

## Overview

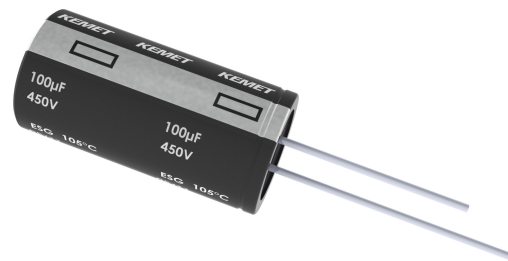
The KEMET ESG single-ended aluminum electrolytic capacitors are designed for long life (5,000 hours) and high reliability applications.

## Applications

Typical applications include electronic ballast, power supplies and long-life equipment.

## Benefits

- Suited for long life, high reliability applications
- Operating temperature of up to 105°C
- 3,000 – 5,000 hour operating life
- High ripple current
- Safety vent on the capacitor base



## Part Number System

ESG	226	M	160		A	H4	AA
Series	Capacitance Code (pF)	Tolerance	Rated Voltage (VDC)		Electrical Parameters	Size Code	Packaging
Single-Ended Aluminum Electrolytic	First two digits represent significant figures for capacitance values. Last digit specifies the number of zeros to be added.	M = ±20%	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 and Reel	Formed to 2.5 mm	$H_0 = 16 \pm 0.75$	LA
6.3	Tape and Reel	2.5 mm lead spacing	$H_0 = 18.5 \pm 0.75$	KA
8	Tape and Reel	Formed to 5 mm	$H_0 = 16 \pm 0.75$	JA
10 – 13	Ammo	5 mm Lead Spacing	$H_0 = 18.5 \pm 0.75$	EA
16 – 18	Ammo	7.5 mm lead spacing	$H_0 = 18.5 \pm 0.75$	EA
Other Packaging Options				
4 – 8	Ammo	Formed to 5 mm	$H_0 = 16 \pm 0.75$	DA
4 – 8	Ammo	Straight	$H_0 = 18.5 \pm 0.75$	EA
4 – 5	Ammo	Formed to 2.5 mm	$H_0 = 16 \pm 0.75$	FA
4 – 6.3	Tape and Reel	Formed to 5 mm	$H_0 = 16 \pm 0.75$	JA
4 – 10	Tape and Reel	Straight	$H_0 = 18.5 \pm 0.75$	KA
Contact KEMET for other lead and packaging options				

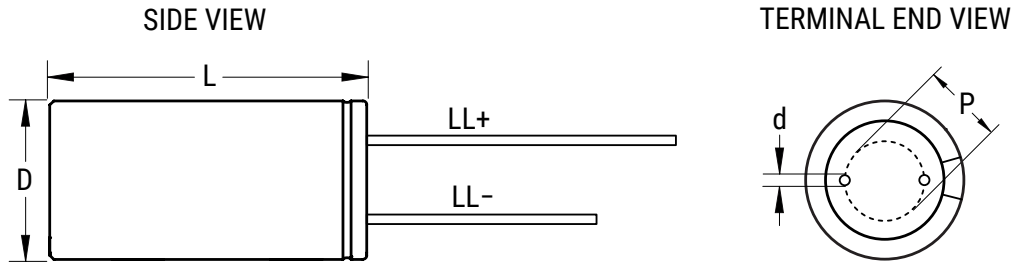
## Environmental Compliance

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 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	Nominal	Tolerance
H9	10	±0.5	12.5	+1.5/-0	5	±0.5	0.6	Nominal	20/15	Minimum
H2	10	±0.5	15	+2.0/-0	5	±0.5	0.6	Nominal	20/15	Minimum
H8	10	±0.5	16	+2.0/-0	5	±0.5	0.6	Nominal	20/15	Minimum
H4	10	±0.5	20	+2.0/-0	5	±0.5	0.6	Nominal	20/15	Minimum
H5	10	±0.5	25	+2.0/-0	5	±0.5	0.6	Nominal	20/15	Minimum
L3	13	±0.5	20	+2.0/-0	5	±0.5	0.6	Nominal	20/15	Minimum
L4	13	±0.5	25	+2.0/-0	5	±0.5	0.6	Nominal	20/15	Minimum
M5	16	±0.5	20	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15	Minimum
M7	16	±0.5	25	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15	Minimum
M1	16	±0.5	26	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15	Minimum
M9	16	±0.5	30	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15	Minimum
M2	16	±0.5	32	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15	Minimum
M3	16	±0.5	36	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15	Minimum
N4	18	±0.5	20	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15	Minimum
N5	18	±0.5	25	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15	Minimum
N1	18	±0.5	32	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15	Minimum
N2	18	±0.5	36	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15	Minimum
N3	18	±0.5	40	+2.0/-0	7.5	±0.5	0.8	Nominal	20/15	Minimum
Q3	22	±0.5	35	+2.0/-0	10.0	±0.5	0.8	Nominal	20/15	Minimum
Q4	22	±0.5	40	+2.0/-0	10.0	±0.5	0.8	Nominal	20/15	Minimum
Q5	22	±0.5	45	+2.0/-0	10.0	±0.5	0.8	Nominal	20/15	Minimum

## Performance Characteristics

Item	Performance Characteristics	
Capacitance Range	4.7 – 330 $\mu$ F	3.3 – 100 $\mu$ F
Capacitance Tolerance	$\pm$ 20% at 120 Hz/20°C	
Rated Voltage	160 – 400 VDC	450 – 500 VDC
Life Test	5,000 hours (see conditions in Test Methods & Performance)	
Operating Temperature	-40°C to +105°C	-25°C to +105°C
Leakage Current	$I = 0.06 CV (\mu A) + 10 \mu A$	
	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)	160	200	250	350	400	450	500
Z (-25°C)/Z (20°C)	3	3	3	5	5	6	6
Z (-40°C)/Z (20°C)	6	6	6	6	6		

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

Rated Voltage (VDC)	50 to 60 Hz	120 Hz	300 Hz	1 kHz	10 to 100 kHz
160 – 450	0.80	1.00	1.20	1.40	1.60
500	0.75	1.00	1.20	1.35	1.50

## Test Method & Performance

Conditions	Load Life Test	Shelf Life Test
Temperature	105°C	105°C
Test Duration	5,000 hours	1,000 hours
	If dimension is down size Endurance is 3,000 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	The following specifications will be satisfied when the capacitor is restored to 20°C:	
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.

The KEMET 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
160	200	22	10 x 20	15	160	222.0	ESG226M160AH4(1)
160	200	33	10 x 20	15	210	327.0	ESG336M160AH4(1)
160	200	47	13 x 20	15	260	461.0	ESG476M160AL3(1)
160	200	68	13 x 25	15	360	663.0	ESG686M160AL4(1)
160	200	68	16 x 20	15	430	663.0	ESG686M160AM5(1)
160	200	100	16 x 25	15	475	970.0	ESG107M160AM7(1)
160	200	100	18 x 20	15	465	970.0	ESG107M160AN4(1)
160	200	150	16 x 32	15	650	1450.0	ESG157M160AM2(1)
160	200	150	18 x 25	15	625	1450.0	ESG157M160AN5(1)
160	200	220	16 x 32	15	750	2122.0	ESG227M160AM2(1)
160	200	220	18 x 25	15	725	2122.0	ESG227M160AN5(1)
160	200	330	18 x 32	15	960	3178.0	ESG337M160AN1(1)
200	250	10	*10 x 16	15	80	274.0	ESG106M200AH8(1)
200	250	15	*10 x 16	15	100	274.0	ESG156M200AH8(1)
200	250	22	10 x 20	15	160	274.0	ESG226M200AH4(1)
200	250	33	*10 x 20	15	160	406.0	ESG336M200AH4(1)
200	250	33	13 x 20	15	210	406.0	ESG336M200AL3(1)
200	250	47	13 x 20	15	260	574.0	ESG476M200AL3(1)
200	250	68	13 x 25	15	360	826.0	ESG686M200AL4(1)
200	250	68	16 x 20	15	430	826.0	ESG686M200AM5(1)
200	250	100	16 x 25	15	475	1210.0	ESG107M200AM7(1)
200	250	100	18 x 20	15	465	1210.0	ESG107M200AN4(1)
200	250	150	18 x 25	15	650	1810.0	ESG157M200AN5(1)
200	250	220	18 x 32	15	780	2650.0	ESG227M200AN1(1)
250	300	10	*10 x 16	15	85	160.0	ESG106M250AH8(1)
250	300	10	10 x 20	15	100	160.0	ESG106M250AH4(1)
250	300	10	*10 x 25	15	145	160.0	ESG106M250AH5(1)
250	300	22	13 x 20	15	160	340.0	ESG226M250AL3(1)
250	300	33	13 x 20	15	210	505.0	ESG336M250AL3(1)
250	300	47	13 x 25	15	270	715.0	ESG476M250AL4(1)
250	300	47	16 x 20	15	275	715.0	ESG476M250AM5(1)
250	300	68	16 x 25	15	380	1030.0	ESG686M250AM7(1)
250	300	68	18 x 20	15	375	1030.0	ESG686M250AN4(1)
250	300	100	16 x 32	15	520	1510.0	ESG107M250AM2(1)
250	300	100	18 x 25	15	500	1510.0	ESG107M250AN5(1)
250	300	150	18 x 32	15	650	2260.0	ESG157M250AN1(1)
250	300	220	18 x 40	15	820	3310.0	ESG227M250AN3(1)
350	400	10	10 x 20	20	100	220.0	ESG106M350AH4(1)
350	400	22	13 x 20	20	160	472.0	ESG226M350AL3(1)
350	400	33	13 x 25	20	230	703.0	ESG336M350AL4(1)
350	400	33	16 x 20	20	250	703.0	ESG336M350AM5(1)
350	400	47	16 x 25	20	300	997.0	ESG476M350AM7(1)
350	400	47	18 x 20	20	315	997.0	ESG476M350AN4(1)
350	400	68	16 x 32	20	400	1438.0	ESG686M350AM2(1)
350	400	68	18 x 25	20	380	1438.0	ESG686M350AN5(1)
350	400	100	18 x 32	20	530	2110.0	ESG107M350AN1(1)
400	450	4.7	*10 x 16	24	60	123.0	ESG475M400AH8(1)
400	450	6.8	*10 x 16	24	72	123.0	ESG685M400AH8(1)
400	450	10	*10 x 16	24	85	123.0	ESG106M400AH8(1)
400	450	10	10 x 20	24	100	250.0	ESG106M400AH4(1)
400	450	22	13 x 20	24	145	538.0	ESG226M400AL3(1)
400	450	22	13 x 25	24	170	538.0	ESG226M400AL4(1)
400	450	22	16 x 20	24	200	538.0	ESG226M400AM5(1)
400	450	33	16 x 25	24	230	802.0	ESG336M400AM7(1)
400	450	33	18 x 20	24	250	802.0	ESG336M400AN4(1)
400	450	47	16 x 25	24	255	1138.0	ESG476M400AM7(1)
400	450	47	16 x 32	24	300	1138.0	ESG476M400AM2(1)
VDC	VDC Surge	Rated Capacitance	Case Size	DF	RC	LC	Part Number

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

\* Dimension is down size, Endurance is 3,000 hours.

**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 20°C (tan δ %)	RC 120 Hz 105°C (mA)	LC 20°C 2 Minutes (µA)	Part Number
400	450	47	18 x 25	24	325	1138.0	ESG476M400AN5(1)
400	450	68	16 x 30	24	340	1642.0	ESG686M400AM9(1)
400	450	68	16 x 32	24	350	1642.0	ESG686M400AM2 (1)
400	450	68	18 x 36	24	420	1642.0	ESG686M400AN2(1)
400	450	100	18 x 32	24	465	2410.0	ESG107M400AN1(1)
400	450	100	18 x 40	24	545	2410.0	ESG107M400AN3(1)
400	450	150	18 x 40	24	525	3610.0	ESG157M400AN3(1)
400	450	150	22 x 40	24	650	3610.0	ESG157M400AQ4(1)
450	500	3.3	10 x 20	24	60	99.0	ESG335M450AH4(1)
450	500	4.7	13 x 20	24	80	137.0	ESG475M450AL3(1)
450	500	6.8	*10 x 20	24	90	194.0	ESG685M450AH4(1)
450	500	10	13 x 20	24	110	280.0	ESG106M450AL3(1)
450	500	10	13 x 25	24	110	280.0	ESG106M450AL4(1)
450	500	22	13 x 20	24	145	604.0	ESG226M450AL3(1)
450	500	22	16 x 25	24	190	604.0	ESG226M450AM7(1)
450	500	22	18 x 20	24	200	604.0	ESG226M450AN4(1)
450	500	33	16 x 25	24	235	901.0	ESG336M450AM7(1)
450	500	33	16 x 32	24	275	901.0	ESG336M450AM2(1)
450	500	33	18 x 25	24	280	901.0	ESG336M450AN5(1)
450	500	47	16 x 26	24	270	1279.0	ESG476M450AM1(1)
450	500	47	18 x 32	24	340	1279.0	ESG476M450AN1(1)
450	500	68	18 x 25	24	335	1846.0	ESG686M450AN5(1)
450	500	68	18 x 32	24	395	1846.0	ESG686M450AN1(1)
450	500	68	18 x 40	24	460	1846.0	ESG686M450AN3(1)
450	500	100	22 x 40	24	580	2710.0	ESG107M450AQ4(1)
500	550	4.7	10 x 20	24	70	151.0	ESG475M500AH4(1)
500	550	6.8	13 x 20	24	100	214.0	ESG685M500AL3(1)
500	550	10	13 x 25	24	130	310.0	ESG106M500AL4(1)
500	550	22	16 x 25	24	225	670.0	ESG226M500AM7(1)
500	550	22	18 x 20	24	220	670.0	ESG226M500AN4(1)
500	550	33	16 x 32	24	305	1000.0	ESG336M500AM2(1)
500	550	33	18 x 25	24	295	1000.0	ESG336M500AN5(1)
500	550	47	16 x 36	24	430	1420.0	ESG476M500AM3(1)
500	550	47	18 x 32	24	435	1420.0	ESG476M500AN1(1)
500	550	68	18 x 32	24	530	2050.0	ESG686M500AN1(1)
500	550	68	18 x 36	24	555	2050.0	ESG686M500AN2(1)
500	550	82	18 x 40	24	640	2470.0	ESG826M500AN3(1)
500	550	82	22 x 35	24	675	2470.0	ESG826M500AQ3(1)
500	550	100	22 x 35	24	746	3010.0	ESG107M500AQ3(1)
500	550	120	22 x 40	24	865	3610.0	ESG127M500AQ4(1)
500	550	150	22 x 45	24	1020	4510.0	ESG157M500AQ5(1)
VDC	VDC Surge	Rated Capacitance	Case Size	DF	RC	LC	Part Number

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

\* Dimension is down size, Endurance is 3,000 hours.

## Mounting Positions (Safety Vent)

In operation, electrolytic capacitors will always conduct a leakage current that 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.
- 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 and Operation Guidelines

### Electrical Ratings:

#### Capacitance (ESC)



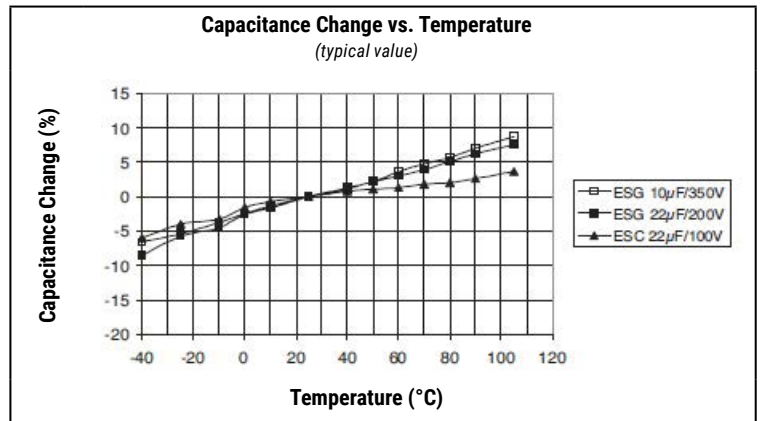
Simplified equivalent circuit diagram of an electrolytic capacitor

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.

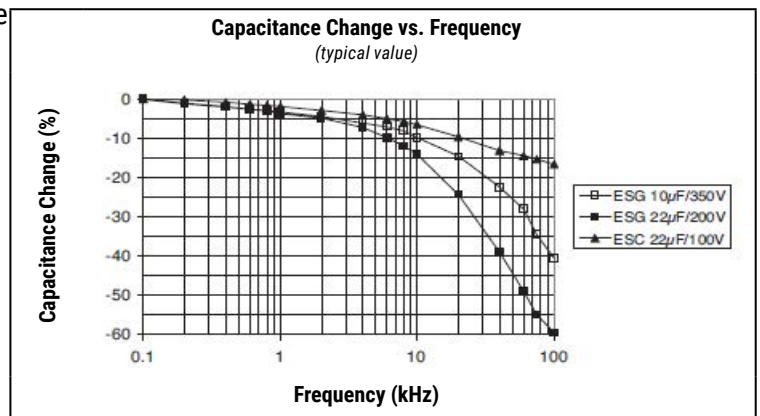


### Frequency Dependence of the Capacitance

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

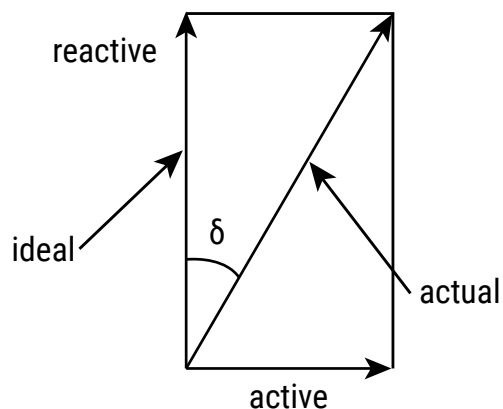
$$C = \frac{1}{2\pi fZ}$$

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.

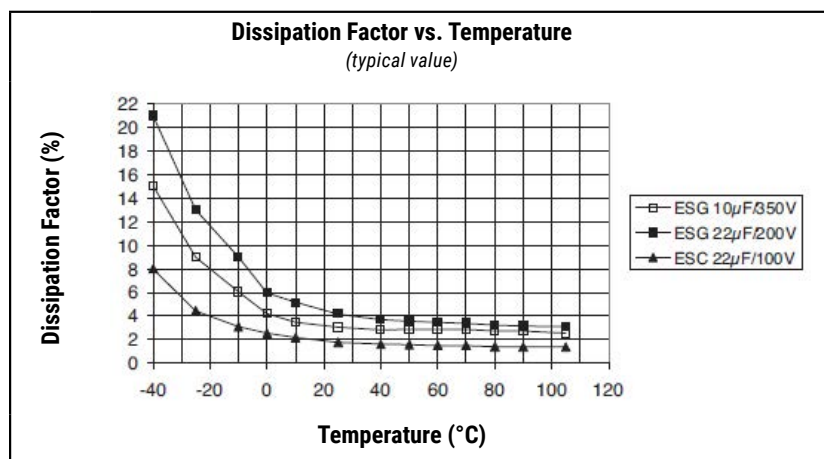
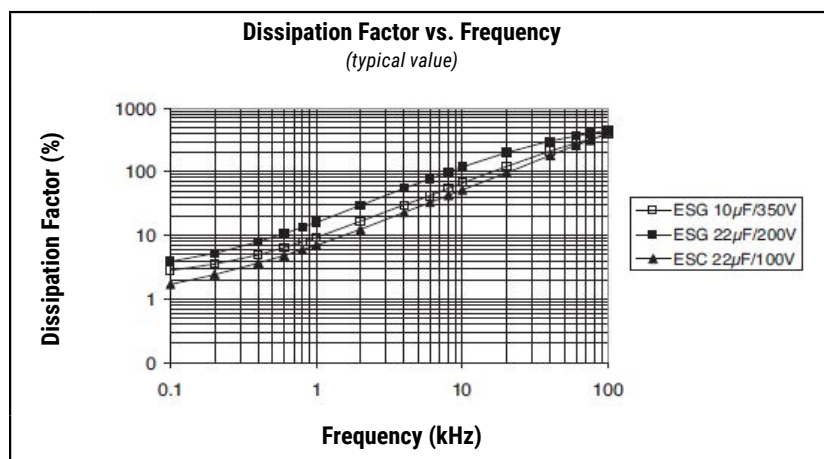


Tan  $\delta$  is measured with the same set-up used for the series capacitance ESC.

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

ESC = Equivalent series capacitance

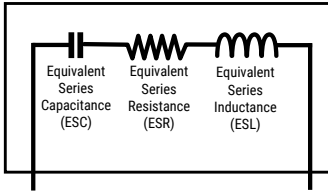
ESR = Equivalent series resistance



### Equivalent Series Inductance (ESL)

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

Capacitor Equivalent Internal Circuit



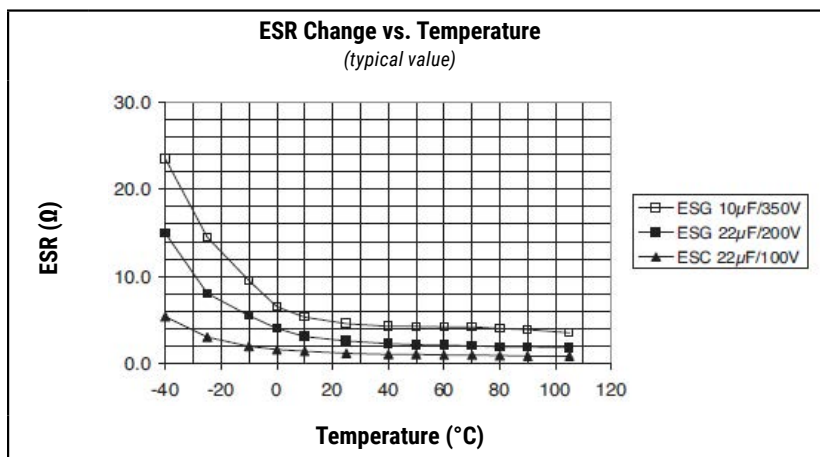
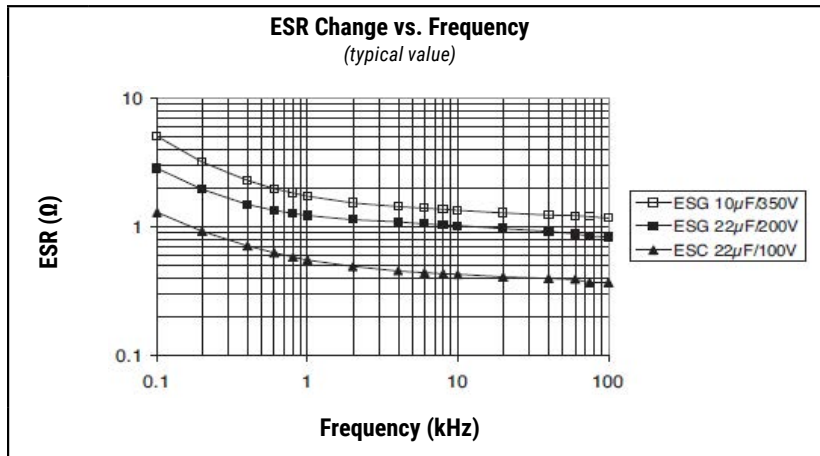
### Equivalent Series Resistance (ESR)

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:

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

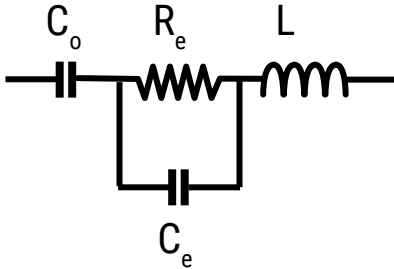
ESR = Equivalent series resistance ( $\Omega$ )  
 $\tan \delta$  = Dissipation factor  
 ESC = Equivalent series capacitance (F)  
 f = Frequency (Hz)

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.)

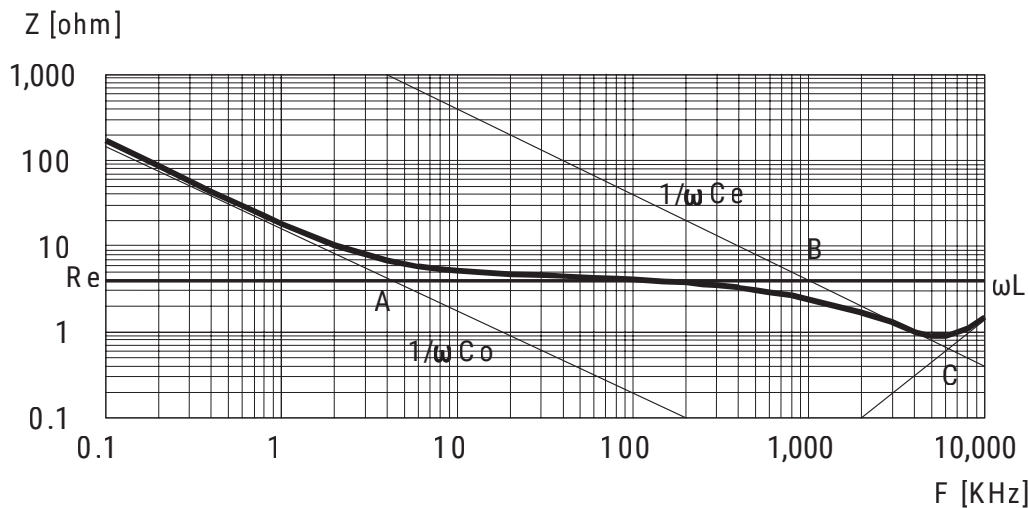
$R_e$  = Resistance of electrolyte and paper mixture (other resistances not depending on the frequency are not considered: tabs, plates, etc.)

$C_e$  = 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:

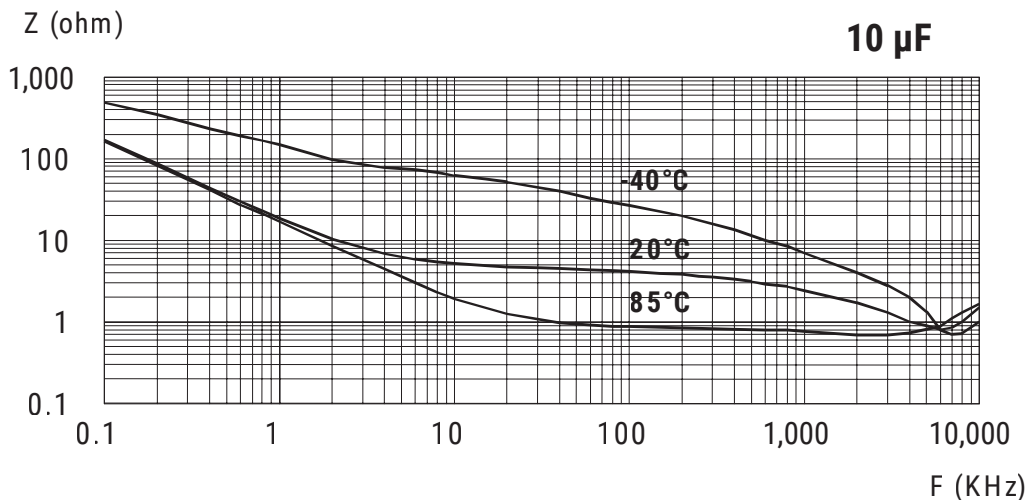


- Capacitive reactance predominates at low frequencies.
- With increasing frequency, capacitive reactance  $X_c = 1/\omega C_o$  decreases until it reaches the order of magnitude of electrolyte resistance  $R_e$  (A)
- At even higher frequencies, resistance of the electrolyte predominates:  $Z = R_e$  (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 (Z) cont'd

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.

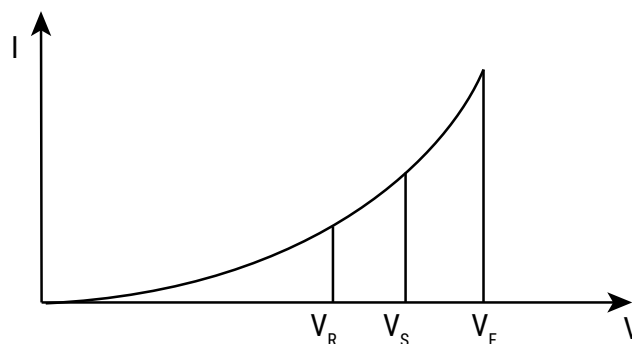
A high leakage current flows after applying voltage to the capacitor then decreases in a few minutes, for example, after prolonged storage without any applied voltage. In the course of continuous operation, the leakage current will decrease and reach an almost constant value.

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.

### Leakage Current (LC) cont'd

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:

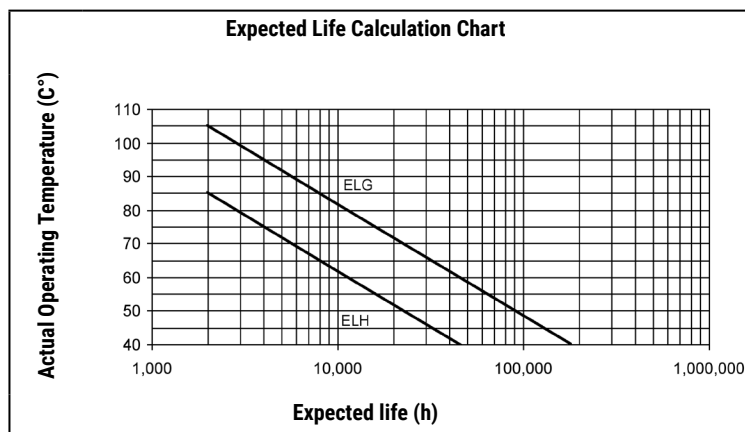
L: Expected life

$L_o$ : Load life at a maximum permissible operating temperature

T: Actual operating temperature

$T_o$ : Maximum permissible operating temperature

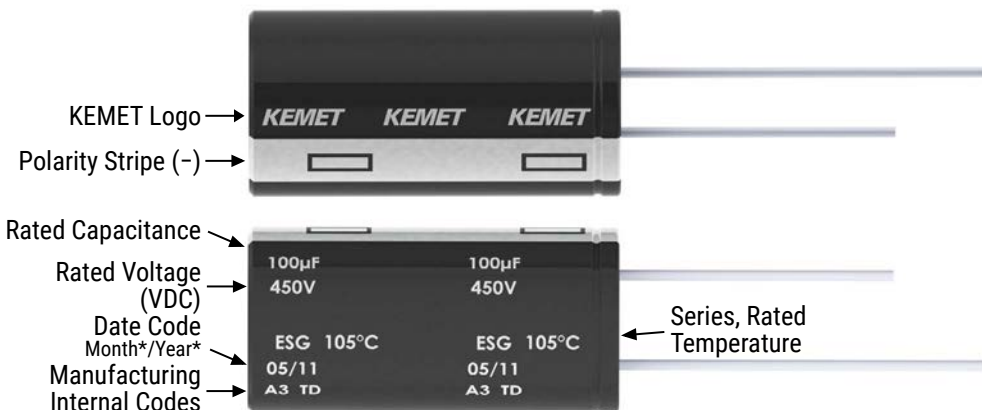
This formula is applicable between 40°C and  $T_o$ .



## Packaging Quantities

Size Code	Diameter (mm)	Length (mm)	Bulk		Auto-insertion	
			Standard Leads	Cut Leads	Ammo	Tape & Reel
H8	10	16	3000	4000	700	1200
H4	10	20	2400	3000	700	1200
H5	10	25	2400	2400	500	
L3	13	20	2000	2000	500	
L4	13	25	1600	1600	500	
M5	16	20	1000	500	300	
M7	16	25	1000	500	300	
M1	16	26	1000	500	300	
M9	16	30	800	500	300	
M2	16	32	800	500	300	
M3	16	36	600	500	300	
N4	18	20	800	500	300	
N5	18	25	800	500	300	
N1	18	32	500	500		
N2	18	36	500	500		
N3	18	40	500	500		
Q3	22	35	400	400		
Q4	22	40	300	400		
Q5	22	45	300	400		

## Marking



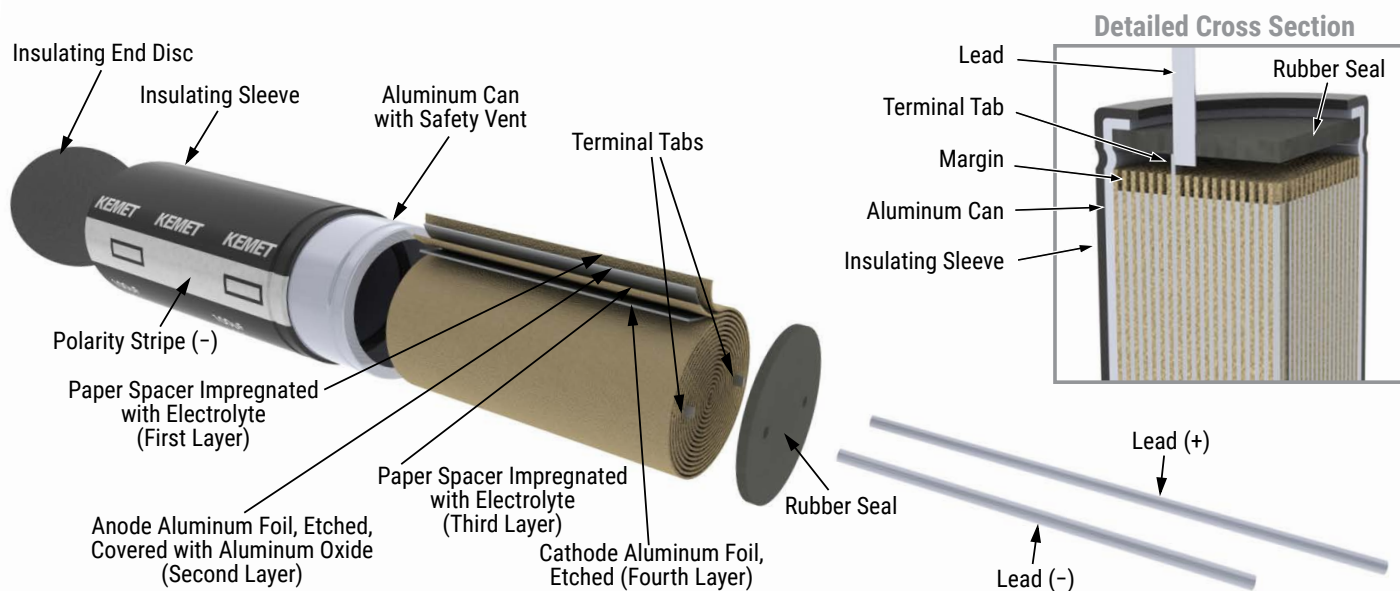
\*Y = Year

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

\*M = Month

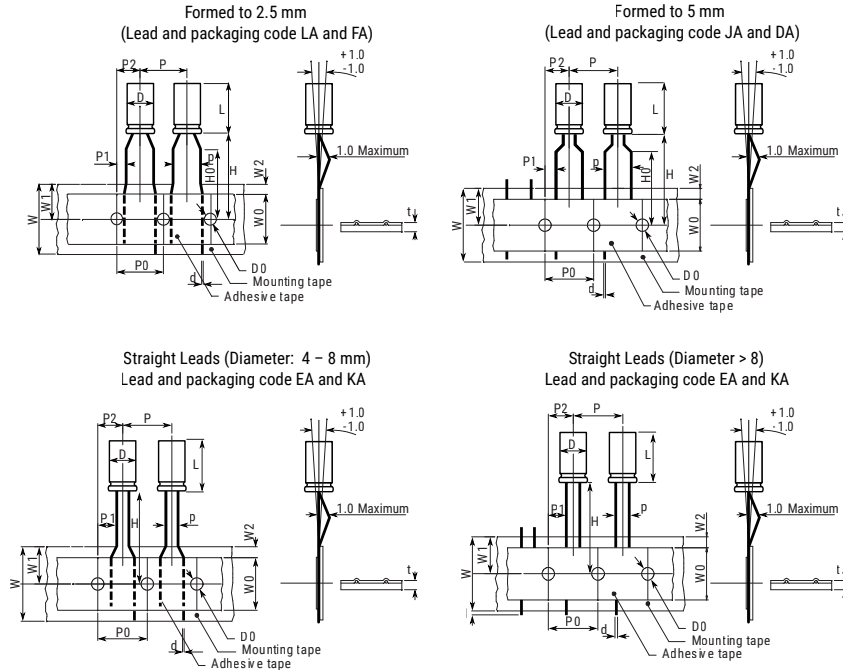
Code	01	02	03	04	05	06	07	08	09	10	11	12
Month	1	2	3	4	5	6	7	8	9	10	11	12

## Construction



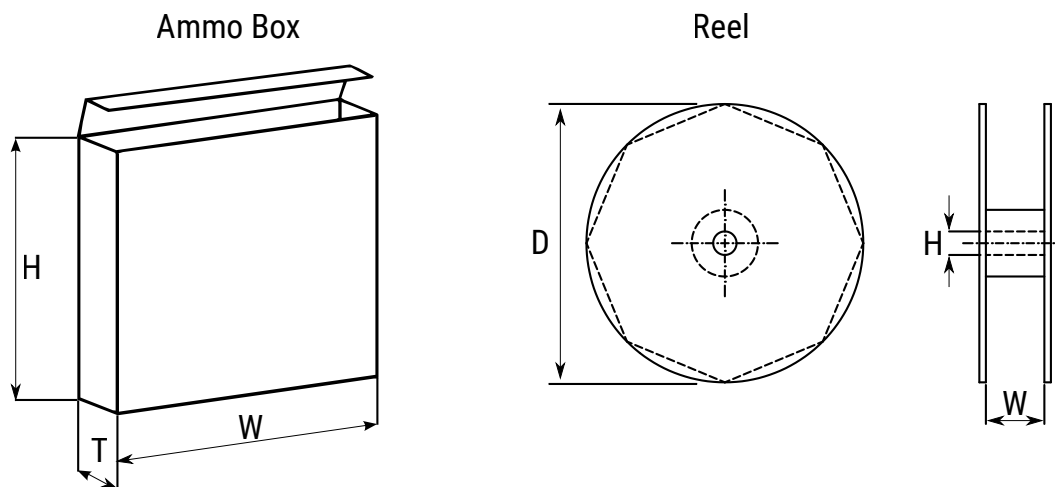


## Taping for Automatic Insertion Machines



Dimensions (mm)	D	L	p	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	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			
6.3 x 5 – 7	275	340	42			
8 x 5 – 9	235	340	45			
5 x 11	230	340	48			
6.3 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 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.

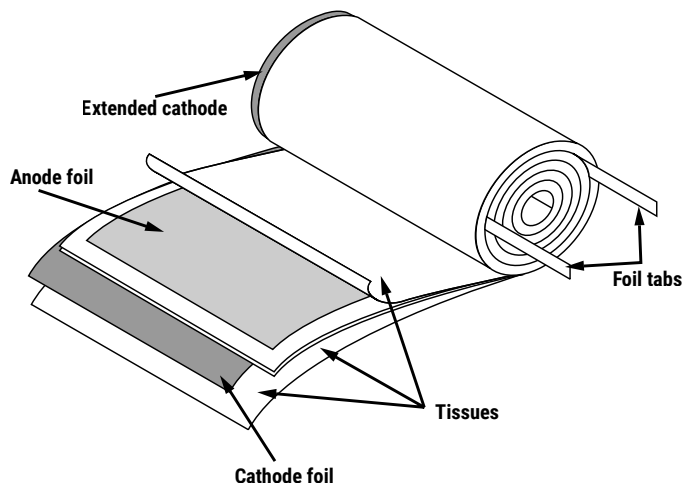
The following tests are applied and may be varied at the request of the customer. In this case the batch, or special procedure, will determine the course of action.

### 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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