

Ruggedized Electrical Double Layer Energy Storage Capacitors

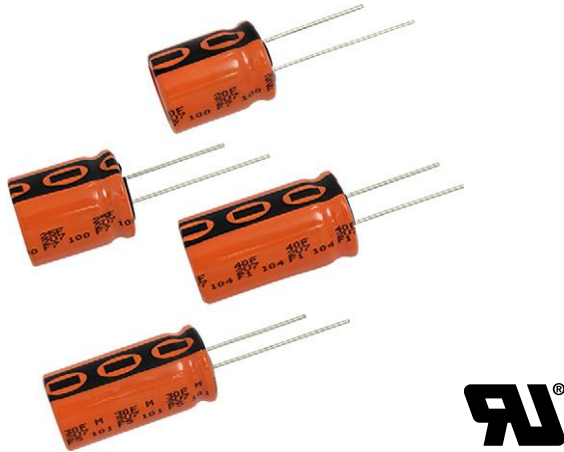


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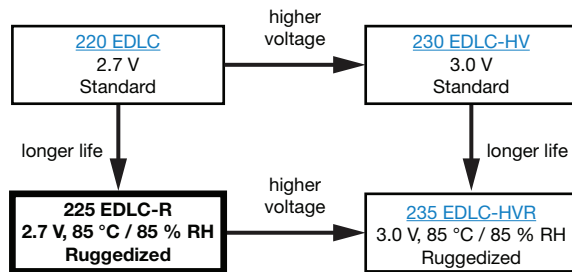


Fig. 1

| 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) | 2.7 V / 2.3 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: 2.7 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
- UL 810A recognized
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

 AUTOMOTIVE
GRADE

RoHS
COMPLIANT

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 (225)

PACKAGING

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

| SELECTION CHART FOR C_R, U_R, AND RELEVANT NOMINAL CASE SIZES ($\varnothing D \times L$ in mm) | |
|--|-------------------------------|
| C_R (F) | U_R (V) = 2.7 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

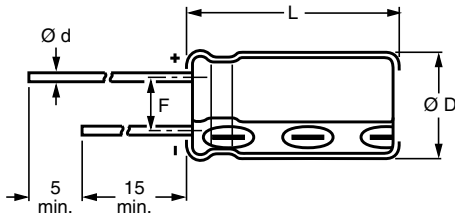
DIMENSIONS in millimeters AND AVAILABLE FORMS


Fig. 2 - Form CA / TRAY: long leads

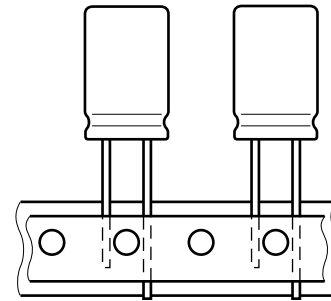


Fig. 3 - Form TFA: taped in box (ammopack)

Table 1

| DIMENSIONS in millimeters, MASS, AND PACKAGING QUANTITIES | | | | | | | | | |
|--|-----------|-----------------|------------------------|------------|---------------|----------|----------------------|----------|-----------|
| NOMINAL CASE SIZE $\varnothing D \times L$ | CASE CODE | $\varnothing d$ | $\varnothing D_{max.}$ | $L_{max.}$ | 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 | - | - |
| 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 kPa and $RH = 45\text{ %}$ to 75 %

Table 2

| ELECTRICAL DATA AND ORDERING INFORMATION | | | | | | | | | | | | | | | | |
|--|-----------------------|------------------------------------|--------------------|---|---|---|--------------------------------------|-------|--|-------------------------------------|-------|---|-------|-------------------------------|-------------|--------------|
| U_R (V) | $U_{CT}^{(1)}$ (V) | U_S (V) ($< 1\text{ s}$) | $C_R^{(2)}$ (F) | NOMINAL CASE SIZE $\varnothing D \times L$ (mm) | MAX. $ESR_{DC}^{(2)}$ INITIAL (m Ω) | MAX. ESR_{AC} INITIAL, 1 kHz (m Ω) | 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 MAL2225..... | | |
| | | | | | | | 65 °C | 85 °C | | 65 °C | 85 °C | 65 °C | 85 °C | FORM CA | FORM TFA | FORM TRAY |
| 2.7 | 2.3 | 2.85 | 5 | 10 x 20 | 45 | 28 | 12 | 10 | 25 | 0.005 | 0.004 | 2.3 | 1.8 | 51011E3 | 31011E3 | - |
| 2.7 | 2.3 | 2.85 | 7 | 10 x 25 | 38 | 24 | 12 | 10 | 35 | 0.007 | 0.005 | 2.3 | 1.7 | 51012E3 | 31012E3 | - |
| 2.7 | 2.3 | 2.85 | 8 | 12.5 x 20 | 42 | 21 | 15 | 12 | 40 | 0.008 | 0.006 | 2.0 | 1.5 | 51014E3 | 31014E3 | - |
| 2.7 | 2.3 | 2.85 | 10 | 10 x 30 | 30 | 20 | 15 | 12 | 45 | 0.009 | 0.007 | 2.6 | 2.0 | 51013E3 | 31013E3 | - |
| 2.7 | 2.3 | 2.85 | 12 | 12.5 x 25 | 33 | 19 | 17 | 14 | 55 | 0.011 | 0.008 | 2.2 | 1.6 | 51015E3 | 31015E3 | - |
| 2.7 | 2.3 | 2.85 | 15 | 12.5 x 30 | 25 | 16 | 20 | 17 | 70 | 0.015 | 0.011 | 2.7 | 2.0 | 51016E3 | 31016E3 | - |
| 2.7 | 2.3 | 2.85 | 20 | 16 x 20 | 24 | 18 | 25 | 20 | 75 | 0.020 | 0.015 | 3.4 | 2.3 | 51003E3 | 31003E3 | 91003E3 |
| 2.7 | 2.3 | 2.85 | 22 | 12.5 x 40 | 22 | 11 | 25 | 20 | 75 | 0.021 | 0.015 | 3.0 | 2.1 | 51017E3 | - | - |
| 2.7 | 2.3 | 2.85 | 25 | 16 x 25 | 22 | 16 | 25 | 20 | 75 | 0.025 | 0.018 | 3.2 | 2.3 | 51006E3 | 31006E3 | 91006E3 |
| 2.7 | 2.3 | 2.85 | 25 | 18 x 20 | 20 | 15 | 25 | 20 | 75 | 0.025 | 0.018 | 3.6 | 2.6 | 51004E3 | 31004E3 | 91004E3 |
| 2.7 | 2.3 | 2.85 | 30 | 18 x 25 | 19 | 13 | 30 | 25 | 140 | 0.030 | 0.022 | 3.0 | 2.2 | 51007E3 | 31007E3 | 91007E3 |
| 2.7 | 2.3 | 2.85 | 35 | 16 x 31 | 20 | 14 | 30 | 25 | 200 | 0.035 | 0.026 | 3.9 | 2.9 | 51002E3 | 31002E3 | 91002E3 |
| 2.7 | 2.3 | 2.85 | 40 | 18 x 31 | 18 | 12 | 35 | 30 | 200 | 0.041 | 0.029 | 3.3 | 2.3 | 51001E3 | 31001E3 | 91001E3 |
| 2.7 | 2.3 | 2.85 | 50 | 18 x 35 | 15 | 10 | 35 | 30 | 250 | 0.051 | 0.037 | 3.5 | 2.6 | 51008E3 | 31008E3 | 91008E3 |
| 2.7 | 2.3 | 2.85 | 60 | 18 x 40 | 13 | 9 | 35 | 30 | 300 | 0.061 | 0.044 | 3.7 | 2.7 | 51009E3 | - | 91009E3 |

Notes

- (1) U_{CT} = rated voltage at upper category temperature
- (2) 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 $\varnothing D \times L$ | 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 $T_{max.} = 85\text{ °C}$ and 85 % relative humidity, and derated permissible maximum operating voltage $U = 2.3\text{ V}$, following parameters are valid within a timeframe of 1000 h: 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 |
| 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 $0.5 \times U_R$. 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 °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 for specified time at maximum category temperature $T_{max.} = 85\text{ °C}$ and derated permissible maximum operating voltage $U = 2.3\text{ V}$, 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 |
| Useful life | After loading the capacitor for specified time at maximum category temperature $T_{max.} = 85\text{ °C}$ and derated permissible maximum operating voltage $U = 2.3\text{ V}$, following parameters are valid within a timeframe of 2000 h: | |
| | 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 $T_{max.} = 85\text{ °C}$ 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 °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 $\pm 30\%$ 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"> temperatures outside specified range high humidity atmospheres; except series 225 which is ruggedized for high humidity 85 °C and 85 % RH 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

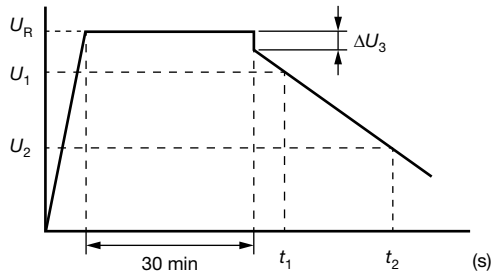


Fig. 4 - Voltage Diagram for Capacitance Measurement

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, $0.8 \times U_R$ in V
- U_2 Ending voltage, $0.4 \times U_R$ 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_3 Voltage drop at internal resistance, in V
- I_D Absolute value of discharge current, in A

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