

## Overview

KEMET's ESH Series of aluminum electrolytic radial capacitors are designed for high quality, high reliability applications.

## Applications

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

## Benefits

- Suited for high quality, high reliability applications
- 2,000 hour operating life
- Operating temperature of up to +105°C
- Case diameters 5 – 18 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 Leaded Aluminum Electrolytic	Digits 4 – 5 represent the first two digits of the capacitance value. The final digit indicates the number of zeros to be added.	M = ±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 = 400 450 = 450 500 = 500	A = Standard	See Dimension Table	See Ordering Options Table

## Ordering Options Table

Diameter	Packaging Type	Lead Type	Lead Length (mm)	Lead and Packaging Code
Standard Bulk Packaging Options				
4 – 22	Bulk (bag)	Straight	20/15 Minimum	AA
Standard Auto-Insertion Packaging Options				
4 – 5	Tape & Reel	Formed to 2.5 mm	$H_0 = 16.5 \pm 0.75$	LA
6.3	Tape & Reel	2.5 mm Lead Spacing	$H_0 = 18.5 \pm 0.75$	KA
8	Tape & Reel	Formed to 5 mm	$H_0 = 16.5 \pm 0.75$	JA
10 – 13	Ammo	5 mm Lead Spacing	$H_0 = 18.5 \pm 0.75$	EA
16	Ammo	7.5 mm Lead Spacing	$H_0 = 18.5 \pm 0.75$	EA
Other Packaging Options				
4 – 8	Ammo	Formed to 5 mm	$H_0 = 16.5 \pm 0.75$	DA
10	Ammo	5 mm Lead Spacing	$H_0 = 16.5 \pm 0.75$	DA
4 – 8	Ammo	Straight	$H_0 = 18.5 \pm 0.75$	EA
4 – 5	Ammo	Formed to 2.5 mm	$H_0 = 16.5 \pm 0.75$	FA
4 – 6.3	Tape & Reel	Formed to 5 mm	$H_0 = 16.5 \pm 0.75$	JA
4 – 5, 8 – 16	Tape & Reel	Straight	$H_0 = 18.5 \pm 0.75$	KA
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 makes any necessary changes in its products, whenever needed.

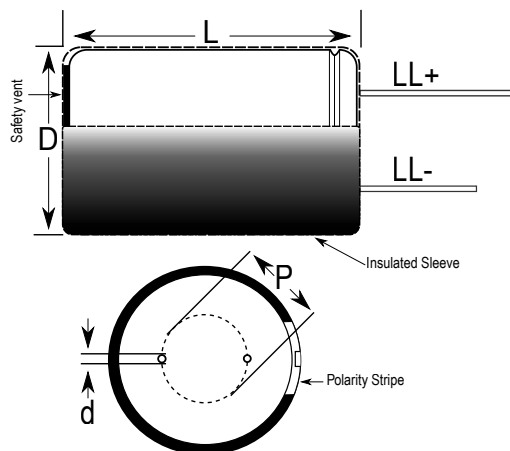
Some customer segments such as medical, military and automotive electronics may still require the use of lead in electrode coatings. To clarify the situation and distinguish products from each other, a special symbol is used on the packaging labels for RoHS compatible capacitors.

Because of customer requirements, there may appear additional markings such as LF = Lead Free or LFW = Lead Free Wires on the label.



RoHS Compliant

## Dimensions – Millimeters



Size Code	D		L		p		d		LL+/LL-	
	Nominal	Tolerance	Nominal	Tolerance	Nominal	Tolerance	Nominal	Tolerance	Nominal	Tolerance
C3	5	$\pm 0.5$	11	+1.5/-0	2	$\pm 0.5$	0.5	Nominal	20/15	Minimum
E3	6.3	$\pm 0.5$	11	+1.5/-0	2.5	$\pm 0.5$	0.5	Nominal	20/15	Minimum
G3	8	$\pm 0.5$	11	+1.5/-0	3.5	$\pm 0.5$	0.6	Nominal	20/15	Minimum
H1	10	$\pm 0.5$	12	+1.5/-0	5	$\pm 0.5$	0.6	Nominal	20/15	Minimum
H2	10	$\pm 0.5$	16	+2.0/-0	5	$\pm 0.5$	0.6	Nominal	20/15	Minimum
H4	10	$\pm 0.5$	20	+2.0/-0	5	$\pm 0.5$	0.6	Nominal	20/15	Minimum
L3	13	$\pm 0.5$	20	+2.0/-0	5	$\pm 0.5$	0.6	Nominal	20/15	Minimum
L4	13	$\pm 0.5$	25	+2.0/-0	5	$\pm 0.5$	0.6	Nominal	20/15	Minimum
M7	16	$\pm 0.5$	25	+2.0/-0	7.5	$\pm 0.5$	0.8	Nominal	20/15	Minimum
M2	16	$\pm 0.5$	32	+2.0/-0	7.5	$\pm 0.5$	0.8	Nominal	20/15	Minimum
M3	16	$\pm 0.5$	36	+2.0/-0	7.5	$\pm 0.5$	0.8	Nominal	20/15	Minimum
N2	18	$\pm 0.5$	36	+2.0/-0	7.5	$\pm 0.5$	0.8	Nominal	20/15	Minimum
N3	18	$\pm 0.5$	40	+2.0/-0	7.5	$\pm 0.5$	0.8	Nominal	20/15	Minimum
Q4	22	$\pm 0.5$	40	+2.0/-0	10.0	$\pm 0.5$	0.8	Nominal	20/15	Minimum

## Performance Characteristics

Item	Performance Characteristics	
Capacitance Range	1 – 15,000 $\mu$ F	0.47 – 470 $\mu$ F
Capacitance Tolerance	$\pm$ 20% at 120 Hz / 20°C	
Rated Voltage	6.3 – 100 VDC	160 – 450 VDC
Life Test	2,000 hours (see conditions in Test Methods & Performance)	
Operating Temperature	-40°C to +105°C	-25°C to +85°C
Leakage Current	$I \leq 0.01 CV (\mu A)$ or 3 $\mu A$ , whichever is greater	$I = 0.03 CV (\mu A) + 10 \mu A$
	C = rated capacitance ( $\mu$ F), V = rated voltage (VDC). Voltage applied for 2 minutes at 20°C.	

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

Rated Voltage (VDC)	Capacitance Range ( $\mu$ F)	50 Hz	120 Hz	300 Hz	1 kHz	10 to 100 kHz
6.3 – 100	0.47 – 68 $\mu$ F	0.75	1.00	1.30	1.57	2.00
6.3 – 100	100 – 470 $\mu$ F	0.75	1.00	1.23	1.34	1.50
6.3 – 100	680 – 15,000 $\mu$ F	0.75	1.00	1.10	1.13	1.15
160 – 450	0.47 – 470 $\mu$ F	0.80	1.00	1.25	1.40	1.60

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

Temperature	65°C	85°C	105°C
Coefficient	1.70	1.40	1.00

## 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
<b>Performance</b>	<b>The following specifications will be satisfied when the capacitor is restored to 20°C:</b>	
Capacitance Change	Within $\pm$ 20% of the initial value	
Dissipation Factor	Does not exceed 200% of the specified value	
Leakage Current	Does not exceed specified value	

**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 25°C (tan δ %)*	RC 120 Hz 105°C (mA)	Part Number
6.3	8	100	5 x 11	26	100	ESH107M6R3AC3(1)
6.3	8	150	5 x 11	26	120	ESH157M6R3AC3(1)
6.3	8	220	6 x 11	26	165	ESH227M6R3AE3(1)
6.3	8	330	6 x 11	26	200	ESH337M6R3AE3(1)
6.3	8	330	8 x 11	26	200	ESH337M6R3AG3(1)
6.3	8	470	8 x 11	26	280	ESH477M6R3AG3(1)
6.3	8	680	10 x 12	26	320	ESH687M6R3AH1(1)
6.3	8	1000	10 x 12	26	470	ESH108M6R3AH1(1)
6.3	8	1500	10 x 16	26	600	ESH158M6R3AH2(1)
6.3	8	2200	13 x 20	26	930	ESH228M6R3AL3(1)
6.3	8	3300	13 x 20	26	1100	ESH338M6R3AL3(1)
6.3	8	4700	16 x 25	26	1320	ESH478M6R3AM7(1)
6.3	8	6800	16 x 25	26	1490	ESH688M6R3AM7(1)
6.3	8	10000	16 x 32	26	1830	ESH109M6R3AM2(1)
6.3	8	15000	16 x 36	26	2280	ESH159M6R3AM3(1)
10	13	47	5 x 11	22	75	ESH476M010AC3(1)
10	13	68	5 x 11	22	80	ESH686M010AC3(1)
10	13	100	5 x 11	22	110	ESH107M010AC3(1)
10	13	150	6 x 11	22	130	ESH157M010AE3(1)
10	13	220	6 x 11	22	180	ESH227M010AE3(1)
10	13	330	8 x 11	22	255	ESH337M010AG3(1)
10	13	470	8 x 11	22	305	ESH477M010AG3(1)
10	13	680	10 x 12	22	420	ESH687M010AH1(1)
10	13	1000	10 x 16	22	570	ESH108M010AH2(1)
10	13	1500	10 x 20	22	750	ESH158M010AH4(1)
10	13	2200	13 x 20	22	1010	ESH228M010AL3(1)
10	13	3300	13 x 25	22	1220	ESH338M010AL4(1)
10	13	4700	16 x 25	22	1410	ESH478M010AM7(1)
10	13	6800	16 x 32	22	1610	ESH688M010AM2(1)
10	13	10000	18 x 36	22	1980	ESH109M010AN2(1)
16	20	33	5 x 11	18	70	ESH336M016AC3(1)
16	20	47	5 x 11	18	85	ESH476M016AC3(1)
16	20	68	5 x 11	18	100	ESH686M016AC3(1)
16	20	100	6 x 11	18	135	ESH107M016AE3(1)
16	20	150	8 x 11	18	180	ESH157M016AG3(1)
16	20	220	8 x 11	18	235	ESH227M016AG3(1)
16	20	330	10 x 12	18	285	ESH337M016AH1(1)
16	20	470	10 x 12	18	395	ESH477M016AH1(1)
16	20	680	10 x 16	18	530	ESH687M016AH2(1)
16	20	1000	10 x 20	18	700	ESH108M016AH4(1)
16	20	1500	13 x 20	18	860	ESH158M016AL3(1)
16	20	2200	13 x 25	18	1150	ESH228M016AL4(1)
16	20	3300	16 x 25	18	1350	ESH338M016AM7(1)
16	20	4700	16 x 32	18	1560	ESH478M016AM2(1)
16	20	6800	18 x 36	18	1790	ESH688M016AN2(1)
25	32	22	5 x 11	16	60	ESH226M025AC3(1)
25	32	33	5 x 11	16	75	ESH336M025AC3(1)
25	32	47	5 x 11	16	90	ESH476M025AC3(1)
25	32	68	6 x 11	16	125	ESH686M025AE3(1)
25	32	100	6 x 11	16	145	ESH107M025AE3(1)
25	32	150	8 x 11	16	200	ESH157M025AG3(1)
25	32	220	8 x 11	16	250	ESH227M025AG3(1)
25	32	220	10 x 12	16	250	ESH227M025AH1(1)
25	32	330	10 x 12	16	355	ESH337M025AH1(1)
25	32	470	10 x 12	16	405	ESH477M025AH1(1)
25	32	470	10 x 16	16	470	ESH477M025AH2(1)
25	32	680	10 x 20	16	650	ESH687M025AH4(1)
25	32	1000	13 x 20	16	855	ESH108M025AL3(1)
25	32	1500	13 x 25	16	1020	ESH158M025AL4(1)
25	32	2200	16 x 25	16	1230	ESH228M025AM7(1)
<b>VDC</b>	<b>VDC Surge</b>	<b>Rated Capacitance</b>	<b>Case Size</b>	<b>DF</b>	<b>RC</b>	<b>Part Number</b>

(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 &amp; Part Number Reference cont'd

VDC	VDC Surge Voltage	Rated Capacitance 120 Hz 20°C (µF)	Case Size D x L (mm)	DF 120 Hz 25°C (tan δ %)*	RC 120 Hz 105°C (mA)	Part Number
25	32	3300	16 x 32	16	1450	ESH338M025AM2(1)
25	32	4700	18 x 36	16	1690	ESH478M025AN2(1)
35	44	10	5 x 11	14	44	ESH106M035AC3(1)
35	44	15	5 x 11	14	50	ESH156M035AC3(1)
35	44	22	5 x 11	14	65	ESH226M035AC3(1)
35	44	33	5 x 11	14	85	ESH336M035AC3(1)
35	44	47	6 x 11	14	115	ESH476M035AE3(1)
35	44	68	8 x 11	14	130	ESH686M035AG3(1)
35	44	100	8 x 11	14	190	ESH107M035AG3(1)
35	44	150	10 x 12	14	240	ESH157M035AH1(1)
35	44	220	10 x 12	14	315	ESH227M035AH1(1)
35	44	330	10 x 16	14	440	ESH337M035AH2(1)
35	44	470	10 x 20	14	580	ESH477M035AH4(1)
35	44	470	13 x 20	14	580	ESH477M035AL3(1)
35	44	680	13 x 20	14	730	ESH687M035AL3(1)
35	44	1000	13 x 25	14	995	ESH108M035AL4(1)
35	44	1500	16 x 25	14	1110	ESH158M035AM7(1)
35	44	2200	16 x 32	14	1450	ESH228M035AM2(1)
35	44	3300	18 x 36	14	1660	ESH338M035AN2(1)
50	63	0.47	5 x 11	12	7	ESH474M050AC3(1)
50	63	1.0	5 x 11	12	12	ESH105M050AC3(1)
50	63	2.2	5 x 11	12	18	ESH225M050AC3(1)
50	63	3.3	5 x 11	12	25	ESH335M050AC3(1)
50	63	4.7	5 x 11	12	30	ESH475M050AC3(1)
50	63	6.8	5 x 11	12	30	ESH685M050AC3(1)
50	63	10	5 x 11	12	50	ESH106M050AC3(1)
50	63	15	5 x 11	12	50	ESH156M050AC3(1)
50	63	22	5 x 11	12	75	ESH226M050AC3(1)
50	63	33	6 x 11	12	105	ESH336M050AE3(1)
50	63	47	8 x 11	12	125	ESH476M050AG3(1)
50	63	68	8 x 11	12	159	ESH686M050AG3(1)
50	63	100	10 x 12	12	210	ESH107M050AH1(1)
50	63	150	10 x 12	12	289	ESH157M050AH1(1)
50	63	220	10 x 16	12	400	ESH227M050AH2(1)
50	63	330	10 x 20	12	535	ESH337M050AH4(1)
50	63	470	13 x 20	12	730	ESH477M050AL3(1)
50	63	680	13 x 25	12	860	ESH687M050AL4(1)
50	63	1000	16 x 25	12	1110	ESH108M050AM7(1)
50	63	1500	16 x 32	12	1350	ESH158M050AM2(1)
50	63	2200	18 x 36	12	1530	ESH228M050AN2(1)
63	79	0.47	5 x 11	10	8	ESH474M063AC3(1)
63	79	1.0	5 x 11	10	12	ESH105M063AC3(1)
63	79	2.2	5 x 11	10	20	ESH225M063AC3(1)
63	79	3.3	5 x 11	10	27	ESH335M063AC3(1)
63	79	4.7	5 x 11	10	34	ESH475M063AC3(1)
63	79	6.8	5 x 11	10	37	ESH685M063AC3(1)
63	79	10	5 x 11	10	55	ESH106M063AC3(1)
63	79	15	5 x 11	10	65	ESH156M063AC3(1)
63	79	22	6 x 11	10	90	ESH226M063AE3(1)
63	79	33	8 x 11	10	110	ESH336M063AG3(1)
63	79	47	8 x 11	10	155	ESH476M063AG3(1)
63	79	68	10 x 12	10	198	ESH686M063AH1(1)
63	79	100	10 x 12	10	260	ESH107M063AH1(1)
63	79	150	10 x 16	10	330	ESH157M063AH2(1)
63	79	220	10 x 20	10	465	ESH227M063AH4(1)
63	79	330	13 x 20	10	650	ESH337M063AL3(1)
63	79	470	13 x 25	10	800	ESH477M063AL4(1)
63	79	680	16 x 25	10	1000	ESH687M063AM7(1)
63	79	1000	16 x 32	10	1200	ESH108M063AM2(1)
63	79	1500	16 x 36	10	1450	ESH158M063AM3(1)
<b>VDC</b>	<b>VDC Surge</b>	<b>Rated Capacitance</b>	<b>Case Size</b>	<b>DF</b>	<b>RC</b>	<b>Part Number</b>

(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 &amp; Part Number Reference cont'd

VDC	VDC Surge Voltage	Rated Capacitance 120 Hz 20°C (µF)	Case Size D x L (mm)	DF 120 Hz 25°C (tan δ %)*	RC 120 Hz 105°C (mA)	Part Number
100	125	0.47	5 x 11	10	10	ESH474M100AC3(1)
100	125	1.0	5 x 11	10	15	ESH105M100AC3(1)
100	125	2.2	5 x 11	10	22	ESH225M100AC3(1)
100	125	3.3	5 x 11	10	29	ESH335M100AC3(1)
100	125	4.7	5 x 11	10	37	ESH475M100AC3(1)
100	125	6.8	5 x 11	10	46	ESH685M100AC3(1)
100	125	10	6 x 11	10	65	ESH106M100AE3(1)
100	125	15	8 x 11	10	82	ESH156M100AG3(1)
100	125	22	8 x 11	10	115	ESH226M100AG3(1)
100	125	33	10 x 12	10	160	ESH336M100AH1(1)
100	125	47	10 x 16	10	210	ESH476M100AH2(1)
100	125	68	10 x 20	10	241	ESH686M100AH4(1)
100	125	100	13 x 20	10	385	ESH107M100AL3(1)
100	125	150	13 x 25	10	414	ESH157M100AL4(1)
100	125	220	16 x 25	10	590	ESH227M100AM7(1)
100	125	330	16 x 25	10	720	ESH337M100AM7(1)
100	125	470	16 x 32	10	875	ESH477M100AM2(1)
100	125	680	16 x 36	10	1200	ESH687M100AM3(1)
160	200	0.47	5 x 11	15	12	ESH474M160AC3(1)
160	200	1.0	5 x 11	15	17	ESH105M160AC3(1)
160	200	2.2	6 x 11	15	25	ESH225M160AE3(1)
160	200	3.3	8 x 11	15	36	ESH335M160AG3(1)
160	200	4.7	8 x 11	15	43	ESH475M160AG3(1)
160	200	6.8	10 x 12	15	54	ESH685M160AH1(1)
160	200	10	10 x 12	15	70	ESH106M160AH1(1)
160	200	15	10 x 16	15	90	ESH156M160AH2(1)
160	200	22	10 x 20	15	130	ESH226M160AH4(1)
160	200	33	13 x 20	15	180	ESH336M160AL3(1)
160	200	47	13 x 25	15	250	ESH476M160AL4(1)
160	200	68	13 x 25	15	270	ESH686M160AL4(1)
160	200	100	16 x 25	15	390	ESH107M160AM7(1)
160	200	150	16 x 32	15	435	ESH157M160AM2(1)
160	200	220	16 x 36	15	700	ESH227M160AM3(1)
160	200	330	18 x 40	15	850	ESH337M160AN3(1)
160	200	470	22 x 40	15	980	ESH477M160AQ4(1)
200	250	0.47	5 x 11	15	12	ESH474M200AC3(1)
200	250	1.0	6 x 11	15	17	ESH105M200AE3(1)
200	250	2.2	6 x 11	15	25	ESH225M200AE3(1)
200	250	3.3	8 x 11	15	36	ESH335M200AG3(1)
200	250	4.7	10 x 12	15	50	ESH475M200AH1(1)
200	250	6.8	10 x 12	15	60	ESH685M200AH1(1)
200	250	10	10 x 16	15	80	ESH106M200AH2(1)
200	250	15	10 x 20	15	110	ESH156M200AH4(1)
200	250	22	10 x 20	15	140	ESH226M200AH4(1)
200	250	33	13 x 20	15	190	ESH336M200AL3(1)
200	250	33	13 x 25	15	190	ESH336M200AL4(1)
200	250	47	13 x 20	15	260	ESH476M200AL3(1)
200	250	47	13 x 25	15	260	ESH476M200AL4(1)
200	250	68	16 x 25	15	280	ESH686M200AM7(1)
200	250	100	16 x 32	15	400	ESH107M200AM2(1)
200	250	150	16 x 36	15	450	ESH157M200AM3(1)
200	250	220	18 x 36	15	750	ESH227M200AN2(1)
200	250	220	18 x 40	15	750	ESH227M200AN3(1)
200	250	330	18 x 40	15	920	ESH337M200AN3(1)
200	250	330	22 x 40	15	920	ESH337M200AQ4(1)
250	300	0.47	5 x 11	15	12	ESH474M250AC3(1)
250	300	1.0	6 x 11	15	17	ESH105M250AE3(1)
250	300	2.2	8 x 11	15	29	ESH225M250AG3(1)
250	300	3.3	10 x 12	15	42	ESH335M250AH1(1)
250	300	4.7	10 x 12	15	52	ESH475M250AH1(1)
VDC	VDC Surge	Rated Capacitance	Case Size	DF	RC	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'd**

VDC	VDC Surge Voltage	Rated Capacitance 120 Hz 20°C (µF)	Case Size D x L (mm)	DF 120 Hz 25°C (tan δ %)*	RC 120 Hz 105°C (mA)	Part Number
250	300	6.8	10 x 12	15	62	ESH685M250AH1(1)
250	300	10	10 x 16	15	75	ESH106M250AH2(1)
250	300	10	10 x 20	15	88	ESH106M250AH4(1)
250	300	15	13 x 20	15	120	ESH156M250AL3(1)
250	300	22	13 x 20	15	155	ESH226M250AL3(1)
250	300	22	13 x 25	15	155	ESH226M250AL4(1)
250	300	33	13 x 25	15	200	ESH336M250AL4(1)
250	300	47	16 x 25	15	270	ESH476M250AM7(1)
250	300	68	16 x 32	15	300	ESH686M250AM2(1)
250	300	100	18 x 36	15	440	ESH107M250AN2(1)
250	300	150	18 x 40	15	600	ESH157M250AN3(1)
250	300	220	22 x 40	15	800	ESH227M250AQ4(1)
350	400	0.47	6 x 11	20	14	ESH474M350AE3(1)
350	400	1.0	8 x 11	20	20	ESH105M350AG3(1)
350	400	2.2	10 x 12	20	35	ESH225M350AH1(1)
350	400	3.3	10 x 16	20	47	ESH335M350AH2(1)
350	400	4.7	10 x 16	20	55	ESH475M350AH2(1)
350	400	6.8	10 x 20	20	65	ESH685M350AH4(1)
350	400	10	13 x 20	20	95	ESH106M350AL3(1)
350	400	15	13 x 20	20	140	ESH156M350AL3(1)
350	400	22	16 x 25	20	165	ESH226M350AM7(1)
350	400	33	16 x 32	20	195	ESH336M350AM2(1)
350	400	47	16 x 36	20	210	ESH476M350AM3(1)
350	400	47	18 x 36	20	240	ESH476M350AN2(1)
350	400	68	18 x 36	20	320	ESH686M350AN2(1)
350	400	100	18 x 40	20	300	ESH107M350AN3(1)
350	400	100	22 x 40	20	360	ESH107M350AQ4(1)
350	400	150	22 x 40	20	480	ESH157M350AQ4(1)
400	450	0.47	6 x 11	20	14	ESH474M400AE3(1)
400	450	1.0	8 x 11	20	20	ESH105M400AG3(1)
400	450	2.2	10 x 12	20	35	ESH225M400AH1(1)
400	450	3.3	10 x 12	20	42	ESH335M400AH1(1)
400	450	3.3	10 x 16	20	49	ESH335M400AH2(1)
400	450	4.7	10 x 16	20	57	ESH475M400AH2(1)
400	450	6.8	10 x 20	20	67	ESH685M400AH4(1)
400	450	10	10 x 20	20	75	ESH106M400AH4(1)
400	450	10	13 x 20	20	97	ESH106M400AL3(1)
400	450	15	13 x 25	20	145	ESH156M400AL4(1)
400	450	22	13 x 25	20	140	ESH226M400AL4(1)
400	450	22	16 x 25	20	170	ESH226M400AM7(1)
400	450	33	16 x 25	20	190	ESH336M400AM7(1)
400	450	33	16 x 32	20	230	ESH336M400AM2(1)
400	450	47	16 x 32	20	250	ESH476M400AM2(1)
400	450	47	18 x 36	20	300	ESH476M400AN2(1)
400	450	68	18 x 36	20	325	ESH686M400AN2(1)
400	450	100	18 x 36	20	290	ESH107M400AN2(1)
400	450	100	22 x 40	20	365	ESH107M400AQ4(1)
400	450	150	22 x 40	20	465	ESH157M400AQ4(1)
450	500	0.47	6 x 11	20	16	ESH474M450AE3(1)
450	500	1.0	8 x 11	20	22	ESH105M450AG3(1)
450	500	2.2	10 x 12	20	37	ESH225M450AH1(1)
450	500	3.3	10 x 16	20	51	ESH335M450AH2(1)
450	500	4.7	10 x 16	20	59	ESH475M450AH2(1)
450	500	6.8	13 x 20	20	69	ESH685M450AL3(1)
450	500	10	13 x 25	20	99	ESH106M450AL4(1)
450	500	15	16 x 25	20	150	ESH156M450AM7(1)
450	500	22	16 x 25	20	145	ESH226M450AM7(1)
450	500	22	16 x 32	20	175	ESH226M450AM2(1)
450	500	33	18 x 36	20	250	ESH336M450AN2(1)
450	500	47	18 x 40	20	350	ESH476M450AN3(1)
450	500	68	22 x 40	20	380	ESH686M450AQ4(1)
VDC	VDC Surge	Rated Capacitance	Case Size	DF	RC	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 (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

- A general principle is that 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 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.
- 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 mm 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 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 and Operation Guidelines

### Electrical Ratings: Capacitance (ESC)

Capacitance is measured by applying an alternate voltage of  $\leq 0.5$  V at a frequency of 120 or 100 Hz and 20°C.

### 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

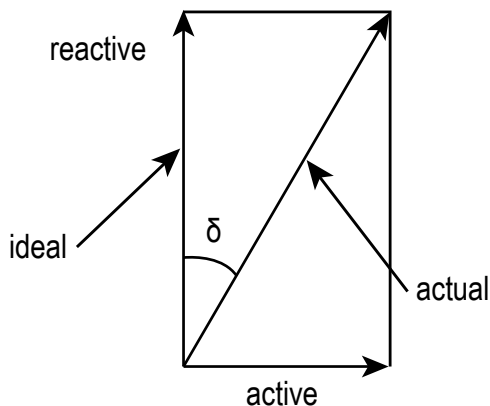
Effective capacitance value is derived from the impedance curve, as long as impedance is still in the range where the capacitance component is dominant.

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

$C$  = 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:

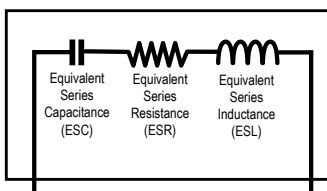
ESC = Equivalent Series Capacitance

ESR = Equivalent Series Resistance

### Equivalent Series Inductance (ESL)

Self inductance or Equivalent Series Inductance results from the terminal configuration and internal design of the capacitor.

Capacitor Equivalent Internal Circuit



### 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:

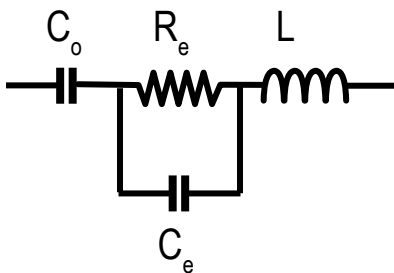
$$ESR = \frac{\tan \delta}{2\pi f ESC}$$

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)

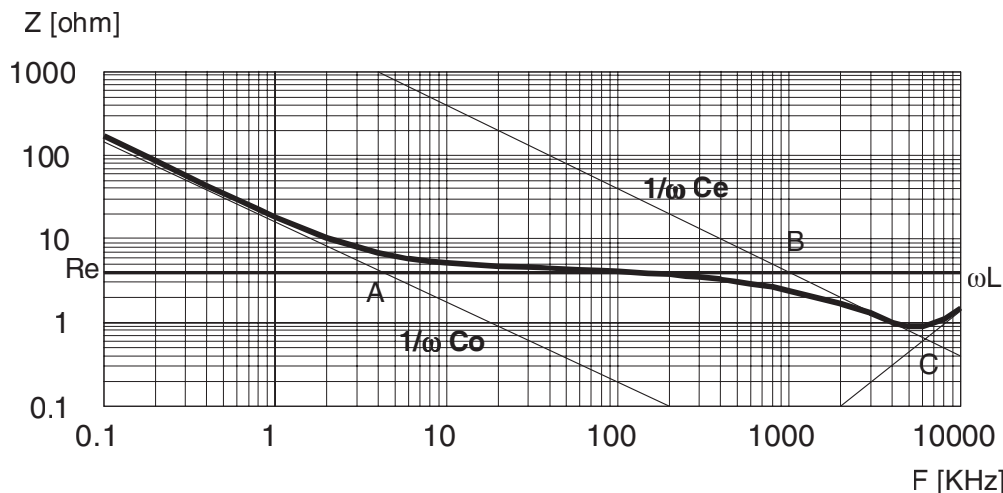
$R_e$  = Resistance of electrolyte and paper mixture (other resistances not depending on the frequency are not considered: tabs, plates, etc.)

$C_e$  = 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.

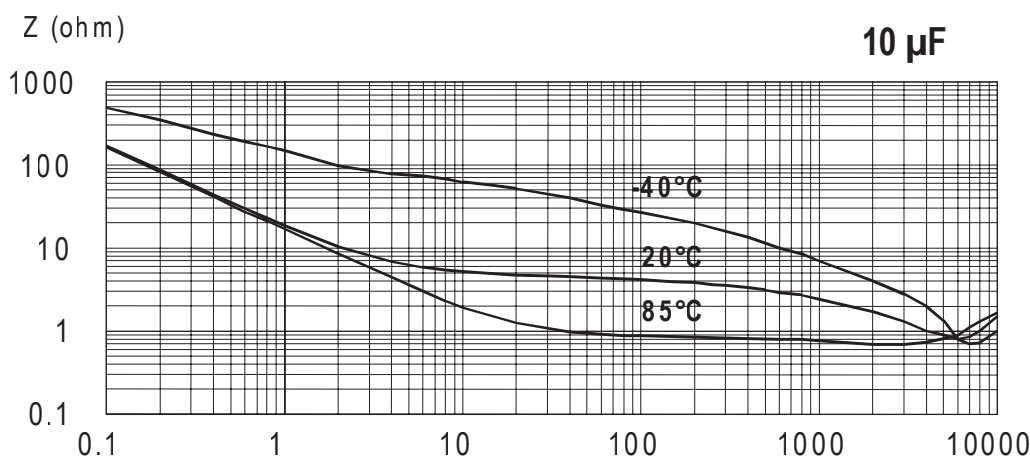
Impedance as a function of frequency (sinusoidal waveform) for a certain temperature can be represented as follows:



- Capacitive reactance predominates at low frequencies
- With increasing frequency, capacitive reactance  $X_c = 1/\omega C_0$  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 ( $\omega_0$ ), capacitive and inductive reactance mutually cancel each other  $1/\omega C_e = \omega L$ ,  $\omega_0 = C\sqrt{1/LC_e}$
- 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  $C_e \approx 0.01 C_0$ .

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.

### Leakage Current (LC)

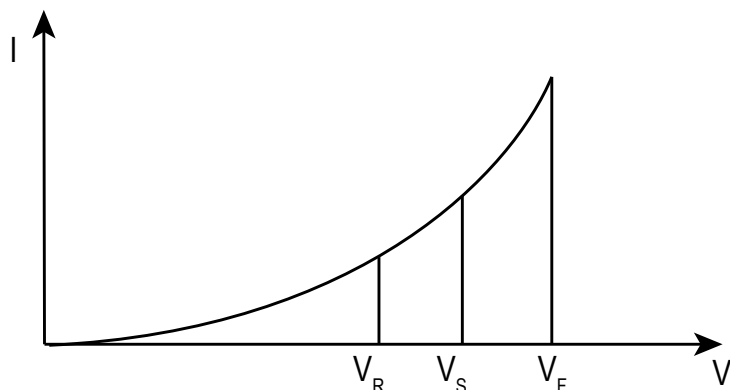
Due to the aluminum oxide layer that serves as a dielectric, a small current will continue to flow even after a DC voltage has been applied for long periods. This current is called leakage current.

A high leakage current flows after applying voltage to the capacitor then decreases in a few minutes, e.g., 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 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.

### 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:  $L = L_o \times 2^{(T_o - T)/10}$

Where:

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

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

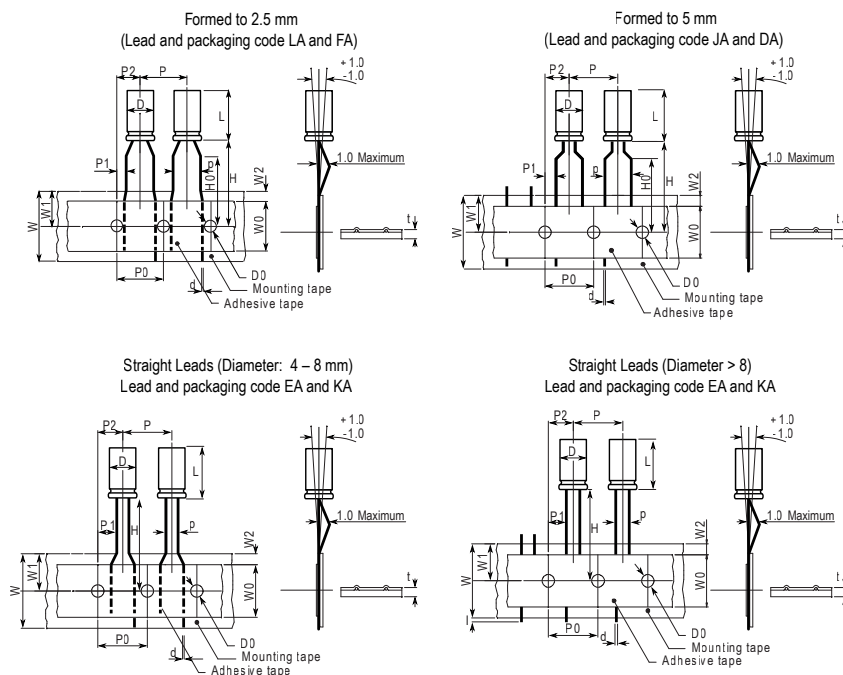
## Packaging Quantities

Size Code	Diameter (mm)	Length (mm)	Bulk Standard Leads	Auto-insertion		
				Cut Leads	Ammo	Tape & Reel
C3	5	11	10000	15000	2000	1300
E3	6.3	11	10000	15000	2000	1100
G3	8	11	6000	8000	1000	750
H1	10	12	4000	4000	700	600
H2	10	16	3000	4000	700	600
H4	10	20	2400	3000	700	600
L3	13	20	2000	2000	500	
L4	13	25	1600	1600	500	
M7	16	25	1000	500	300	
M2	16	32	800	500		
M3	16	36	600	500		
N2	18	36	500	500		
N3	18	40	500	500		
Q4	22	40	300	400		

## Standard Marking for Radial Types

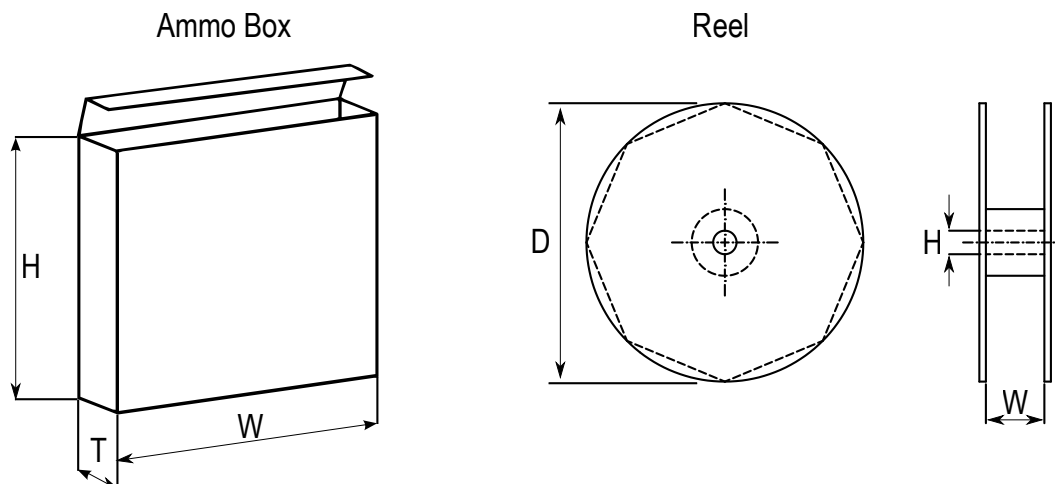
- KEMET logo
- Series
- Operating temperature (°C)
- Rated capacitance (µF)
- Rated voltage (VDC)
- Negative polarity: white line
- Date code

## Taping for Automatic Insertion Machines



Dimensions (mm)	D	L	p	d	P	P0	P1	P2	W	W0	W1	W2	H0	H1	I	D0	t
Tolerance	+0.5		+0.8/-0.2	±0.05	±1.0	±0.3	±0.7	±1.3	+1/-0.5	±0.5	Maximum	Maximum	±0.75	±0.5	Maximum	±0.2	±0.2
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	18.5		4	0.7
	5	≤7	2.5	0.45	12.7	12.7	5.1	6.35	18	12	11	3	16	18.5		4	0.7
		>7	2.5	0.5	12.7	12.7	5.1	6.35	18	12	11	3	16	18.5		4	0.7
Formed to 5 mm	4	5-7	5	0.45	12.7	12.7	3.85	6.35	18	12	11	3	16	18.5		4	0.7
	5	≤7	5	0.45	12.7	12.7	3.85	6.35	18	12	11	3	16	18.5		4	0.7
		>7	5	0.5	12.7	12.7	3.85	6.35	18	12	11	3	16	18.5		4	0.7
	6	≤7	5	0.5	12.7	12.7	3.85	6.35	18	12	11	3	16	18.5		4	0.7
		>7	5	0.5	12.7	12.7	3.85	6.35	18	12	11	3	16	18.5		4	0.7
	8	≤7	5	0.5	12.7	12.7	3.85	6.35	18	12	11	3	16	18.5		4	0.7
>7	5	0.5	12.7	12.7	3.85	6.35	18	12	11	3	16	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	0.45	12.7	12.7	5.35	6.35	18	12	11	3	18.5			4	0.7
		>7	2	0.5	12.7	12.7	5.35	6.35	18	12	11	3	18.5			4	0.7
	6	≤7	2.5	0.5	12.7	12.7	5.1	6.35	18	12	11	3	18.5			4	0.7
		>7	2.5	0.5	12.7	12.7	5.1	6.35	18	12	11	3	18.5			4	0.7
	8	≤7	3.5	0.5	12.7	12.7	4.6	6.35	18	12	11	3	18.5			4	0.7
		>7	3.5	0.5	12.7	12.7	4.6	6.35	18	12	11	3	18.5			4	0.7
	10	12-25	5	0.6	12.7	12.7	3.85	6.35	18	12	11	3	18.5		1	4	1
	12	15-25	5	0.6	15	15	3.85	7.5	18	12	11	3	18.5		1	4	1
13	5		0.6	15	15	3.85	7.5	18	12	11	3	18.5		1	4	1	
	5		0.6	15	15	3.85	7.5	18	12	11	3	18.5		1	4	1	
16	7.5		0.8	30	30	3.75	7.5	18	12	11	3	18.5		1	4	1	
18	7.5		0.8	30	30	3.75	7.5	18	12	11	3	18.5		1	4	1	

## Lead Taping & Packaging

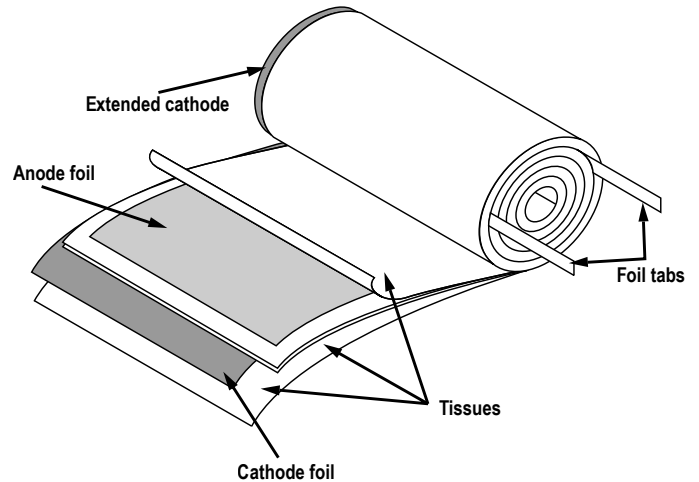


Case Size (mm)	Ammo			Reel		
	H	W	T	D	H	W
		Maximum	Maximum	±2	±0.5	+1/-0.1
4	230	340	42	350	30	50
5 x 5 – 7	230	340	42			
6 x 5 – 7	275	340	42			
8 x 5 – 9	235	340	45			
5 x 11	230	340	48			
6 x 11	270	340	48			
8 x 11	235	340	48			
8 x 14 – 20	240	340	57			
10 x 12	250	340	52			
10 x 15 – 19	256	340	57			
10 x 22 – 25	250	340	60			
12	270	340	57			
13	285	340	62			
16	265	340	62			



## Construction

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.

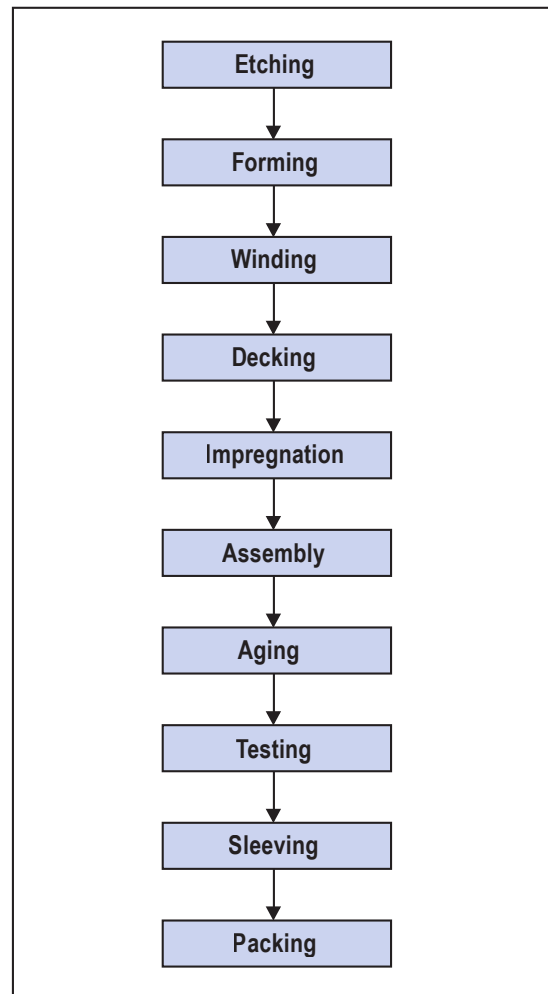
The following tests are applied and may be varied at the request of the customer. In this case the batch, or special procedure, will determine the course of action.

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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Although all product-related warnings, cautions and notes must be observed, the customer should not assume that all safety measures are indicated or that other measures may not be required.