

## Ruggedized Electrical Double Layer Energy Storage Capacitors Up to 3 V Operating Voltage

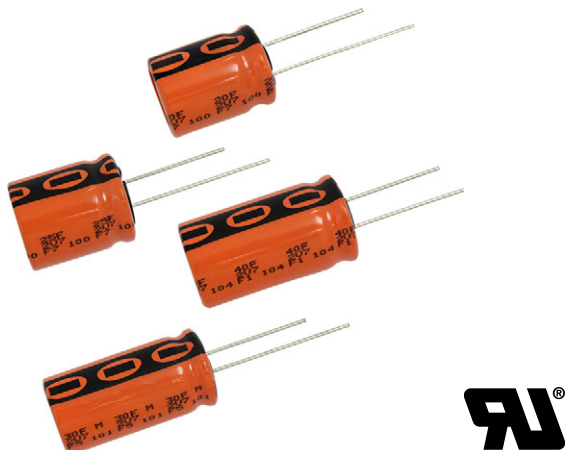


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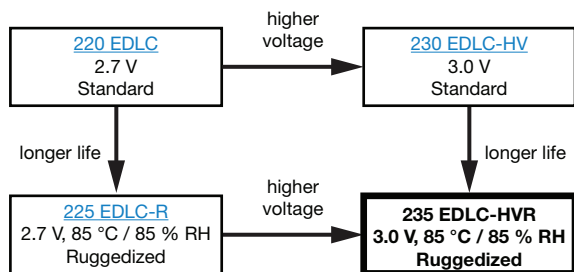


Fig. 1

QUICK REFERENCE DATA	
DESCRIPTION	VALUE
Nominal case sizes (Ø D x L in mm)	10 x 20; 10 x 25; 10 x 30; 12.5 x 20; 12.5 x 25; 12.5 x 30; 12.5 x 40; 16 x 20; 18 x 20; 16 x 25; 18 x 25; 16 x 31; <b>18 x 31</b> ; 18 x 35; 18 x 40
Rated capacitance range, C <sub>R</sub>	5 F to 60 F
Rated voltage, U <sub>R</sub> (65 °C / 85 °C)	3.0 V / 2.6 V 2.8 V / 2.4 V
Category temperature range	-40 °C to +85 °C
Endurance test at 85 °C	Up to 1000 h
Useful life at 85 °C	Up to 2000 h
Useful life at 20 °C	> 10 years
Shelf life at 20 °C	2 years
Cycle life	> 500 000 cycles

### FEATURES

- Polarized energy storage capacitor with high capacity and energy density
- Rated voltage: 3.0 V
- Available in through-hole (radial) version
- Useful life: up to 2000 h at 85 °C
- Ruggedized for high humidity operation
- Rapid charge and discharge
- Maintenance-free, no service necessary
- AEC-Q200 qualified (rev. E)
- UL 810A recognized
- Material categorization: for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)



### APPLICATIONS

- Power backup
- Burst power support
- Storage device for energy harvesting
- Micro UPS power source
- Energy recovery

### MARKING

The capacitors are marked (where possible) with the following information:

- Rated capacitance (in F)
- Rated voltage (in V)
- Date code, in accordance with IEC 60062
- Code indicating factory of origin
- Logo of manufacturer
- Negative terminal identification
- Series number (235)

### PACKAGING

Supplied loose in box, taped ammo, or in ESD trays.

**SELECTION CHART FOR  $C_R$  AND RELEVANT NOMINAL CASE SIZES**

$C_R$ (F)	$U_R$ (V) = 3.0 V
5	10 x 20
7	10 x 25
8	12.5 x 20
10	10 x 30
12	12.5 x 25
15	12.5 x 30
20	16 x 20
22	12.5 x 40
25	16 x 25; 18 x 20
30	18 x 25
35	16 x 31
40	<b>18 x 31</b> <sup>(1)</sup>
50	18 x 35
60	18 x 40

**Note**
<sup>(1)</sup> Preferred case size

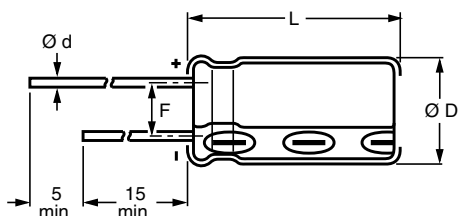
**DIMENSIONS in millimeters AND AVAILABLE FORMS**


Fig. 2 - Form CA / TRAY: long leads

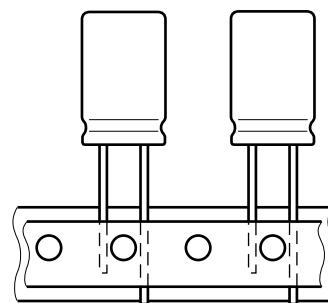


Fig. 3 - Form TFA: taped in box (ammopack)

Table 1

<b>DIMENSIONS in millimeters, MASS, AND PACKAGING QUANTITIES</b>									
NOMINAL CASE SIZE Ø D x L	CASE CODE	Ø d	Ø D <sub>max.</sub>	L <sub>max.</sub>	F	MASS (g)	PACKAGING QUANTITIES		
							FORM CA	FORM TFA	FORM TRAY
10 x 20	16	0.6	10.5	22	5.0 ± 0.5	≈ 2.2	500	800	-
10 x 25	16L	0.6	10.5	27	5.0 ± 0.5	≈ 3.0	500	800	-
10 x 30	16LL	0.8	10.5	32	5.0 ± 0.5	≈ 3.5	500	800	-
12.5 x 20	17	0.6	13.0	22	5.0 ± 0.5	≈ 4.0	500	500	-
12.5 x 25	18	0.6	13.0	27	5.0 ± 0.5	≈ 5.0	250	500	-
12.5 x 30	18L	0.8	13.0	33.5	5.0 ± 0.5	≈ 5.5	250	500	-
12.5 x 40	18LL	0.8	13.0	42.5	5.0 ± 0.5	≈ 7.0	250	500	-
16 x 20	19a	0.8	16.5	22	7.5 ± 0.5	≈ 6.0	250	250	200
16 x 25	19	0.8	16.5	27	7.5 ± 0.5	≈ 8.0	250	250	200
18 x 20	1820	0.8	18.5	22	7.5 ± 0.5	≈ 7.0	100	250	200
18 x 25	1825	0.8	18.5	27	7.5 ± 0.5	≈ 10.0	100	250	200
16 x 31	20	0.8	16.5	33.5	7.5 ± 0.5	≈ 9.0	100	250	200
18 x 31	1831	0.8	18.5	33.5	7.5 ± 0.5	≈ 12.5	100	250	200
18 x 35	22	0.8	18.5	37.5	7.5 ± 0.5	≈ 14.5	100	250	200
18 x 40	1840	0.8	18.5	42.5	7.5 ± 0.5	≈ 16.5	100	-	150

**ELECTRICAL DATA**

SYMBOL	DESCRIPTION
$C_R$	Rated capacitance, tolerance -20 % / +50 %
$I_P$	Max. peak current
$I_L$	Max. leakage current after 0.5 h / 72 h at $U_R$

**Note**

- Unless otherwise specified, all electrical values in Table 2 apply at  $T_{amb} = 20\text{ °C}$ ,  $P = 86\text{ kPa}$  to  $106\text{ kPa}$  and  $RH = 45\text{ %}$  to  $75\text{ %}$

**ORDERING EXAMPLE**

Capacitor series 235 EDLC-HVR

40 F / 3.0 V

Nominal case size: Ø 18 mm x 31 mm; Form TRAY

Ordering code: MAL223591001E3

**Table 2**

ELECTRICAL DATA AND ORDERING INFORMATION																	
U <sub>R</sub> (V)	U <sub>MT</sub> <sup>(1)</sup> (V)	U <sub>CT</sub> <sup>(2)</sup> (V)	U <sub>S</sub> (V) ( $< 1\text{ s}$ )	C <sub>R</sub> <sup>(3)</sup> (F)	NOMINAL CASE SIZE Ø D x L (mm)	MAX. ESR <sub>DC</sub> <sup>(3)</sup> INITIAL (mΩ)	MAX. ESR <sub>AC</sub> INITIAL, 1 kHz (mΩ)	I <sub>P</sub> MAX. PEAK CURRENT (A)		I <sub>L</sub> MAX. LEAKAGE CURRENT AFTER 72 h (µA)	STORED ENERGY E AT U <sub>R</sub> (Wh)		SPECIFIC ENERGY Ed AT U <sub>R</sub> (Wh/kg)		ORDERING CODE MAL2235.....		
65 °C	75 °C	85 °C						65 °C	85 °C		65 °C	85 °C	65 °C	85 °C	65 °C	85 °C	FORM CA
3.0	2.8	2.6	3.15	5	10 x 20	74	37	12	10	25	0.006	0.005	2.8	2.1	51011E3	31011E3	-
3.0	2.8	2.6	3.15	7	10 x 25	60	30	12	10	35	0.009	0.007	2.9	2.2	51012E3	31012E3	-
3.0	2.8	2.6	3.15	8	12.5 x 20	58	29	15	12	40	0.010	0.008	2.5	1.9	51014E3	31014E3	-
3.0	2.8	2.6	3.15	10	10 x 30	46	24	15	12	45	0.013	0.009	3.6	2.7	51013E3	31013E3	-
3.0	2.8	2.6	3.15	12	12.5 x 25	41	23	17	14	55	0.015	0.011	3.0	2.3	51015E3	31015E3	-
3.0	2.8	2.6	3.15	15	12.5 x 30	34	20	20	17	70	0.019	0.014	3.4	2.6	51016E3	31016E3	-
3.0	2.8	2.6	3.15	20	16 x 20	38	22	25	20	75	0.025	0.019	4.2	3.1	51003E3	31003E3	91003E3
3.0	2.8	2.6	3.15	22	12.5 x 40	26	15	25	20	75	0.028	0.021	3.9	3.0	51017E3	31017E3	-
3.0	2.8	2.6	3.15	25	16 x 25	34	20	25	20	75	0.031	0.023	3.9	2.9	51006E3	31006E3	91006E3
3.0	2.8	2.6	3.15	25	18 x 20	36	19	25	20	75	0.031	0.023	4.5	3.4	51004E3	31004E3	91004E3
3.0	2.8	2.6	3.15	30	18 x 25	26	17	30	25	140	0.038	0.028	3.8	2.8	51007E3	31007E3	91007E3
3.0	2.8	2.6	3.15	35	16 x 31	24	18	30	25	200	0.044	0.033	4.9	3.7	51002E3	31002E3	91002E3
3.0	2.8	2.6	3.15	40	18 x 31	24	16	35	30	200	0.050	0.038	4.0	3.0	51001E3	31001E3	91001E3
3.0	2.8	2.6	3.15	50	18 x 35	22	14	35	30	250	0.063	0.047	4.3	3.2	51008E3	31008E3	91008E3
3.0	2.8	2.6	3.15	60	18 x 40	22	13	35	30	300	0.075	0.056	4.5	3.4	51009E3	-	91009E3

**Notes**

- (1)  $U_{MT}$  = rated voltage at 75 °C  
 (2)  $U_{CT}$  = rated voltage at upper category temperature  
 (3) Rated capacitance  $C_R$  and maximum  $ESR_{DC}$  are typical values for case sizes

**Table 3**

<b>ENDURANCE TEST DURATION AND USEFUL LIFE</b>			
NOMINAL CASE SIZE Ø D x L	CASE CODE	ENDURANCE AT 85 °C (h)	USEFUL LIFE AT 85 °C (h)
10 x 20	16	750	1000
10 x 25	16L	750	1000
10 x 30	16LL	750	1000
12.5 x 20	17	1000	1500
12.5 x 25	18	1000	1500
12.5 x 30	18L	1000	1500
12.5 x 40	18LL	1000	1500
16 x 20	19a	1000	2000
16 x 25	19	1000	2000
18 x 20	1820	1000	2000
18 x 25	1825	1000	2000
16 x 31	20	1000	2000
18 x 31	1831	1000	2000
18 x 35	22	1000	2000
18 x 40	1840	1000	2000

**Table 4**

<b>RUGGEDIZED FOR HIGH HUMIDITY - BIASED HUMIDITY TESTING</b>		
PARAMETER	PROCEDURE (AT RATED VOLTAGE)	REQUIREMENTS
Humidity (relative)	85 %	After loading the capacitor for the specified time at maximum category temperature $T_{max.} = 85^{\circ}\text{C}$ and 85 % relative humidity, and derated permissible maximum operation voltage $U = 2.6\text{ V}$ , following parameters are valid within a timeframe of 1000 h:
Temperature	85 °C	No visible damage No leakage of electrolyte $\Delta C/C$ : within $\pm 30\%$ of minimum initial specified value ESR: less than 3 x initial specified value Leakage: less than initial specified value

<b>TEST PROCEDURES AND REQUIREMENTS <sup>(1)</sup></b>		
NAME OF TEST	PROCEDURE (quick reference)	
Capacitance $C_R$ and $ESR_{DC}$	Measured by DC discharging method as described in "Measuring of Characteristics". <sup>(2)</sup>	
Maximum peak current	Non-repetitive current for maximum 1 s at specified operating temperature. Maximum operating voltage (refer to derating table) must not be exceeded. Usually to be tested with constant current discharge from $U_R$ to $0.5 \times U_R$ . Maximum current should not be used in normal operation and is only provided as reference value.	
Leakage current $I_L$	Measured at $U_R$ . Capacitor is charged to the rated voltage at $20^{\circ}\text{C}$ . Leakage current is the current at specified time that is required to keep the capacitor charged at the rated voltage.	
Endurance	After loading the capacitor of specified time at maximum category temperature $T_{max.} = 85^{\circ}\text{C}$ and derated permissible maximum operating voltage $U = 2.6\text{ V}$ , following parameters are valid within a timeframe as specified in Table 3:	
	Capacitance	Within $\pm 30\%$ of minimum initial specified value
	ESR	Less than 3 x initial specified value
	Leakage	Within specified value
Useful life	After loading the capacitor of specified time at maximum category temperature $T_{max.} = 85^{\circ}\text{C}$ and derated permissible maximum operating voltage $U = 2.6\text{ V}$ , following parameters are valid within a timeframe as specified in Table 3:	
	Capacitance	Within $\pm 50\%$ of minimum initial specified value
	ESR	Less than 4 x initial specified value
	Leakage	Within specified value
Storage at upper category temperature	After loading the capacitor of specified time at maximum category temperature $T_{max.} = 85^{\circ}\text{C}$ and without charge and under 40 % RH, following parameters are valid within a timeframe of 1000 h:	
	Capacitance	Within $\pm 30\%$ of minimum initial specified value
	ESR	Less than 3 x initial specified value
	Leakage	Within specified value
Shelf life	Stored uncharged at $20^{\circ}\text{C}$ . Parameter within initial specification	
Cycle life	Cycles at $20^{\circ}\text{C}$ between rated voltage and half of rated voltage $U_R$ with constant current and 1 s rest between charge and discharge: > 500 000 cycles	
	Capacitance	Within $\pm 30\%$ of minimum initial specified value
	ESR	Less than 3 x initial specified value
Stored energy $E_s$ , specific energy $E_d$ and $E_v$	$E [\text{Wh}] = \frac{1}{2} \times C \times (U_R)^2 \times 1/3600$ $E_d [\text{Wh/kg}] = \frac{1}{2} \times C \times (U_R)^2 \times 1/3600 \times 1/\text{mass}$ $E_v [\text{Wh/L}] = \frac{1}{2} \times C \times (U_R)^2 \times 1/3600 \times 1/\text{volume}$	
Soldering	Hand or wave soldering allowed. For details refer to soldering requirements for radial aluminum electrolytic capacitors in supplementary document.	
Cleaning	For printed circuit board cleaning apply non-aggressive cleaning agents only. For details refer to cleaning requirements for aluminum electrolytic capacitors in supplementary document.	
Environmental conditions	Do not expose capacitors to <ul style="list-style-type: none"> <li>temperatures outside specified range</li> <li>high humidity atmospheres</li> <li>corrosive atmospheres, e.g. halogenides, sulphurous or nitrous gases, acid or alkaline solutions, etc.</li> <li>environments containing oil and grease</li> </ul>	

**Notes**

- General remark: temperatures to be measured at capacitor case
- (1) Conditions: electrical measurements at  $20^{\circ}\text{C}$ , unless otherwise specified
- (2) Rated capacitance  $C_R$  and  $ESR_{DC}$

## MEASURING OF CHARACTERISTICS

### CAPACITANCE (C)

Capacitance shall be measured by constant current discharge method.

- Constant current charge with 10 mA/F to  $U_R$
- Constant voltage charge at  $U_R$
- Constant current discharge with 10 mA/F to 0.1 V

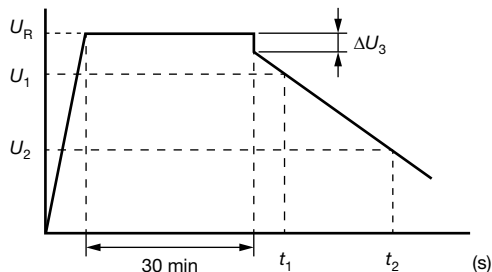


Fig. 4 - Voltage Diagram for Capacitance Measurement

Capacitance value  $C_R$  is given by discharge current  $I_D$ , time  $t$  and rated voltage  $U_R$ , according to the following equation:

$$C_R [F] = \frac{I_D [A] \times (t_2 [s] - t_1 [s])}{U_1 [V] - U_2 [V]}$$

$C_R$	Rated capacitance, in F
$U_R$	Rated voltage, in V
$U_1$	Starting voltage, $0.8 \times U_R$ in V
$U_2$	Ending voltage, $0.4 \times U_R$ in V
$\Delta U_3$	Voltage drop at internal resistance, in V
$t_1$	Time from start of discharge until voltage $U_1$ is reached, in s
$t_2$	Time from start of discharge until voltage $U_2$ is reached, in s
$I_D$	Absolute value of discharge current, in A

### EQUIVALENT SERIES RESISTANCE ( $ESR_{DC}$ )

- Constant current charge to  $U_R$
- Constant voltage charge at  $U_R$
- Constant current discharge to 0.1 V

$$ESR_{DC} [\Omega] = \frac{\Delta U_3 [V]}{I_D [A]}$$

$ESR_{DC}$	Equivalent series resistance, in $\Omega$
$\Delta U_R$	Voltage drop at internal resistance, in V
$I_D$	Absolute value of discharge current, in A

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