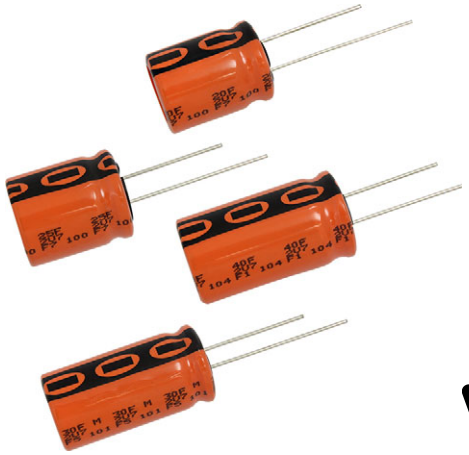
Ruggedized Electrical Double Layer Energy Storage Capacitors Up to 3 V Operating Voltage



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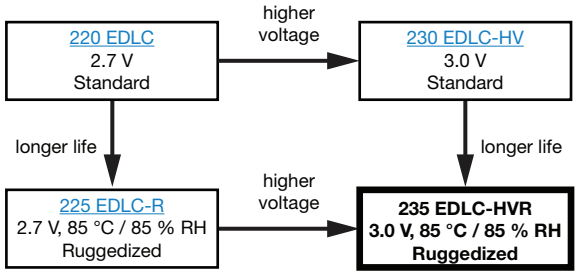

Fig. 1

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; **18 x 31**; 18 x 35; 18 x 40
Rated capacitance range, C_R	5 F to 60 F
Rated voltage, U_R (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

AUTOMOTIVE GRADE

Pb-free

RoHS COMPLIANT

- 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

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	**18 x 31** (1)
50	18 x 35
60	18 x 40

Note

(1) Preferred case size

DIMENSIONS in millimeters **AND AVAILABLE FORMS**

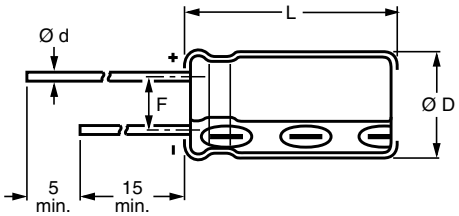

Fig. 2 - **Form CA / TRAY:** long leads

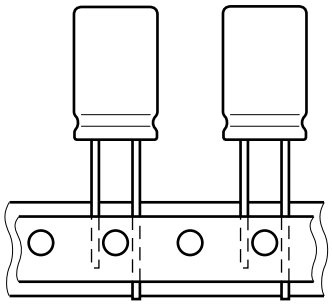

Fig. 3 - **Form TFA**: taped in box (ammopack)

Table 1

DIMENSIONS in millimeters, MASS, AND PACKAGING QUANTITIES									
NOMINAL CASE SIZE Ø D x L	CASE CODE	Ø d	Ø $D_{max.}$	$L_{max.}$	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 °C, P = 86 kPa to 106 kPa and RH = 45 % to 75 %

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_R (V)	U_{MT} (1) (V)	U_{CT} (2) (V)	U_S (V) (< 1 s)	C_R (3) (F)	NOMINAL CASE SIZE Ø D x L (mm)	MAX. ESR_{DC} (3) INITIAL (mΩ)	MAX. ESR_{AC} INITIAL, 1 kHz (mΩ)	I_P MAX. PEAK CURRENT (A)		I_L MAX. LEAKAGE CURRENT AFTER 72 h (µA)	STORED ENERGY E AT U_R (Wh)		SPECIFIC ENERGY Ed AT U_R (Wh/kg)		ORDERING CODE MAL2235.....		
65 °C	75 °C	85 °C						65 °C	85 °C		65 °C	85 °C	65 °C	85 °C	FORM CA	FORM TFA	FORM TRAY
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

ENDURANCE TEST DURATION AND USEFUL LIFE

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

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

TEST PROCEDURES AND REQUIREMENTS (1)		
NAME OF TEST	**PROCEDURE (quick reference)**	
Capacitance C_R and ESR_{DC}	Measured by DC discharging method as described in "Measuring of Characteristics". (2)	
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 x 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 °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 °C and derated permissible maximum operating voltage U = 2.6 V, following parameters are valid within a timeframe as specified in Table 3:	
	Capacitance	Within ± 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 °C and derated permissible maximum operating voltage U = 2.6 V, following parameters are valid within a timeframe as specified in Table 3:	
	Capacitance	Within ± 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 °C and without charge and under 40 % RH, following parameters are valid within a timeframe of 1000 h:	
	Capacitance	Within ± 30 % of minimum initial specified value
	ESR	Less than 3 x initial specified value
	Leakage	Within specified value
Shelf life	Stored uncharged at 20 °C. Parameter within initial specification	
Cycle life	Cycles at 20 °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 ± 30 % of minimum initial specified value
	ESR	Less than 3 x initial specified value
Stored energy E, specific energy Ed and Ev	E [Wh] = ½ x C x $(U_R)^2$ x 1/3600 Ed [Wh/kg] = ½ x C x $(U_R)^2$ x 1/3600 x 1/mass Ev [Wh/L] = ½ x C x $(U_R)^2$ x 1/3600 x 1/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 • temperatures outside specified range • high humidity atmospheres • corrosive atmospheres, e.g. halogenides, sulphurous or nitrous gases, acid or alkaline solutions, etc. • environments containing oil and grease	

Notes

- General remark: temperatures to be measured at capacitor case

(1) Conditions: electrical measurements at 20 °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

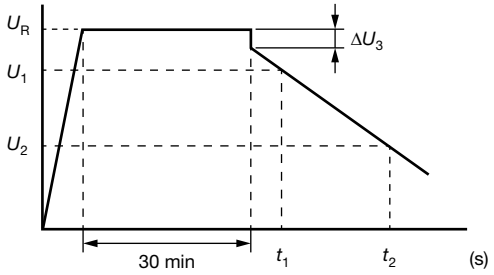

Fig. 4 - Voltage Diagram for Capacitance Measurement

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 x U_R in V
U_2	Ending voltage, 0.4 x U_R in V
ΔU_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 Ω
ΔU_R	Voltage drop at internal resistance, in V
I_D	Absolute value of discharge current, in A

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