Hybrid Energy Storage Capacitors

**FEATURES**
- Polarized energy storage capacitor with high capacity and energy density
- Voltage flexibility: 1.4 V (single cell) to 2.8 V / 4.2 V / 5.6 V / 7.0 V / 8.4 V (multiple cells)
- Available in stacked through-hole (STH, radial), surface-mount flat (SMF) and lay flat configurations (LFC) with wire and connectors
- Useful life: up to 2000 h at 85 °C
- No cell balancing necessary
- Soft and low transient-voltage-controlled charging characteristic
- Non-hazardous electrolyte
- Maintenance-free, no service necessary
- Evaluation kits for engineering are available under ordering code: MAL219699001E3
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

**APPLICATIONS**
- Power backup for memory controller, flash backup, RAID systems, SRAM, DRAM
- Power failure and write cache protection for enterprise SSD and HDD
- Real time clock power source
- Burst power support for flash lights, wireless transmitters
- Backup power for industrial PC’s and industrial controls
- Storage device for energy harvesting
- Emergency light and micro UPS power source

**MARKING**
The capacitors are marked with the following information:
- Rated capacitance (in F)
- Rated voltage (in V)
- Date code
- Negative / positive terminal identification

**PACKAGING**
Supplied in ESD trays only
### QUICK REFERENCE DATA

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>VALUE</th>
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<tbody>
<tr>
<td>Nominal case size (Ø D x L in mm)</td>
<td>SINGLE CELL</td>
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<tr>
<td>Stacked Through-Hole (STH)</td>
<td>7 x 2.5</td>
</tr>
<tr>
<td></td>
<td>12 x 2.5</td>
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<tr>
<td></td>
<td>35 x 25 x 5</td>
</tr>
<tr>
<td>Nominal case size (Ø W x L x H in mm)</td>
<td>Surface-Mount Flat (SMF)</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lay Flat (LFC)</td>
</tr>
<tr>
<td>Rated capacitance range, CR</td>
<td>4.0 F</td>
</tr>
<tr>
<td></td>
<td>15.0 F</td>
</tr>
<tr>
<td></td>
<td>90.0 F</td>
</tr>
<tr>
<td>Tolerance on CR at 20 °C</td>
<td>-20 % to +80 %</td>
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<tr>
<td>Rated voltage, UR</td>
<td>1.4 V</td>
</tr>
<tr>
<td>Maximum surge voltage, U₅₃ (max. 30 s)</td>
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<tr>
<td>Minimum stored energy</td>
<td>4 Ws</td>
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<tr>
<td></td>
<td>17 Ws</td>
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<tr>
<td></td>
<td>115 Ws</td>
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<tr>
<td>Energy density</td>
<td>9 Ws/g to 13 Ws/g</td>
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<tr>
<td>Category temperature range</td>
<td>4.0 F: -20 °C to +70 °C</td>
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<tr>
<td></td>
<td>15.0 F / 45.0 F / 90.0 F: -20 °C to +85 °C</td>
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<tr>
<td>Storage temperature range</td>
<td>-40 °C to +85 °C</td>
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<td>Useful life at UR</td>
<td>4.0 F: at 70 °C: 1000 h</td>
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<td>at 55 °C: 2800 h</td>
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<tr>
<td></td>
<td>at 45 °C: 5600 h</td>
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<tr>
<td>Shelf life</td>
<td>1000 h at upper category temperature</td>
</tr>
<tr>
<td>Climatic category IEC 60068</td>
<td>25 / 085 / 21</td>
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### SELECTION CHART FOR CR, UR, AND FORM AT UPPER CATEGORY TEMPERATURE (UCT)

<table>
<thead>
<tr>
<th>CR (F)</th>
<th>FORM</th>
<th>1.4</th>
<th>2.8</th>
<th>4.2</th>
<th>5.6</th>
<th>7.0</th>
<th>8.4</th>
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<tr>
<td>4</td>
<td>A2</td>
<td>7.0 x 2.5</td>
<td>7.0 x 5.0</td>
<td>7.0 x 7.5</td>
<td>7.0 x 10.0</td>
<td>7.0 x 12.5</td>
<td>7.0 x 15.0</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>7.0 x 2.5</td>
<td>7.0 x 5.0</td>
<td>7.0 x 7.5</td>
<td>7.0 x 10.0</td>
<td>7.0 x 12.5</td>
<td>7.0 x 15.0</td>
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<tr>
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<td>B3</td>
<td>7.0 x 7.0 x 2.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7.0 x 7.0 x 2.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7.0 x 7.0 x 2.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>-</td>
<td>7.0 x 14.0 x 2.5</td>
<td>13.0 x 14.0 x 2.5</td>
<td>14.0 x 14.0 x 2.5</td>
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<td>-</td>
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<td>12.0 x 7.5</td>
<td>12.0 x 10.0</td>
<td>12.0 x 12.5</td>
<td>12.0 x 15.0</td>
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<td>B2</td>
<td>12.0 x 2.5</td>
<td>12.0 x 5.0</td>
<td>12.0 x 7.5</td>
<td>12.0 x 10.0</td>
<td>12.0 x 12.5</td>
<td>12.0 x 15.0</td>
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<tr>
<td></td>
<td>B3</td>
<td>12.0 x 12.0 x 2.5</td>
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<td>-</td>
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<td>-</td>
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<tr>
<td></td>
<td>C</td>
<td>12.0 x 12.0 x 2.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>12.0 x 12.0 x 2.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>-</td>
<td>12.0 x 24.0 x 2.5</td>
<td>22.0 x 24.0 x 2.5</td>
<td>24.0 x 24.0 x 2.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>14.5 x 12.0 x 2.5</td>
<td>14.5 x 24.0 x 2.5</td>
<td>14.5 x 36.0 x 2.5</td>
<td>14.5 x 48.0 x 2.5</td>
<td>14.5 x 60.0 x 2.5</td>
<td>14.5 x 72.0 x 2.5</td>
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<tr>
<td>45</td>
<td>I</td>
<td>-</td>
<td>25 x 15 x 5</td>
<td>25 x 15 x 7.5</td>
<td>25 x 15 x 10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>-</td>
<td>25 x 15 x 5</td>
<td>25 x 15 x 7.5</td>
<td>25 x 15 x 10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>90</td>
<td>G</td>
<td>35 x 25 x 5</td>
<td>35 x 25 x 7.5</td>
<td>35 x 25 x 10</td>
<td>35 x 25 x 15</td>
<td>35 x 25 x 17.5</td>
<td>35 x 25 x 20</td>
</tr>
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</table>
DIMENSIONS in millimeters AND AVAILABLE FORMS

STacked THROUGH HOle CONFIGURATION (STH): Examples VERTICAL MOUNT

![Diagram](image1)

Fig. 1 - Form A2: Stacked Through Hole (example 4 cells, 2 pins) (1)

STACKED THROUGH HOle CONFIGURATION (STH): Examples HORIZONTAL MOUNT

![Diagram](image2)

Fig. 2 - Form B2: Stacked Through Hole (example 5 cells, 2 pins) (1)

![Diagram](image3)

Fig. 3 - Form B3: Stacked Through Hole (example 4 cells, keyed polarity - 3 pins) (1)

Note
(1) Bottom and top are not isolated

SURFACE MOUNT FLAT CONFIGURATION (SMF): Examples

![Diagram](image4)

Fig. 4 - Form C: Surface Mount Flat (single cell, keyed polarity)
Fig. 5 - Form D1: Surface Mount Flat (single cell, keyed polarity)

Fig. 6 - Form D2: Surface Mount Flat (single cell, keyed polarity)

Fig. 7 - Form E2: Surface Mount Flat

Fig. 8 - Form E3: Surface Mount Flat

Fig. 9 - Form E4: Surface Mount Flat
LAY FLAT CONFIGURATION (LFC) WITH CONNECTOR: Example 5 cells in series

Fig. 10 - **Form F**: Lay Flat (example for 5 cells)

Fig. 11 - **Form I**: Stacked Through Hole Oval (PCBD)

Fig. 12 - **Form K**: Stacked Through Hole Oval Horizontal

Fig. 13 - **Form G**: Stacked Through Hole Oval (PCBD)
### Table 1

**DIMENSIONS** in millimeters, **MASS AND PACKAGING QUANTITIES**

<table>
<thead>
<tr>
<th>NOMINAL CASE SIZE D x L x H (mm)</th>
<th>FORM</th>
<th>Ø Dmax.</th>
<th>Lmax.</th>
<th>L1max.</th>
<th>Hmax.</th>
<th>MASS (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.0 x 7.0 x 2.5 A2, B2, B3</td>
<td></td>
<td>7.5</td>
<td>2.3 + 0.3</td>
<td>7.0 + 0.5</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>7.0 x 7.0 x 2.5 C</td>
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<td>7.5</td>
<td>7.0</td>
<td>7.0 + 8.0</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
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<td>7.5</td>
<td>7.0</td>
<td>7.0 + 4.0</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>7.0 x 7.0 x 5.0 A2, B2, B3</td>
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<td>7.5</td>
<td>4.2</td>
<td>4.2 + 0.5</td>
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<td>7.5</td>
<td>7.8 + 0.5</td>
<td>-</td>
<td>1.5</td>
</tr>
<tr>
<td>7.0 x 7.0 x 10.0 A2, B2, B3</td>
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<td>10.5</td>
<td>10.2 + 0.5</td>
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<td>1.8</td>
</tr>
<tr>
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<tr>
<td>12.0 x 12.0 x 2.5 C</td>
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<td>12.5</td>
<td>12.5 + 8.0</td>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
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<td>12.5</td>
<td>12.5 + 4.0</td>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>12.0 x 12.0 x 5.0 A2, B2, B3</td>
<td></td>
<td>12.5</td>
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<td>4.2 + 0.5</td>
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<td>2.2</td>
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<td>12.5</td>
<td>8.0</td>
<td>7.8 + 0.5</td>
<td>-</td>
<td>3.3</td>
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<tr>
<td>12.0 x 12.0 x 10.0 A2, B2, B3</td>
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<td>12.5</td>
<td>10.5</td>
<td>10.5 + 0.5</td>
<td>-</td>
<td>4.0</td>
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<tr>
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<td>12.5</td>
<td>12.5 + 0.5</td>
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<td>5.4</td>
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<td>14.8 + 0.5</td>
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<td>6.5</td>
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<td>7.5</td>
<td>14.8</td>
<td>14.8 + 8.0</td>
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<td>24.0 + 8.0</td>
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<td>14.8 + 8.0</td>
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<td>12.0 + 50.0</td>
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<td>1.0</td>
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<tr>
<td>14.5 x 24.0 x 2.5 F</td>
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<td>24.0</td>
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<td>3.0</td>
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<td>48.0</td>
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<td>14.5 x 72.0 x 2.5 F</td>
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<td>14.5</td>
<td>72.0</td>
<td>72.0 + 50.0</td>
<td>-</td>
<td>9.0</td>
</tr>
<tr>
<td>25 x 15 x 5.0 I, K</td>
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<td>27 x 15.5</td>
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<td>5.0 ± 0.5</td>
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<td>3.0</td>
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<td>25 x 15 x 7.5 I, K</td>
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<td>27 x 15.5</td>
<td>7.0</td>
<td>7.0 ± 0.5</td>
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<td>9.0 ± 0.5</td>
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<td>6.0</td>
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<td>3.7</td>
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<td>7.5</td>
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<td>7.5 ± 0.5</td>
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<td>15.0</td>
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<td>35 x 25</td>
<td>10.5</td>
<td>10.5 ± 0.5</td>
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</tr>
<tr>
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<td>15.0</td>
<td>14.5 ± 0.5</td>
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<td>45.0</td>
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<td>35 x 25</td>
<td>21.1</td>
<td>20.1 ± 1.0</td>
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<td>50.0</td>
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**ELECTRICAL DATA**

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_R$</td>
<td>Rated capacitance, tolerance -20% / +80%, measured by constant current discharge method</td>
</tr>
<tr>
<td>UCT</td>
<td>Upper category temperature</td>
</tr>
<tr>
<td>$I_L$</td>
<td>Max. leakage current after 24h at $U_R$</td>
</tr>
<tr>
<td>$R_I$</td>
<td>Max. internal resistance at 1 kHz</td>
</tr>
</tbody>
</table>

*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**

Hybrid Storage Capacitor
15 F / 1.4 V
Nominal case size: Ø 12.0 mm x 2.5 mm; Form B3
Ordering code: MAL219691211E3

**Table 2**

**ELECTRICAL DATA AND ORDERING INFORMATION**

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<thead>
<tr>
<th>$U_R$ (V)</th>
<th>$C_R$ (F)</th>
<th>NOMINAL CASE SIZE</th>
<th>CASE CODE</th>
<th>F (mm)</th>
<th>F1 (mm)</th>
<th>UCT (°C)</th>
<th>$I_L$ 24 h (mA)</th>
<th>ESR AC (1) 1 kHz ()</th>
<th>ESR DC (2) ()</th>
<th>MIN. STORAGE ENERGY (Ws)</th>
<th>PACKAGING QUANTITIES</th>
<th>ORDERING CODE</th>
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<td>1.4</td>
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<td>70</td>
<td>0.03</td>
<td>2.5</td>
<td>7.5</td>
<td>4.6</td>
<td>80</td>
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<tr>
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<td>7.0 x 5.0</td>
<td>2 pin A2</td>
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<td>-</td>
<td>70</td>
<td>0.03</td>
<td>5.0</td>
<td>15.0</td>
<td>9.2</td>
<td>80</td>
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<td>-</td>
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<td>80</td>
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<td>-</td>
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<td>-</td>
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<td>80</td>
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<td>-</td>
<td>85</td>
<td>0.12</td>
<td>3.0</td>
<td>12.5</td>
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<td>-</td>
<td>85</td>
<td>0.12</td>
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<td>90</td>
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<td>2.5</td>
<td>70</td>
<td>0.03</td>
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<td>15.0</td>
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<td>4</td>
<td>7.0 x 7.5</td>
<td>3 pin B3</td>
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<td>2.5</td>
<td>70</td>
<td>0.03</td>
<td>7.5</td>
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<td>13.8</td>
<td>96</td>
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<td>7.0 x 10.0</td>
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<td>2.5</td>
<td>70</td>
<td>0.03</td>
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<td>30.0</td>
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<td>96</td>
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<td>0.03</td>
<td>12.5</td>
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<td>60</td>
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<td>7.0 x 15.0</td>
<td>3 pin B3</td>
<td>15.7</td>
<td>-</td>
<td>85</td>
<td>0.12</td>
<td>3.6</td>
<td>15.0</td>
<td>105.0</td>
<td>40</td>
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<tr>
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<td>7.0 x 2.5</td>
<td>3 pin B3</td>
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<td>2.5</td>
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<td>0.03</td>
<td>2.5</td>
<td>7.5</td>
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<td>100</td>
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<td>7.0 x 5.0</td>
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<td>2.5</td>
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<td>15.0</td>
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<td>100</td>
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<td>2.5</td>
<td>70</td>
<td>0.03</td>
<td>7.5</td>
<td>22.5</td>
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<td>96</td>
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<td>7.0 x 10.0</td>
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<td>2.5</td>
<td>70</td>
<td>0.03</td>
<td>10.0</td>
<td>30.0</td>
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<td>96</td>
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<td>2.5</td>
<td>70</td>
<td>0.03</td>
<td>12.5</td>
<td>37.5</td>
<td>23.0</td>
<td>60</td>
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<td>3 pin B3</td>
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<td>-</td>
<td>85</td>
<td>0.12</td>
<td>3.6</td>
<td>15.0</td>
<td>105.0</td>
<td>40</td>
<td>MAL219691116E3</td>
</tr>
</tbody>
</table>

**STACKED THROUGH HOLE CONFIGURATION (STH) - VERTICAL MOUNT**

**STACKED THROUGH HOLE CONFIGURATION (STH) - HORIZONTAL MOUNT**
## Notes

1. ESR AC 1 kHz are typical values
2. ESR DC are typical values

### Table 3

#### LOAD CURRENTS AND VOLTAGES

<table>
<thead>
<tr>
<th>$C_R$ (F)</th>
<th>RECOMMENDED CHARGE CURRENT</th>
<th>MAX. CHARGE CURRENT</th>
<th>MAX. DISCHARGE CURRENT</th>
<th>LOWEST DISCHARGE VOLTAGE (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>2 mA to 8 mA</td>
<td>14 mA</td>
<td>25 mA</td>
<td>n x 0.8 V</td>
</tr>
<tr>
<td>15</td>
<td>5 mA to 20 mA</td>
<td>50 mA</td>
<td>70 mA</td>
<td>n x 0.8 V</td>
</tr>
<tr>
<td>45</td>
<td>30 mA to 300 mA</td>
<td>0.5 A</td>
<td>0.5 A</td>
<td>n x 0.8 V</td>
</tr>
<tr>
<td>90</td>
<td>0.3 A to 1 A</td>
<td>1.5 A</td>
<td>3 A</td>
<td>n x 0.8 V</td>
</tr>
</tbody>
</table>

**Note**

1. $n$: number of cells, permanent operation below lowest discharge voltage is not permitted
MEASURING OF CHARACTERISTICS

CAPACITANCE (C)
Capacitance shall be measured by constant current discharge method.

DISCHARGE CURRENT AS A FUNCTION OF RATED CAPACITANCE

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated capacitance, (C_R)</td>
<td>4</td>
<td>F</td>
</tr>
<tr>
<td>Discharge current, (I_D)</td>
<td>4</td>
<td>mA</td>
</tr>
</tbody>
</table>

For \(I_D\), \(U_R\), \(U_1\), \(U_2\), \(t_1\), and \(t_2\) the following definitions have to be used:

- \(C_R\) : Rated capacitance, in F
- \(U_R\) : Rated voltage, in V
- \(U_1\) : Starting voltage, in V
- \(U_2\) : Ending voltage, 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

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

For \(I_D\), \(U_1\), and \(U_2\) the following definitions have to be used:

- \(C_R\) : Rated capacitance, in F
- \(U_R\) : Rated voltage, in V
- \(U_1\) : Starting voltage, in V
- \(U_2\) : Ending voltage, 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
- \(I_D\) : Discharge current, in A

Table 4

<table>
<thead>
<tr>
<th>CAPACITANCE</th>
<th>(C) (F)</th>
<th>(I_D) (A)</th>
<th>(U_R) (V)</th>
<th>(U_1) (V)</th>
<th>(U_2) (V)</th>
<th>(t_1) (s)</th>
<th>(t_2) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.004</td>
<td>1.4</td>
<td>1.3</td>
<td>0.7</td>
<td>5</td>
<td>5</td>
<td>&gt; 600</td>
</tr>
<tr>
<td>4</td>
<td>0.004</td>
<td>2.8</td>
<td>2.7</td>
<td>1.9</td>
<td>5</td>
<td>5</td>
<td>&gt; 600</td>
</tr>
<tr>
<td>4</td>
<td>0.004</td>
<td>4.2</td>
<td>4.0</td>
<td>3.1</td>
<td>5</td>
<td>5</td>
<td>&gt; 600</td>
</tr>
<tr>
<td>4</td>
<td>0.004</td>
<td>5.6</td>
<td>5.4</td>
<td>4.4</td>
<td>5</td>
<td>5</td>
<td>&gt; 600</td>
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<td>7.0</td>
<td>6.7</td>
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<td>5</td>
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<td>0.004</td>
<td>8.4</td>
<td>8.1</td>
<td>6.9</td>
<td>5</td>
<td>5</td>
<td>&gt; 600</td>
</tr>
<tr>
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<td>0.015</td>
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<td>1.3</td>
<td>0.7</td>
<td>5</td>
<td>5</td>
<td>&gt; 600</td>
</tr>
<tr>
<td>15</td>
<td>0.015</td>
<td>2.8</td>
<td>2.7</td>
<td>1.9</td>
<td>5</td>
<td>5</td>
<td>&gt; 600</td>
</tr>
<tr>
<td>15</td>
<td>0.015</td>
<td>4.2</td>
<td>4.0</td>
<td>3.1</td>
<td>5</td>
<td>5</td>
<td>&gt; 600</td>
</tr>
<tr>
<td>15</td>
<td>0.015</td>
<td>5.6</td>
<td>5.4</td>
<td>4.4</td>
<td>5</td>
<td>5</td>
<td>&gt; 600</td>
</tr>
<tr>
<td>15</td>
<td>0.015</td>
<td>7.0</td>
<td>6.7</td>
<td>5.6</td>
<td>5</td>
<td>5</td>
<td>&gt; 600</td>
</tr>
</tbody>
</table>

INTERNAL RESISTANCE \((R_I)\) AT 1 kHz

\[
R_I (\Omega) = \frac{U_C (V)}{10^{-3}} 
\]

LEAKAGE CURRENT \((I_L)\)
Leakage current shall be measured after 30 min application of rated voltage \(U_R\):

\[
I_L (\mu A) = \frac{U_S (V)}{10^{-4}} 
\]
DISCHARGE CHARACTERISTICS

Backup time of 196 HVC series capacitors depends on minimum memory holding voltage and discharge current (corresponding with the current consumption of the load).

For minimum backup times of standard and vertical miniaturized series see Fig. 20 to Fig. 23 (charging time ≥ 24 h and CC-CV charging according to table 3).

### VOLTAGE TO BE USED FOR SERIES CONNECTION

<table>
<thead>
<tr>
<th>N CELLS IN SERIES</th>
<th>U_R (V)</th>
<th>U_1 (V)</th>
<th>U_2 (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.4</td>
<td>1.3</td>
<td>0.7</td>
</tr>
<tr>
<td>2</td>
<td>2.8</td>
<td>2.7</td>
<td>1.9</td>
</tr>
<tr>
<td>3</td>
<td>4.2</td>
<td>4.0</td>
<td>3.1</td>
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<tr>
<td>4</td>
<td>5.6</td>
<td>5.4</td>
<td>4.4</td>
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<td>5</td>
<td>7.0</td>
<td>6.7</td>
<td>5.6</td>
</tr>
<tr>
<td>6</td>
<td>8.4</td>
<td>8.1</td>
<td>6.9</td>
</tr>
</tbody>
</table>

Fig. 19 - Typical Leakage Current at 20 °C as a Function of Time

![Fig. 19 - Typical Leakage Current at 20 °C as a Function of Time](image)

Table 5

![Table 5 - VOLTAGE TO BE USED FOR SERIES CONNECTION](image)

Fig. 20 - Typical Backup Time as a Function of Discharge Current

![Fig. 20 - Typical Backup Time as a Function of Discharge Current](image)

Fig. 21 - Typical Backup Time as a Function of Discharge Current

![Fig. 21 - Typical Backup Time as a Function of Discharge Current](image)
**CHARGE CHARACTERISTICS**

**Fig. 22** - Typical Backup Time as a Function of Discharge Current

**Fig. 23** - Typical Backup Time as a Function of Discharge Current

**Note**
- Charge and discharge cycles at room temperature (RT) - maximal 50 000 cycles at room temperature allowed!
**Note**
- Charge and discharge cycles at room temperature (RT) - maximal 50,000 cycles at room temperature allowed!

### CHARGING VOLTAGE AT DIFFERENT TEMPERATURES

<table>
<thead>
<tr>
<th>OPERATING TEMPERATURE RANGE</th>
<th>0 °C UP TO +45 °C</th>
<th>+45 °C UP TO +60 °C</th>
<th>+60 °C UP TO +70 °C / +85 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge voltage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 cell</td>
<td>( U_R + 0.03 ) V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 cells</td>
<td>( U_R + 0.06 ) V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 cells</td>
<td>( U_R + 0.09 ) V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 4 cells</td>
<td>( U_R + 0.10 ) V</td>
<td></td>
<td>( U_R - n^{(1)} \times 0.0015 \times (T[°C] - 45) )</td>
</tr>
</tbody>
</table>

**Notes**
- Capacitor is polarized, product will be damaged if reverse charged
- Voltages higher than specified need to be avoided; otherwise reduction of life time, internal gas generation or damage of HVC hybrid capacitor will occur
- For other operating temperatures, a temperature derating factor has to be considered for correct charging voltage
- Surge voltage is only allowed a few seconds per day, but not as a charging process

**(1)** \( n \)... number of cells

### DERATING

Working voltage at temperatures above 60 °C should be below rated voltage \( U_R \). A derating-factor of -1.5 mV/°C per cell is recommended.
PRODUCT AND MOUNTING CHARACTERISTICS

Attention: parts are pre-charged at delivery - handle appropriate.

At delivery products are pre-charged and voltage over terminals is near nominal voltage. Short circuiting of product terminals is permitted. Do not short circuit permanently. Short circuiting of charged cells may heat up the cells.

For printed circuit board mounting it has to be taken into account, that for certain form factors top and bottom of products may not be insulated.

Capacitor disposal methods should be in accordance with local and state regulations.

Table 6.1

<table>
<thead>
<tr>
<th>NAME OF TEST</th>
<th>ENYCAP TESTS SUBCLAUSE</th>
<th>PROCEDURE (quick reference)</th>
<th>REQUIREMENTS (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damp heat, steady state</td>
<td>4.12</td>
<td>500 h at 55 °C; RH 90 % to 95 %; no voltage applied</td>
<td>△C/C: ± 30 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R₁ ≤ 4 x spec. limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Iₗ ≤ 2 x spec. limit</td>
</tr>
<tr>
<td>Endurance</td>
<td>4.13.1</td>
<td>Tₐmb = 70 °C / 85 °C; rated voltage Uₐ applied;</td>
<td>△C/C: ± 30 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.0 F, 15 F: 1000 h</td>
<td>R₁ ≤ 4 x spec. limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45 F, 90 F: 2000 h</td>
<td>Iₗ ≤ 2 x spec. limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Useable life</td>
<td>4.13.2</td>
<td>Tₐmb = 70 °C / 85 °C; rated voltage U_R applied;</td>
<td>△C/C: ± 30 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.0 F, 15 F: 1000 h</td>
<td>R₁ ≤ 4 x spec. limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45 F, 90 F: 2000 h</td>
<td>Iₗ ≤ 2 x spec. limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage at upper category</td>
<td>4.17</td>
<td>Tₐmb = 70 °C / 85 °C; no voltage applied;</td>
<td>△C/C: ± 30 %</td>
</tr>
<tr>
<td>temperature</td>
<td></td>
<td>1000 h</td>
<td>R₁ ≤ 4 x spec. limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Iₗ ≤ 2 x spec. limit</td>
</tr>
<tr>
<td>Self discharge</td>
<td>4.1.5</td>
<td>24 h storage at room temperature after application of Uₐ for 1 h</td>
<td>Remaining voltage: ≥ (U_R x 0.9)</td>
</tr>
<tr>
<td>Characteristics at high and low</td>
<td>4.19</td>
<td>Step 1: reference measurement at 20 °C of C, R₁, and Iₗ</td>
<td>△C/C: ± 30 % of +20 °C value</td>
</tr>
<tr>
<td>temperature</td>
<td></td>
<td>Step 2: measurement at -20 °C</td>
<td>R₁ ≤ 5 x the +20 °C value</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Step 3: measurement at +20 °C</td>
<td>Iₗ ≤ 4 x the +20 °C value</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Step 4: measurement at -70 °C</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Step 5: measurement at +20 °C</td>
<td></td>
</tr>
<tr>
<td>Surge voltage</td>
<td>4.15</td>
<td>Max. 30 s at room temperature</td>
<td>No change of parameter!</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Uₛ = n (1) x 1.6 V</td>
<td>After surge voltage, discharge product below rated voltage</td>
</tr>
</tbody>
</table>

Notes
(1) n... number of cells
(2) R₁ equals ESRₐC or ESRₐ₀C

Table 6.2: Stacked Through Hole configuration (STH), Surface Mount Flat configuration (SMF), and Lay Flat configuration with Connector

<table>
<thead>
<tr>
<th>NAME OF TEST</th>
<th>ENYCAP TESTS SUBCLAUSE</th>
<th>PROCEDURE (quick reference)</th>
<th>REQUIREMENTS (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robustness of terminations</td>
<td>4.4</td>
<td>Tensile strength; application of load force in pin / tab direction for 10 s:</td>
<td>No breaks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 N: for product size Ø ≥ 8 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 N: for product size Ø &lt; 8 mm</td>
<td></td>
</tr>
<tr>
<td>Resistance to soldering heat</td>
<td>4.5</td>
<td>260 °C; 5 s</td>
<td>△C/C: ± 10 %</td>
</tr>
<tr>
<td>Solderability</td>
<td>4.6</td>
<td>Solder bath; 236 °C; 2 s; one pin immersed</td>
<td>R₁ and Iₗ ≤ spec. limit</td>
</tr>
<tr>
<td>Vibration</td>
<td>4.8</td>
<td>10 Hz to 55 Hz; 1.5 mm; 3 directions; 2 h per direction</td>
<td>△C/C: ± 10 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R₁ and Iₗ ≤ spec. limit</td>
</tr>
</tbody>
</table>

Notes
- Robustness - bending limited to ± 15°, force in direction of tab / pin, no twisting allowed
- Solder bath test: max. allowed case temperature during test is e.g. 85 °C or immersion of one (1) pad only
- Wave soldering allowed
(1) R₁ equals ESRₐC or ESRₐ₀C
SOLDERING

As a general principle, temperature and duration shall be the minimum necessary required to ensure good soldering connections. However, the maximum specified soldering time and case temperature should never be exceeded.

EVALUATION KIT

Evaluation kits are available under ordering code: MAL219699001E3. The engineering kit includes a charge and discharge demo board with different 196 HVC capacitor samples.

For further details, please contact hybridstorage@vishay.com.
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