	ESH476M160AL4(1)
160	200	68	13 x 20	15	255	336.4	ESH686M160AL3(1)
160	200	68	13 x 25	15	270	336.4	ESH686M160AL4(1)
160	200	100	13 x 25	15	350	490.0	ESH107M160AL4(1)
VDC	VDC Surge	Rated Capacitance	Case Size	DF	RC	LC	Part Number

(1) Insert packaging code. See Ordering Options Table for available options.

\* When capacitance exceeds 1,000 µF, the DF value (%) is increased by 2% for every additional 1,000 µF.

**Table 1 – Ratings & Part Number Reference cont.**

VDC	VDC Surge Voltage	Rated Capacitance 120 Hz 20°C (µF)	Case Size D x L (mm)	DF 120 Hz 20°C (tan δ %)*	RC 120 Hz 105°C (mA)	LC 20°C 2 minutes (µA)	Part Number
160	200	100	16 x 25	15	390	490.0	ESH107M160AM7(1)
160	200	150	16 x 32	15	435	730.0	ESH157M160AM2(1)
160	200	150	16 x 25	15	435	730.0	ESH157M160AM7(1)
160	200	220	16 x 32	15	550	1066.0	ESH227M160AM2(1)
160	200	220	16 x 36	15	700	1066.0	ESH227M160AM3(1)
160	200	330	18 x 36	15	800	1594.0	ESH337M160AN2(1)
160	200	330	18 x 40	15	850	1594.0	ESH337M160AN3(1)
160	200	470	18 x 40	15	900	2266.0	ESH477M160AN3(1)
160	200	470	22 x 40	15	980	2266.0	ESH477M160AQ4(1)
200	250	1.0	6.3 x 11	15	17	16.0	ESH105M200AE3(1)
200	250	2.2	6.3 x 11	15	25	23.2	ESH225M200AE3(1)
200	250	3.3	6.3 x 11	15	36	29.8	ESH335M200AE3(1)
200	250	4.7	8 x 11	15	50	38.2	ESH475M200AG3(1)
200	250	4.7	10 x 12	15	50	38.2	ESH475M200AH1(1)
200	250	6.8	8 x 11	15	60	50.8	ESH685M200AG3(1)
200	250	10	10 x 16	15	80	70.0	ESH106M200AH2(1)
200	250	10	10 x 12.5	15	80	70.0	ESH106M200AH9(1)
200	250	15	10 x 15	15	110	100.0	ESH156M200AH2(1)
200	250	15	10 x 20	15	110	100.0	ESH156M200AH4(1)
200	250	22	10 x 20	15	140	142.0	ESH226M200AH4(1)
200	250	33	13 x 20	15	200	208.0	ESH336M200AL3(1)
200	250	47	13 x 20	15	220	292.0	ESH476M200AL3(1)
200	250	68	13 x 25	15	280	418.0	ESH686M200AL4(1)
200	250	68	16 x 25	15	280	418.0	ESH686M200AM7(1)
200	250	100	16 x 32	15	400	610.0	ESH107M200AM2(1)
200	250	100	16 x 25	15	350	610.0	ESH107M200AM7(1)
200	250	150	16 x 32	15	480	910.0	ESH157M200AM2(1)
200	250	150	16 x 36	15	450	910.0	ESH157M200AM3(1)
200	250	220	16 x 36	15	675	1330.0	ESH227M200AM3(1)
200	250	220	18 x 32	15	685	1330.0	ESH227M200AN1(1)
200	250	330	18 x 36	15	750	1990.0	ESH337M200AN2(1)
200	250	330	22 x 40	15	920	1990.0	ESH337M200AQ4(1)
250	300	1.0	6.3 x 11	15	17	17.5	ESH105M250AE3(1)
250	300	2.2	6.3 x 11	15	29	26.5	ESH225M250AE3(1)
250	300	2.2	8 x 11	15	29	26.5	ESH225M250AG3(1)
250	300	3.3	8 x 11	15	42	34.8	ESH335M250AG3(1)
250	300	4.7	8 x 11	15	52	45.3	ESH475M250AG3(1)
250	300	4.7	10 x 12	15	52	45.3	ESH475M250AH1(1)
250	300	6.8	8 x 11	15	62	61.0	ESH685M250AG3(1)
250	300	10	10 x 20	15	88	85.0	ESH106M250AH4(1)
250	300	10	10 x 12.5	15	80	85.0	ESH106M250AH9(1)
250	300	15	10 x 15	15	110	122.5	ESH156M250AH2(1)
250	300	15	13 x 20	15	120	122.5	ESH156M250AL3(1)
250	300	22	10 x 20	15	140	175.0	ESH226M250AH4(1)
250	300	22	13 x 20	15	155	175.0	ESH226M250AL3(1)
250	300	33	13 x 20	15	200	257.5	ESH336M250AL3(1)
250	300	33	13 x 25	15	200	257.5	ESH336M250AL4(1)
250	300	47	13 x 25	15	240	362.5	ESH476M250AL4(1)
250	300	47	16 x 25	15	270	362.5	ESH476M250AM7(1)
250	300	68	13 x 25	15	290	520.0	ESH686M250AL4(1)
250	300	68	16 x 32	15	300	520.0	ESH686M250AM2(1)
250	300	100	16 x 25	15	380	760.0	ESH107M250AM7(1)
250	300	100	16 x 36	15	440	760.0	ESH107M250AM3(1)
250	300	150	16 x 32	15	420	1135.0	ESH157M250AM2(1)
250	300	150	18 x 40	15	600	1135.0	ESH157M250AN3(1)
250	300	220	18 x 36	15	680	1660.0	ESH227M250AN2(1)
250	300	220	22 x 40	15	800	1660.0	ESH227M250AQ4(1)
VDC	VDC Surge	Rated Capacitance	Case Size	DF	RC	LC	Part Number

(1) Insert packaging code. See Ordering Options Table for available options.

\* When capacitance exceeds 1,000 µF, the DF value (%) is increased by 2% for every additional 1,000 µF.

**Table 1 – Ratings & Part Number Reference cont.**

VDC	VDC Surge Voltage	Rated Capacitance 120 Hz 20°C (µF)	Case Size D x L (mm)	DF 120 Hz 20°C (tan δ %)*	RC 120 Hz 105°C (mA)	LC 20°C 2 minutes (µA)	Part Number
350	400	1.0	6.3 x 11	20	16	20.5	ESH105M350AE3(1)
350	400	2.2	8 x 11	20	31	33.1	ESH225M350AG3(1)
350	400	2.2	10 x 12	20	35	33.1	ESH225M350AH1(1)
350	400	3.3	8 x 11	20	35	44.7	ESH335M350AG3(1)
350	400	4.7	8 x 11	20	45	59.4	ESH475M350AG3(1)
350	400	4.7	10 x 20	20	65	59.4	ESH475M350AH4(1)
350	400	10	10 x 15	20	80	115.0	ESH106M350AH2(1)
350	400	10	13 x 20	20	95	115.0	ESH106M350AL3(1)
350	400	15	13 x 20	20	140	167.5	ESH156M350AL3(1)
350	400	22	13 x 20	20	150	241.0	ESH226M350AL3(1)
350	400	22	16 x 25	20	165	241.0	ESH226M350AM7(1)
350	400	33	13 x 25	20	200	356.5	ESH336M350AL4(1)
350	400	33	16 x 32	20	195	356.5	ESH336M350AM2(1)
350	400	47	16 x 36	20	210	503.5	ESH476M350AM3(1)
350	400	47	16 x 25	20	260	503.5	ESH476M350AM7(1)
350	400	47	18 x 36	20	240	503.5	ESH476M350AN2(1)
350	400	68	18 x 36	20	320	724.0	ESH686M350AN2(1)
350	400	100	18 x 32	20	400	1060.0	ESH107M350AN1(1)
350	400	100	18 x 40	20	300	1060.0	ESH107M350AN3(1)
350	400	150	22 x 40	20	480	1585.0	ESH157M350AQ4(1)
400	450	1.0	6.3 x 11	20	17	22.0	ESH105M400AE3(1)
400	450	2.2	8 x 11	20	31	36.4	ESH225M400AG3(1)
400	450	3.3	8 x 11	20	35	49.6	ESH335M400AG3(1)
400	450	4.7	8 x 11	20	45	66.4	ESH475M400AG3(1)
400	450	4.7	10 x 15	20	60	66.4	ESH475M400AH2(1)
400	450	4.7	10 x 12.5	20	55	66.4	ESH475M400AH9(1)
400	450	6.8	8 x 15	20	60	91.6	ESH685M400AG4(1)
400	450	6.8	10 x 20	20	67	91.6	ESH685M400AH4(1)
400	450	6.8	10 x 12.5	20	65	91.6	ESH685M400AH9(1)
400	450	10	10 x 15	20	80	130.0	ESH106M400AH2(1)
400	450	10	10 x 20	20	75	130.0	ESH106M400AH4(1)
400	450	15	10 x 20	20	100	190.0	ESH156M400AH4(1)
400	450	15	13 x 20	20	120	190.0	ESH156M400AL3(1)
400	450	22	13 x 20	20	140	274.0	ESH226M400AL3(1)
400	450	22	13 x 25	20	140	274.0	ESH226M400AL4(1)
400	450	33	13 x 25	20	200	406.0	ESH336M400AL4(1)
400	450	33	16 x 25	20	190	406.0	ESH336M400AM7(1)
400	450	47	16 x 25	20	265	574.0	ESH476M400AM7(1)
400	450	68	16 x 32	20	410	826.0	ESH686M400AM2(1)
400	450	68	18 x 36	20	325	826.0	ESH686M400AN2(1)
400	450	68	18 x 25	20	390	826.0	ESH686M400AN5(1)
400	450	100	18 x 32	20	500	1210.0	ESH107M400AN1(1)
400	450	100	18 x 36	20	290	1210.0	ESH107M400AN2(1)
400	450	120	18 x 32	20	520	1450.0	ESH127M400AN1(1)
400	450	120	18 x 36	20	550	1450.0	ESH127M400AN2(1)
400	450	150	18 x 40	20	620	1810.0	ESH157M400AN3(1)
400	450	150	18 x 36	20	560	1810.0	ESH157M400AN2(1)
420	470	1.0	6.3 x 11	20	17	22.6	ESH105M420AE3(1)
420	470	2.2	8 x 11	20	29	37.7	ESH225M420AG3(1)
420	470	3.3	8 x 11	20	34	51.6	ESH335M420AG3(1)
420	470	4.7	10 x 12.5	20	55	69.2	ESH475M420AH9(1)
420	470	6.8	10 x 15	20	68	95.7	ESH685M420AH2(1)
420	470	10	10 x 20	20	98	136.0	ESH106M420AH4(1)
420	470	15	13 x 20	20	130	199.0	ESH156M420AL3(1)
420	470	22	13 x 25	20	155	287.2	ESH226M420AL4(1)
420	470	33	16 x 25	20	205	425.8	ESH336M420AM7(1)
420	470	47	16 x 25	20	235	602.2	ESH476M420AM7(1)
VDC	VDC Surge	Rated Capacitance	Case Size	DF	RC	LC	Part Number

(1) Insert packaging code. See Ordering Options Table for available options.

\* When capacitance exceeds 1,000 µF, the DF value (%) is increased by 2% for every additional 1,000 µF.

**Table 1 – Ratings & Part Number Reference cont.**

VDC	VDC Surge Voltage	Rated Capacitance 120 Hz 20°C (µF)	Case Size D x L (mm)	DF 120 Hz 20°C (tan δ %)*	RC 120 Hz 105°C (mA)	LC 20°C 2 minutes (µA)	Part Number
420	470	68	16 x 32	20	400	866.8	ESH686M420AM2(1)
420	470	68	18 x 25	20	380	866.8	ESH686M420AN5(1)
420	470	100	18 x 36	20	490	1270.0	ESH107M420AN2(1)
420	470	120	18 x 40	20	430	1522.0	ESH127M420AN3(1)
420	470	150	18 x 45	20	570	1900.0	ESH157M420AN7(1)
450	500	1.0	6.3 x 11	20	18	23.5	ESH105M450AE3(1)
450	500	1.0	8 x 11	20	22	23.5	ESH105M450AG3(1)
450	500	2.2	8 x 11	20	30	39.7	ESH225M450AG3(1)
450	500	2.2	10 x 12	20	37	39.7	ESH225M450AH1(1)
450	500	2.2	10 x 12.5	20	37	39.7	ESH225M450AH9(1)
450	500	3.3	8 x 15	20	42	54.6	ESH335M450AG4(1)
450	500	3.3	10 x 16	20	51	54.6	ESH335M450AH2(1)
450	500	3.3	10 x 12.5	20	40	54.6	ESH335M450AH9(1)
450	500	4.7	10 x 12.5	20	52	73.5	ESH475M450AH9(1)
450	500	4.7	10 x 20	20	60	73.5	ESH475M450AH4(1)
450	500	6.8	10 x 15	20	62	101.8	ESH685M450AH2(1)
450	500	10	10 x 20	20	85	145.0	ESH106M450AH4(1)
450	500	10	13 x 25	20	99	145.0	ESH106M450AL4AR
450	500	15	13 x 20	20	120	212.5	ESH156M450AL3(1)
450	500	22	13 x 25	20	150	307.0	ESH226M450AL4(1)
450	500	22	16 x 25	20	145	307.0	ESH226M450AM7(1)
450	500	33	16 x 25	20	210	455.5	ESH336M450AM7(1)
450	500	33	16 x 32	20	230	455.5	ESH336M450AM2(1)
450	500	47	16 x 25	20	260	644.5	ESH476M450AM7(1)
450	500	47	18 x 40	20	350	644.5	ESH476M450AN3(1)
450	500	68	18 x 32	20	370	928.0	ESH686M450AN1(1)
450	500	68	18 x 36	20	380	928.0	ESH686M450AN2(1)
450	500	100	18 x 36	20	495	1360.0	ESH107M450AN2(1)
450	500	120	18 x 40	20	565	1630.0	ESH127M450AN3(1)
450	500	150	18 x 45	20	650	2035.0	ESH157M450AN7(1)
500	550	2.2	8 x 11	25	25	144.0	ESH225M500AG3(1)
500	550	3.3	8 x 16	25	30	166.0	ESH335M500AG8(1)
500	550	4.7	8 x 16	25	34	194.0	ESH475M500AG8(1)
500	550	4.7	10 x 12.5	25	38	194.0	ESH475M500AH9(1)
500	550	6.8	10 x 16	25	50	236.0	ESH685M500AH8(1)
500	550	8.2	10 x 20	25	65	264.0	ESH825M500AH4(1)
500	550	10	10 x 20	25	70	300.0	ESH106M500AH4(1)
500	550	10	13 x 20	25	85	300.0	ESH106M500AL3(1)
500	550	15	13 x 25	25	100	400.0	ESH156M500AL4(1)
500	550	22	13 x 25	25	115	540.0	ESH226M500AL4(1)
500	550	22	16 x 25	25	130	540.0	ESH226M500AM7(1)
500	550	33	18 x 25	25	180	760.0	ESH336M500AN5(1)
500	550	47	16 x 32	25	180	1040.0	ESH476M500AM2(1)
500	550	47	18 x 30	25	230	1040.0	ESH476M500AN8(1)
500	550	68	18 x 32	25	250	1460.0	ESH686M500AN1(1)
500	550	68	18 x 36	25	290	1460.0	ESH686M500AN2(1)
500	550	82	18 x 40	25	335	1740.0	ESH826M500AN3(1)
VDC	VDC Surge	Rated Capacitance	Case Size	DF	RC	LC	Part Number

(1) Insert packaging code. See Ordering Options Table for available options.

\* When capacitance exceeds 1,000 µF, the DF value (%) is increased by 2% for every additional 1,000 µF.

## Mounting Positions (Safety Vent)

In operation, electrolytic capacitors will always conduct a leakage current, which causes electrolysis. The oxygen produced by electrolysis will regenerate the dielectric layer but, at the same time, the hydrogen released may cause the internal pressure of the capacitor to increase. The overpressure vent, or safety vent, ensures that the gas can escape when the pressure reaches a certain value. All mounting positions must allow the safety vent to work properly.

## Installing

- As a general principle, lower-use temperatures result in a longer, useful life of the capacitor. For this reason, it should be ensured that electrolytic capacitors are placed away from heat-emitting components. Adequate space should be allowed between components for cooling air to circulate, particularly when high ripple current loads are applied. In any case, the maximum category temperature must not be exceeded.
- Do not deform the case of the capacitors or use capacitors with a deformed case.
- Verify that the connections of the capacitors are able to insert on the board without excessive mechanical force.
- If the capacitors require mounting through additional means, the recommended mounting accessories shall be used.
- Verify the correct polarization of the capacitor on the board.
- Verify that the space around the pressure relief device is according to the following guideline:

Case Diameter	Space Around Safety Vent
≤ 16 mm	> 2 mm
> 16 to ≤ 40 mm	> 3 mm
> 40 mm	> 5 mm

It is recommended that capacitors always be mounted with the safety device uppermost or in the upper part of the capacitor.

- If the capacitors are stored for a long time, the leakage current must be verified. If the leakage current is superior to the value listed in this catalog, the capacitors must be reformed. In this case, they can be reformed by application of the rated voltage through a series resistor approximately 1 kΩ for capacitors with  $V_R \leq 160$  V (5 W resistor) and 10 kΩ for the other rated voltages.
- In the case of capacitors connected in a series, a suitable voltage sharing must be used.  
In the case of balancing resistors, the approximate resistance value can be calculated as:  $R = 60/C$ .

KEMET recommends, nevertheless, to ensure that the voltage across each capacitor does not exceed its rated voltage.

## Application & Operation Guidelines

### Electrical Ratings:

#### Capacitance (ESC)



*Simplified equivalent circuit diagram of an electrolytic capacitor*

The capacitive component of the equivalent series circuit, (equivalent series capacitance - ESC), is determined by applying an alternate voltage of  $\leq 0.5$  V at a frequency of 120 or 100 Hz and 20°C (IEC 384-1, 384-4).

#### Temperature Dependence of the Capacitance

Capacitance of an electrolytic capacitor depends upon temperature: with decreasing temperature the viscosity of the electrolyte increases, thereby reducing its conductivity.

Capacitance will decrease if temperature decreases. Furthermore, temperature drifts cause armature dilatation and, therefore, capacitance changes (up to 20% depending on the series considered, from 0 to 80°C). This phenomenon is more evident for electrolytic capacitors than for other types.

#### Frequency Dependence of the Capacitance

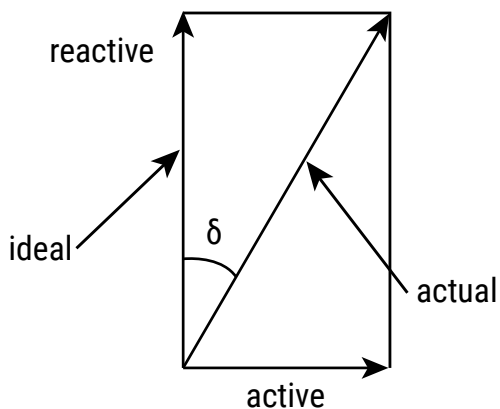
Effective capacitance value is derived from the impedance curve, as long as impedance is still in the range where the capacitance component is dominant.

$$C = \frac{1}{2\pi fZ}$$

C = capacitance (F)  
 f = frequency (Hz)  
 Z = impedance ( $\Omega$ )

#### Dissipation Factor $\tan \delta$ (DF)

Dissipation Factor  $\tan \delta$  is the ratio between the active and reactive power for a sinusoidal waveform voltage. It can be thought of as a measurement of the gap between an actual and ideal capacitor.



Tan  $\delta$  is measured with the same set-up used for the series capacitance ESC.

Tan  $\delta = \omega \times \text{ESC} \times \text{ESR}$  where:

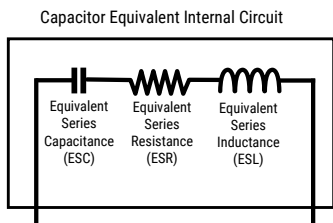
ESC = Equivalent series capacitance

ESR = Equivalent series resistance

## Application & Operation Guidelines cont.

### Equivalent Series Inductance (ESL)

Equivalent series inductance or self inductance results from the terminal configuration and internal design of the capacitor.



### Equivalent Series Resistance (ESR)

Equivalent series resistance is the resistive component of the equivalent series circuit. ESR value depends on frequency and temperature, and is related to the  $\tan \delta$  by the following equation:

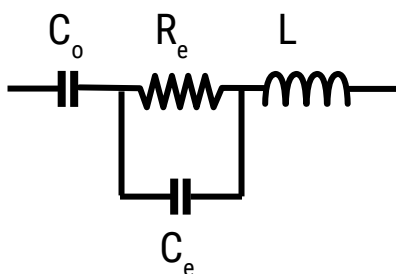
$$ESR = \frac{\tan \delta}{2\pi f ESC}$$

ESR = Equivalent series resistance ( $\Omega$ )  
 $\tan \delta$  = Dissipation factor  
 ESC = Equivalent series capacitance (F)  
 f = Frequency (Hz)

Tolerance limits of the rated capacitance must be taken into account when calculating this value.

### Impedance (Z)

Impedance of an electrolytic capacitor results from a circuit formed by the following individual equivalent series components:



$C_o$  = Aluminum oxide capacitance (surface and thickness of the dielectric.)

$R_e$  = Resistance of electrolyte and paper mixture (other resistances not depending on the frequency are not considered: tabs, plates, etc.)

$C_e$  = Electrolyte soaked paper capacitance.

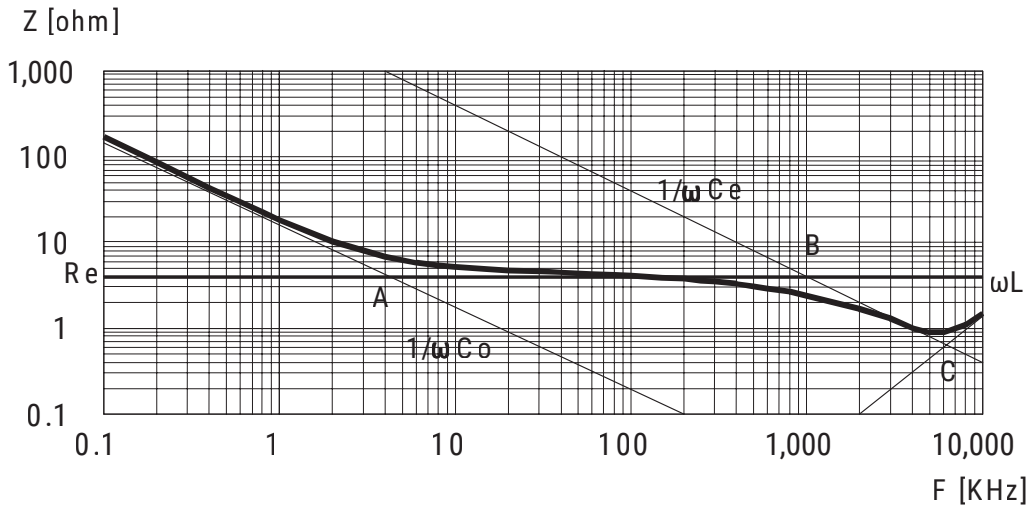
L = Inductive reactance of the capacitor winding and terminals.

Impedance of an electrolytic capacitor is not a constant quantity that retains its value under all conditions; it changes depending on frequency and temperature.

Impedance as a function of frequency (sinusoidal waveform) for a certain temperature can be represented as follows:

**Application & Operation Guidelines cont.**

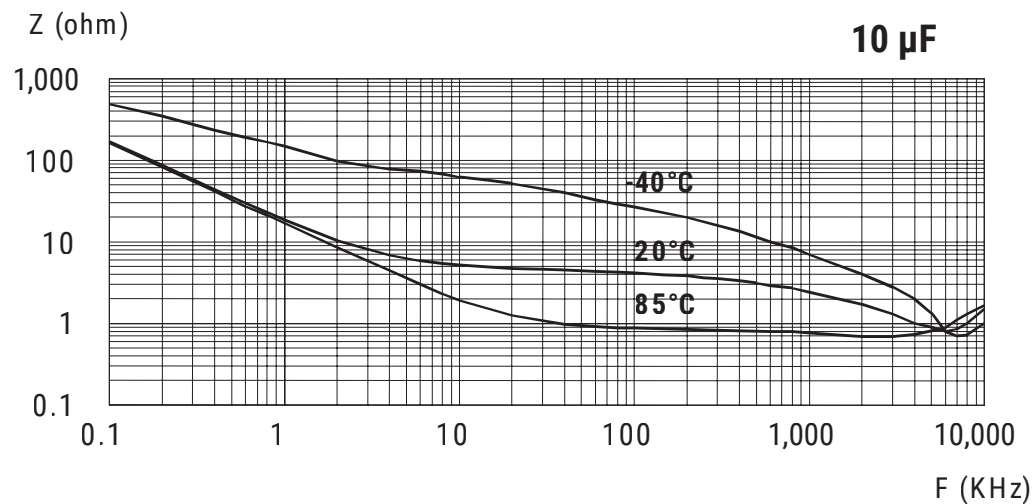
**Impedance (Z) cont.**



- Capacitive reactance predominates at low frequencies.
- With increasing frequency, capacitive reactance  $X_c = 1/\omega C_o$  decreases until it reaches the order of magnitude of electrolyte resistance  $R_e$  (A)
- At even higher frequencies, resistance of the electrolyte predominates:  $Z = R_e$  (A - B)
- When the capacitor's resonance frequency is reached ( $\omega_o$ ), capacitive and inductive reactance mutually cancel each other  $1/\omega C_e = \omega L$ ,  $\omega_o = 1/\text{SQR}(LC_e)$
- Above this frequency, inductive reactance of the winding and its terminals ( $X_L = Z = \omega L$ ) becomes effective and leads to an increase in impedance

Generally speaking, it can be estimated that  $C_e \approx 0.01 C_o$ .

Impedance as a function of frequency (sinusoidal waveform) for different temperature values can be represented as follows (typical values):



$R_e$  is the most temperature-dependent component of an electrolytic capacitor equivalent circuit. Electrolyte resistivity will decrease if temperature rises.

In order to obtain a low impedance value throughout the temperature range,  $R_e$  must be as little as possible. However,  $R_e$  values that are too low indicate a very aggressive electrolyte, resulting in a shorter life of the electrolytic capacitor at high temperatures. A compromise must be reached.



## Application & Operation Guidelines cont.

### Leakage Current (LC)

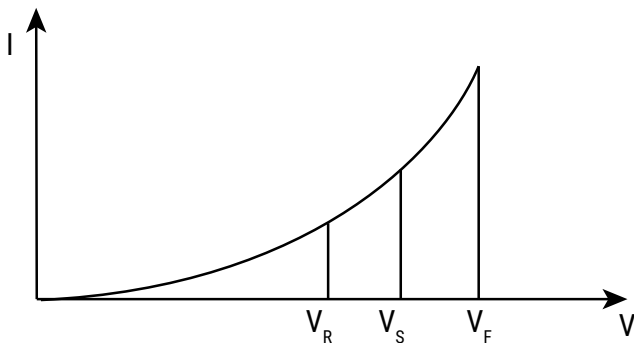
Due to the aluminum oxide layer that serves as a dielectric, a small current will continue to flow even after a DC voltage has been applied for long periods. This current is called leakage current.

A high leakage current flows after applying voltage to the capacitor then decreases in a few minutes, for example, after prolonged storage without any applied voltage. In the course of continuous operation, the leakage current will decrease and reach an almost constant value.

After a voltage-free storage the oxide layer may deteriorate, especially at a high temperature. Since there are no leakage currents to transport oxygen ions to the anode, the oxide layer is not regenerated. The result is that a higher than normal leakage current will flow when voltage is applied after prolonged storage.

As the oxide layer is regenerated in use, the leakage current will gradually decrease to its normal level.

The relationship between the leakage current and voltage applied at constant temperature can be shown schematically as follows:



Where:

$V_F$  = Forming voltage

If this level is exceeded, a large quantity of heat and gas will be generated and the capacitor could be damaged.

$V_R$  = Rated voltage

This level represents the top of the linear part of the curve.

$V_S$  = Surge voltage

This lies between  $V_R$  and  $V_F$ . The capacitor can be subjected to  $V_S$  for short periods only.

Electrolytic capacitors are subjected to a reforming process before acceptance testing. The purpose of this preconditioning is to ensure that the same initial conditions are maintained when comparing different products.

### Ripple Current (RC)

The maximum ripple current value depends on:

- Ambient temperature
- Surface area of the capacitor (heat dissipation area)
- $\tan \delta$  or ESR
- Frequency

The capacitor's life depends on the thermal stress.

## Application & Operation Guidelines cont.

### Frequency Dependence of the Ripple Current

ESR and, thus, the  $\tan \delta$  depend on the frequency of the applied voltage. This indicates that the allowed ripple current is also a function of the frequency.

### Temperature Dependence of the Ripple Current

The data sheet specifies maximum ripple current at the upper category temperature for each capacitor.

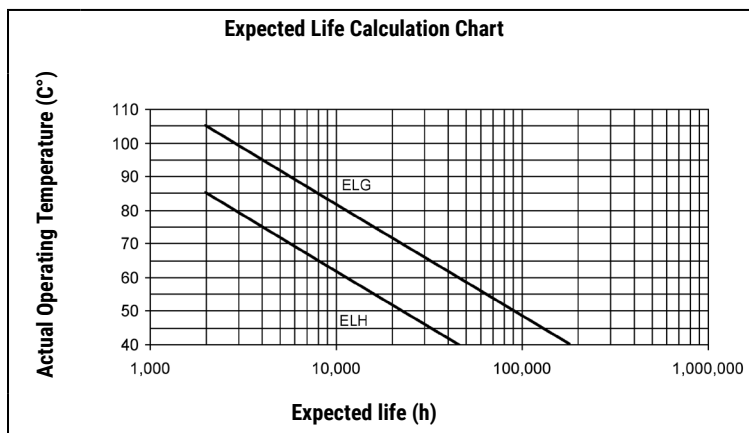
### Expected Life Calculation

Expected life depends on operating temperature according to the following formula:  $L = L_0 \times 2^{(T_0-T)/10}$

Where:

- L: Expected life
- L<sub>0</sub>: Load life at a maximum permissible operating temperature
- T: Actual operating temperature
- T<sub>0</sub>: Maximum permissible operating temperature

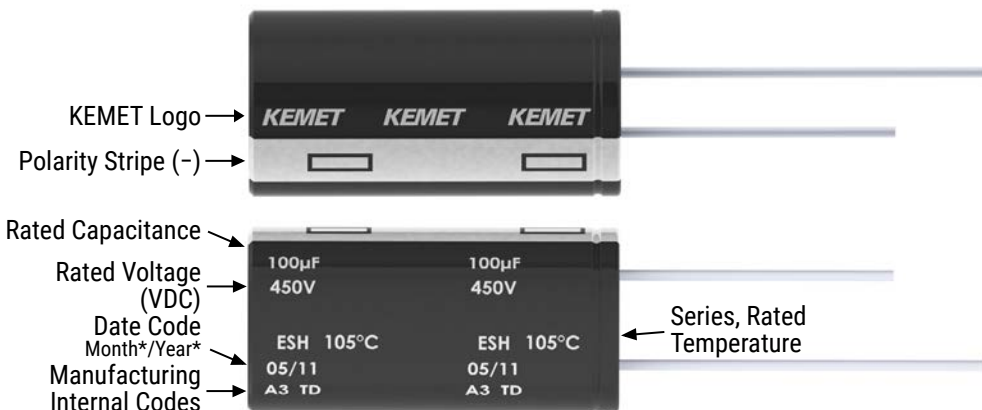
This formula is applicable between 40°C and T<sub>0</sub>.



## Packaging Quantities

Size Code	Diameter (mm)	Length (mm)	Bulk		Auto-insertion	
			Standard Leads	Cut Leads	Ammo	Tape & Reel
C3	5.0	11.0	10,000	15,000	2,000	2,600
E3	6.3	11.0	10,000	15,000	2,000	2,200
G3	8.0	11.0	6,000	8,000	1,000	1,500
G4	8.0	15.0	5,000	5,000	1,000	1,500
G8	8.0	16.0	5,000	5,000	1,000	1,500
H1	10.0	12.0	4,000	4,000	700	1,200
H9	10.0	12.5	4,000	4,000	700	1,200
H2	10.0	15.0	3,000	4,000	700	1,200
H8	10.0	16.0	3,000	4,000	700	1,200
H4	10.0	20.0	2,400	3,000	700	1,200
L3	13.0	20.0	2,000	2,000	500	
L4	13.0	25.0	1,600	1,600	500	
M7	16.0	25.0	1,000	500	300	
M2	16.0	32.0	800	500	300	
M3	16.0	36.0	600	500	300	
N5	18.0	25.0	800	500	300	
N8	18.0	30.0	800	500		
N1	18.0	32.0	500	500		
N2	18.0	36.0	500	500		
N3	18.0	40.0	500	500		
N7	18.0	45.0	500	500		

## Marking



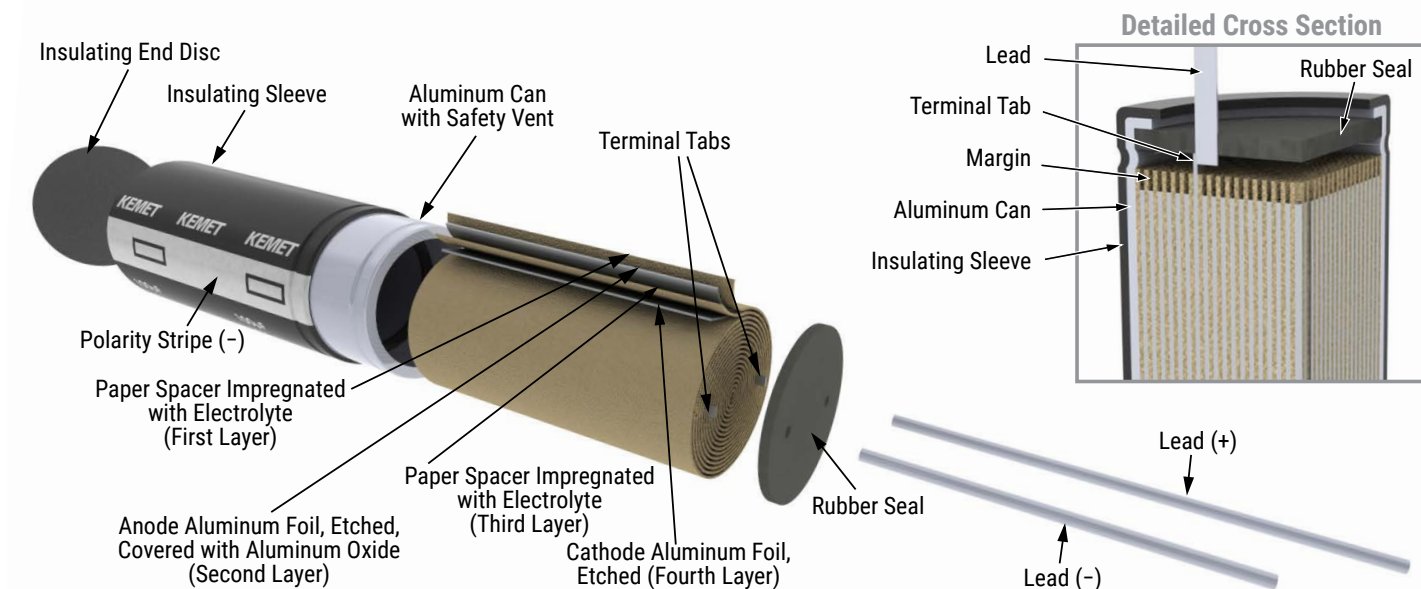
\*Y = Year

Code	01	02	03	04	05	06	07	08	09
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019

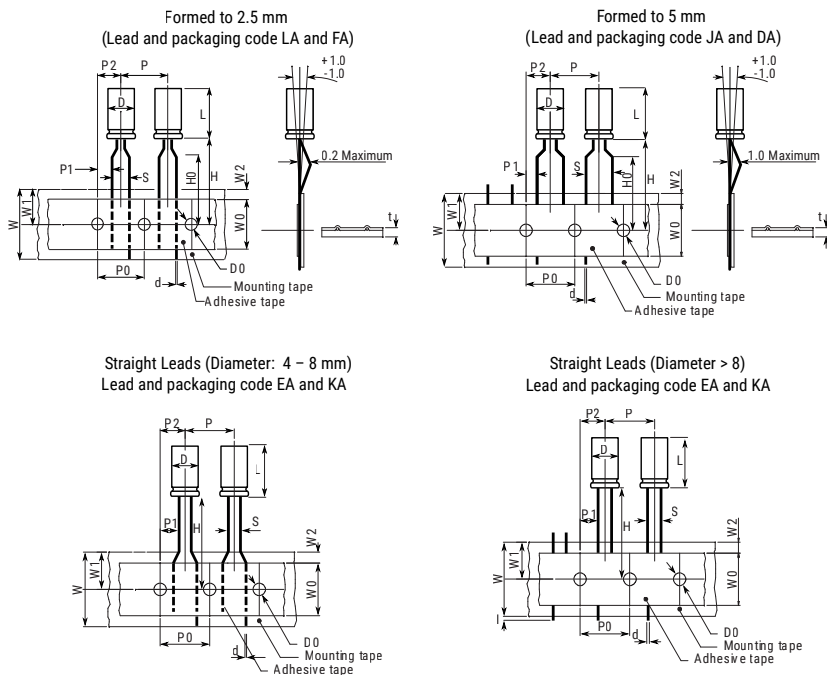
\*M = Month

Code	01	02	03	04	05	06	07	08	09	10	11	12
Month	1	2	3	4	5	6	7	8	9	10	11	12

## Construction

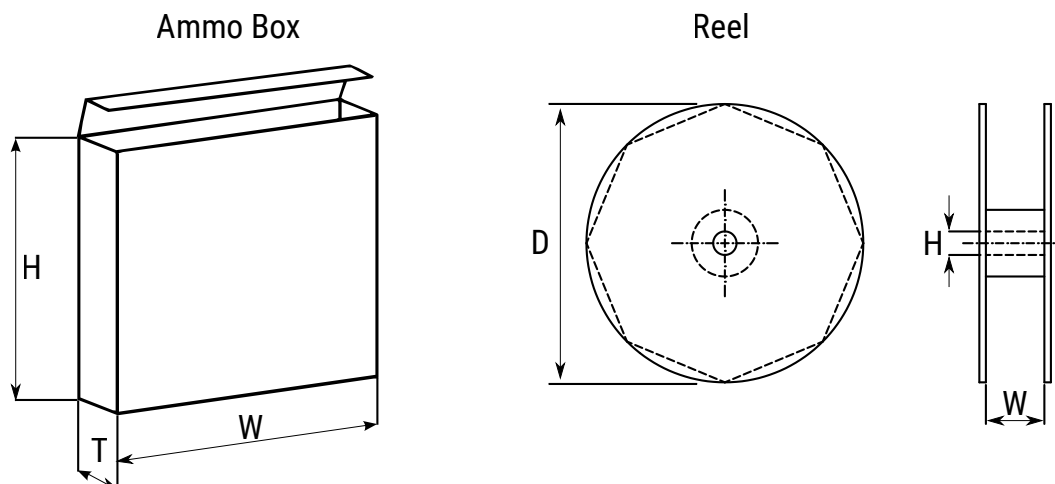


## Taping for Automatic Insertion Machines



Dimensions (mm)	D	L	S	d	P	P0	P1	P2	W	W0	W1	W2	H0	H1	I	D0	t
<b>Tolerance</b>	<b>+0.5</b>		<b>+0.8/-0.2</b>	<b>±0.05</b>	<b>±1.0</b>	<b>±0.3</b>	<b>±0.7</b>	<b>±1.3</b>	<b>+1/-0.5</b>	<b>±0.5</b>	<b>Maximum</b>	<b>Maximum</b>	<b>±0.75</b>	<b>±0.5</b>	<b>Maximum</b>	<b>±0.2</b>	<b>±0.2</b>
Formed to 2.5 mm	4	5 – 7	2.5	0.45	12.7	12.7	5.1	6.35	18	12	11	3	16.0	18.5		4	0.7
	5	≤ 7	2.5	0.45	12.7	12.7	5.1	6.35	18	12	11	3	16.0	18.5		4	0.7
		> 7	2.5	0.50	12.7	12.7	5.1	6.35	18	12	11	3	16.0	18.5		4	0.7
Formed to 5 mm	4	5 – 7	5.0	0.45	12.7	12.7	3.85	6.35	18	12	11	3	16.0	18.5		4	0.7
	5	≤ 7	5.0	0.45	12.7	12.7	3.85	6.35	18	12	11	3	16.0	18.5		4	0.7
		> 7	5.0	0.50	12.7	12.7	3.85	6.35	18	12	11	3	16.0	18.5		4	0.7
	6	≤ 7	5.0	0.50	12.7	12.7	3.85	6.35	18	12	11	3	16.0	18.5		4	0.7
		> 7	5.0	0.50	12.7	12.7	3.85	6.35	18	12	11	3	16.0	18.5		4	0.7
	8	≤ 7	5.0	0.50	12.7	12.7	3.85	6.35	18	12	11	3	16.0	18.5		4	0.7
> 7	5.0	0.50	12.7	12.7	3.85	6.35	18	12	12	11	3	16.0	18.5		4	0.7	
Straight leads	4	5 – 7	1.5	0.45	12.7	12.7	5.6	6.35	18	12	11	3	18.5			4	0.7
	5	≤ 7	2.0	0.45	12.7	12.7	5.35	6.35	18	12	11	3	18.5			4	0.7
		> 7	2.0	0.50	12.7	12.7	5.35	6.35	18	12	11	3	18.5			4	0.7
	6	≤ 7	2.5	0.50	12.7	12.7	5.1	6.35	18	12	11	3	18.5			4	0.7
		> 7	2.5	0.50	12.7	12.7	5.1	6.35	18	12	11	3	18.5			4	0.7
	8	≤ 7	3.5	0.50	12.7	12.7	4.6	6.35	18	12	11	3	18.5			4	0.7
		> 7	3.5	0.50	12.7	12.7	4.6	6.35	18	12	11	3	18.5			4	0.7
10	≤ 20	5.0	0.60	12.7	12.7	3.85	6.35	18	12	11	3	18.5		1	4	1.0	

## Lead Taping & Packaging



Diameter	Length	Ammo			Reel		
		H	W	T	D	H	W
			Maximum	Maximum	±2	±0.5	+1/-0.1
4	All	230	340	42	350	30	50
5	≤ 7	230	340	42			
5	11	275	340	42			
6.3	≤ 7	235	340	45			
6.3	11	230	340	48			
8	≤ 7	270	340	48			
8	11	235	340	48			
8	>11 ≤ 20	240	340	57			
10	≤ 13	250	340	52			
10	>13 ≤ 20	256	340	57			
10	>20	250	340	60	NA	NA	NA
12	All	270	340	57			
13	All	285	340	62			
16	All	265	340	62			

## Construction Data

The manufacturing process begins with the anode foil being electrochemically etched to increase the surface area and then “formed” to produce the aluminum oxide layer. Both the anode and cathode foils are then interleaved with absorbent paper and wound into a cylinder. During the winding process, aluminum tabs are attached to each foil to provide the electrical contact.

The deck, complete with terminals, is attached to the tabs and then folded down to rest on top of the winding. The complete winding is impregnated with electrolyte before being housed in a suitable container, usually an aluminum can, and sealed. Throughout the process, all materials inside the housing must be maintained at the highest purity and be compatible with the electrolyte.

Each capacitor is aged and tested before being sleeved and packed. The purpose of aging is to repair any damage in the oxide layer and thus reduce the leakage current to a very low level. Aging is normally carried out at the rated temperature of the capacitor and is accomplished by applying voltage to the device while carefully controlling the supply current. The process may take several hours to complete.

Damage to the oxide layer can occur due to variety of reasons:

- Slitting of the anode foil after forming
- Attaching the tabs to the anode foil
- Minor mechanical damage caused during winding

A sample from each batch is taken by the quality department after completion of the production process. This sample size is controlled by the use of recognized sampling tables defined in BS 6001.

The following tests are applied and may be varied at the request of the customer. In this case the batch, or special procedure, will determine the course of action.

**Electrical:**

- Leakage current
- Capacitance
- ESR
- Impedance
- Tan Delta

**Mechanical/Visual:**

- Overall dimensions
- Torque test of mounting stud
- Print detail
- Box labels
- Packaging, including packed quantity



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