

## Aluminum Electrolytic Capacitors SMD (Chip), High Voltage

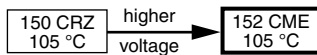


Fig. 1

 AUTOMOTIVE  
GRADE

**RoHS**  
COMPLIANT

### FEATURES

- Extended useful life: up to 6000 h at 105 °C
- Polarized aluminum electrolytic capacitors, non-solid electrolyte, self healing
- SMD-version with base plate, lead (Pb)-free reflow solderable
- Charge and discharge proof, no peak current limitation
- Advanced temperature reflow soldering according to JEDEC® J-STD-020
- Vibration proof, 4-pin version and 6-pin version
- AEC-Q200 qualified
- High reliability
- Material categorization: for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)

### APPLICATIONS

- SMD technology, for high temperature reflow soldering
- Industrial and professional applications
- Automotive, general industrial, telecom
- Smoothing, filtering, buffering

### MARKING

- Rated capacitance (in  $\mu\text{F}$ )
- Rated voltage (in V)
- Date code, in accordance with IEC 60062
- Black mark or “-” sign indicating the cathode (the anode is identified by beveled edges)
- Code indicating group number (E)

### PACKAGING

Supplied in blister tape on reel

| QUICK REFERENCE DATA                        |                                       |
|---|---------------------------------------|
| DESCRIPTION                                 | VALUE                                 |
| Nominal case sizes (L x W x H in mm)        | 10 x 10 x 10 to 18 x 18 x 21          |
| Rated capacitance range, $C_R$              | 2.2 $\mu\text{F}$ to 33 $\mu\text{F}$ |
| Tolerance on $C_R$                          | $\pm 20\%$                            |
| Rated voltage range, $U_R$                  | 400 V to 450 V                        |
| Category temperature range                  | -40 °C to +105 °C                     |
| Endurance test at 105 °C                    | 1000 h to 5000 h                      |
| Useful life at 105 °C                       | 1500 h to 6000 h                      |
| Useful life at 40 °C<br>1.8 x $I_R$ applied | 75 000 h to 300 000 h                 |
| Shelf life at 0 V, 105 °C                   | 1000 h                                |
| Based on sectional specification            | IEC 60384-18 / CECC 32300             |
| Climatic category IEC 60068                 | 40 / 105 / 56                         |

| SELECTION CHART FOR $C_R$ , $U_R$ , AND RELEVANT NOMINAL CASE SIZES (L x W x H in mm) |                              |                  |
|---|------------------------------|------------------|
| $C_R$<br>( $\mu\text{F}$ )  | $U_R$ (V)                    |                  |
|   | 400                          | 450              |
| 2.2   | 10 x 10 x 10                 | 10 x 10 x 10     |
| 3.9   | 10 x 10 x 10                 | -                |
| 4.7   | →                            | 12.5 x 12.5 x 13 |
| 5.6   | →                            | 12.5 x 12.5 x 16 |
| 6.8   | 12.5 x 12.5 x 13             | -                |
| 10  | 12.5 x 12.5 x 16             | 16 x 16 x 16     |
| 15  | →                            | 16 x 16 x 21     |
| 18  | 16 x 16 x 16                 | -                |
| 22  | 16 x 16 x 21<br>18 x 18 x 16 | 18 x 18 x 16     |
| 33  | 18 x 18 x 21                 | 18 x 18 x 21     |

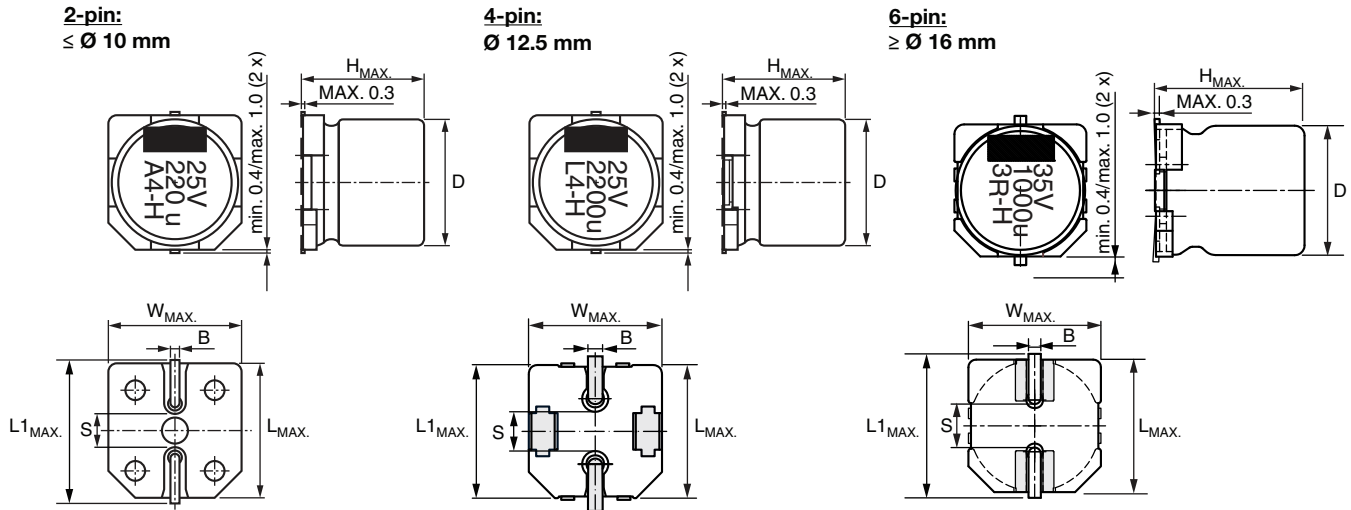


Fig. 2 - Dimensional outline

Table 1

| DIMENSIONS in millimeters AND MASS |           |                   |                   |                   |      |                   |     |                    |          |
|------------------------------------|-----------|-------------------|-------------------|-------------------|------|-------------------|-----|--------------------|----------|
| NOMINAL CASE SIZE L x W x H        | CASE CODE | L <sub>MAX.</sub> | W <sub>MAX.</sub> | H <sub>MAX.</sub> | Ø D  | B <sub>MAX.</sub> | S   | L1 <sub>MAX.</sub> | MASS (g) |
| 10 x 10 x 10                       | 1010      | 10.5              | 10.5              | 10.5              | 10.0 | 1.0               | 3.5 | 12.1               | ≈ 1.3    |
| 12.5 x 12.5 x 13                   | 1213      | 12.9              | 12.9              | 14.0              | 12.5 | 1.3               | 3.6 | 14.9               | ≈ 2.6    |
| 12.5 x 12.5 x 16                   | 1216      | 12.9              | 12.9              | 16.5              | 12.5 | 1.3               | 3.6 | 14.9               | ≈ 2.8    |
| 16 x 16 x 16                       | 1616      | 16.6              | 16.6              | 17.5              | 16.0 | 1.3               | 6.5 | 18.6               | ≈ 5.5    |
| 16 x 16 x 21                       | 1621      | 16.6              | 16.6              | 22.0              | 16.0 | 1.3               | 6.5 | 18.6               | ≈ 6.0    |
| 18 x 18 x 16                       | 1816      | 19.0              | 19.0              | 17.5              | 18.0 | 1.3               | 6.5 | 21.0               | ≈ 8.0    |
| 18 x 18 x 21                       | 1821      | 19.0              | 19.0              | 22.0              | 18.0 | 1.3               | 6.5 | 21.0               | ≈ 8.3    |

Table 2

| TAPE AND REEL DIMENSIONS in millimeters, PACKAGING QUANTITIES |           |                      |              |                               |               |                             |
|---|-----------|----------------------|--------------|-------------------------------|---------------|-----------------------------|
| NOMINAL CASE SIZE L x W x H                                   | CASE CODE | PITCH P <sub>1</sub> | TAPE WIDTH W | TAPE THICKNESS T <sub>2</sub> | REEL DIAMETER | PACKAGING QUANTITY PER REEL |
| 10 x 10 x 10  | 1010      | 16                   | 24           | 11.6                          | 380           | 500                         |
| 12.5 x 12.5 x 13  | 1213      | 20                   | 24           | 16.2                          | 380           | 250                         |
| 12.5 x 12.5 x 16  | 1216      | 24                   | 32           | 18.5                          | 380           | 200                         |
| 16 x 16 x 16  | 1616      | 28                   | 44           | 18.9                          | 380           | 150                         |
| 16 x 16 x 21  | 1621      | 28                   | 44           | 23.4                          | 380           | 100                         |
| 18 x 18 x 16  | 1816      | 32                   | 44           | 18.9                          | 380           | 125                         |
| 18 x 18 x 21  | 1821      | 32                   | 44           | 23.4                          | 380           | 100                         |

**Note**

- Detailed tape dimensions see section "PACKAGING"

**MOUNTING**

The capacitors are designed for automatic placement on to printed-circuit boards.

Optimum dimensions of soldering pads depend amongst others on soldering method, mounting accuracy, print layout and / or adjacent components.

For recommended soldering pad dimensions, refer to Fig. 3 and Table 3.

**SOLDERING**

Soldering conditions are defined by the curve, temperature versus time, where the temperature is that measured on the component during processing.

For maximum conditions refer to Fig. 4.

Any temperature versus time curve which does not exceed the specified maximum curves may be applied.

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

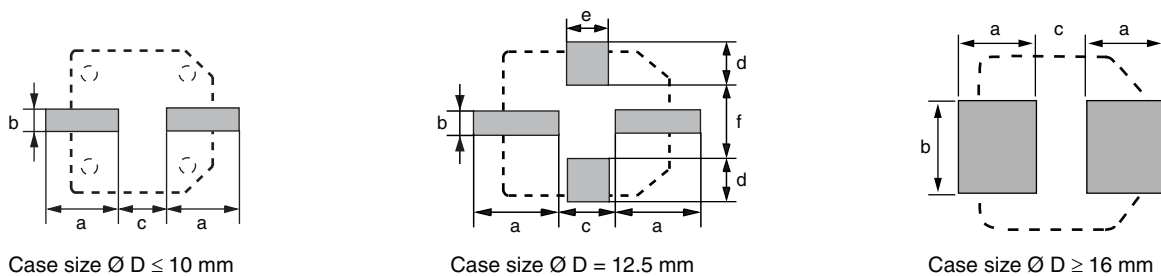


Fig. 3 - Recommended soldering pad dimensions

Table 3

| RECOMMENDED SOLDERING PAD DIMENSIONS in millimeters |     |     |     |     |     |     |
|---|-----|-----|-----|-----|-----|-----|
| CASE CODE   | a   | b   | c   | d   | e   | f   |
| 1010  | 4.4 | 2.5 | 4.0 | -   | -   | -   |
| 1213  | 6.3 | 2.5 | 4.0 | 4.2 | 5.0 | 5.6 |
| 1216  | 6.3 | 2.5 | 4.0 | 4.2 | 5.0 | 5.6 |
| 1616  | 7.8 | 9.6 | 4.7 | -   | -   | -   |
| 1621  | 7.8 | 9.6 | 4.7 | -   | -   | -   |
| 1816  | 8.8 | 9.6 | 4.7 | -   | -   | -   |
| 1821  | 8.8 | 9.6 | 4.7 | -   | -   | -   |

**ADVANCED SOLDERING PROFILE FOR LEAD (Pb)-FREE REFLOW PROCESS  
ACCORDING TO JEDEC J-STD-020**


Fig. 4 - Maximum temperature load during reflow soldering

**Table 4**

| REFLOW SOLDERING CONDITIONS for MAL215299xxxE3    |                  |                        |                        |
|---|------------------|------------------------|------------------------|
| PROFILE FEATURES                                  | CASE CODE 1010   | CASE CODE 1213 TO 1216 | CASE CODE 1616 TO 1821 |
| Max. time from 25 °C to $T_{Peak}$                | 300 s            | 300 s                  | 300 s                  |
| Max. ramp-up rate to 150 °C                       | 3 K/s            | 3 K/s                  | 3 K/s                  |
| Max. time from 150 °C to 200 °C ( $t_1$ )         | 150 s            | 150 s                  | 150 s                  |
| Max. time from 190 °C to 200 °C ( $t_2$ )         | 110 s            | 110 s                  | 110 s                  |
| Ramp up rate from 200 °C to $T_{Peak}$            | 0.5 K/s to 3 K/s | 0.5 K/s to 3 K/s       | 0.5 K/s to 3 K/s       |
| Max. time above $T_{Liquidus}$ (217 °C) ( $t_3$ ) | 90 s             | 90 s                   | 90 s                   |
| Max. time above 230 °C ( $t_4$ )                  | 70 s             | 65 s                   | 60 s                   |
| Peak temperature $T_{Peak}$                       | 260 °C           | 250 °C                 | 245 °C                 |
| Max. time above $T_{Peak}$ minus 5 °C             | 40 s             | 30 s                   | 30 s                   |
| Ramp-down rate from $T_{Liquidus}$                | 3 K/s to 6 K/s   | 3 K/s to 6 K/s         | 3 K/s to 6 K/s         |

**Notes**

- Temperature measuring point on top of the case and on terminals
- Max. 2 runs with pause of min. 30 min in between



| ELECTRICAL DATA |   |
|-----------------|---|
| SYMBOL          | DESCRIPTION                                       |
| $C_R$           | Rated capacitance at 100 Hz, tolerance $\pm 20\%$ |
| $I_R$           | Rated RMS ripple current at 100 Hz, 105 °C        |
| $I_{L2}$        | Max. leakage current after 2 min at $U_R$         |
| $\tan \delta$   | Max. dissipation factor at 100 Hz                 |
| $Z$             | Max. impedance at 100 kHz                         |

**Note**

- Unless otherwise specified, all electrical values in Table 5 apply at  $T_{amb} = 20\text{ °C}$ ,  $P = 86\text{ kPa}$  to  $106\text{ kPa}$ ,  $RH = 45\%$  to  $75\%$

Table 5

| ELECTRICAL DATA AND ORDERING INFORMATION |                            |   |                                   |  |                         |  |                  |                               |
|--|----------------------------|---|-----------------------------------|--|-------------------------|--|------------------|-------------------------------|
| $U_R$<br>(V)                             | $C_R$<br>( $\mu\text{F}$ ) | NOMINAL<br>CASE SIZE<br>L x W x H<br>(mm) | $I_R$<br>105 °C<br>100 Hz<br>(mA) | $I_{L1}$<br>1 min<br>( $\mu\text{A}$ ) | $\tan \delta$<br>100 Hz | $Z$<br>10 kHz<br>20 °C<br>( $\Omega$ ) | LIFE<br>CODE (1) | ORDERING CODE<br>MAL2152..... |
| 400                                      | 2.2                        | 10 x 10 x 10                              | 30                                | 97                                     | 0.15                    | 13.0                                   | L1               | 99601E3                       |
|  | 3.9                        | 10 x 10 x 10                              | 50                                | 117                                    | 0.15                    | 8.5                                    | L1               | 99602E3                       |
|  | 6.8                        | 12.5 x 12.5 x 13                          | 60                                | 152                                    | 0.15                    | 4.7                                    | L2               | 99603E3                       |
|  | 10                         | 12.5 x 12.5 x 16                          | 80                                | 190                                    | 0.15                    | 3.5                                    | L3               | 99604E3                       |
|  | 18                         | 16 x 16 x 16                              | 100                               | 286                                    | 0.15                    | 2.1                                    | L4               | 99605E3                       |
|  | 22                         | 16 x 16 x 21                              | 130                               | 334                                    | 0.15                    | 1.5                                    | L5               | 99606E3                       |
|  | 22                         | 18 x 18 x 16                              | 140                               | 334                                    | 0.15                    | 1.5                                    | L4               | 99607E3                       |
|  | 33                         | 18 x 18 x 21                              | 190                               | 466                                    | 0.15                    | 1.1                                    | L5               | 99608E3                       |
| 450                                      | 2.2                        | 10 x 10 x 10                              | 30                                | 100                                    | 0.20                    | 14.5                                   | L1               | 99701E3                       |
|  | 4.7                        | 12.5 x 12.5 x 13                          | 50                                | 134                                    | 0.20                    | 5.9                                    | L2               | 99702E3                       |
|  | 5.6                        | 12.5 x 12.5 x 16                          | 65                                | 146                                    | 0.20                    | 5.2                                    | L3               | 99703E3                       |
|  | 10                         | 16 x 16 x 16                              | 90                                | 205                                    | 0.20                    | 2.9                                    | L4               | 99704E3                       |
|  | 15                         | 16 x 16 x 21                              | 110                               | 273                                    | 0.20                    | 2.1                                    | L5               | 99705E3                       |
|  | 22                         | 18 x 18 x 16                              | 120                               | 367                                    | 0.20                    | 1.7                                    | L4               | 99706E3                       |
|  | 33                         | 18 x 18 x 21                              | 160                               | 516                                    | 0.20                    | 1.1                                    | L5               | 99707E3                       |

**Note**

- Determines the applicable row in the table "Endurance Test Duration and Useful Life"

Table 6

| ADDITIONAL ELECTRICAL DATA                   |   |   |
|--|---|---|
| PARAMETER                                    | CONDITIONS  | VALUE   |
| <b>Voltage</b>                               |   |   |
| Surge voltage for short periods              | IEC 60384-18, subclause 4.14                                | $U_s \leq 1.10 \times U_R$                                  |
| Reverse voltage for short periods            | IEC 60384-18, subclause 4.16; $T_A \leq 105\text{ °C}$      | $U_{rev} \leq 1\text{ V}$                                   |
| <b>Current</b>                               |   |   |
| Leakage current                              | After 1 min at $U_R$  | $I_{L1} \leq 0.03 \times C_R \times U_R + 70\ \mu\text{A}$  |
|  | After 5 min at $U_R$  | $I_{L5} \leq 0.015 \times C_R \times U_R + 30\ \mu\text{A}$ |
| <b>Inductance</b>                            |   |   |
| Equivalent series inductance (ESL)           | $\varnothing D = 10\text{ mm}$                              | Typ. 16 nH  |
|  | $\varnothing D \geq 12.5\text{ mm}$                         | Typ. 18 nH  |
| <b>Resistance</b>                            |   |   |
| Equivalent series resistance (ESR) at 100 Hz | Calculated from $\tan \delta_{max}$ and $C_R$ (see Table 5) | $ESR = \tan \delta / 2\pi f C_R$                            |

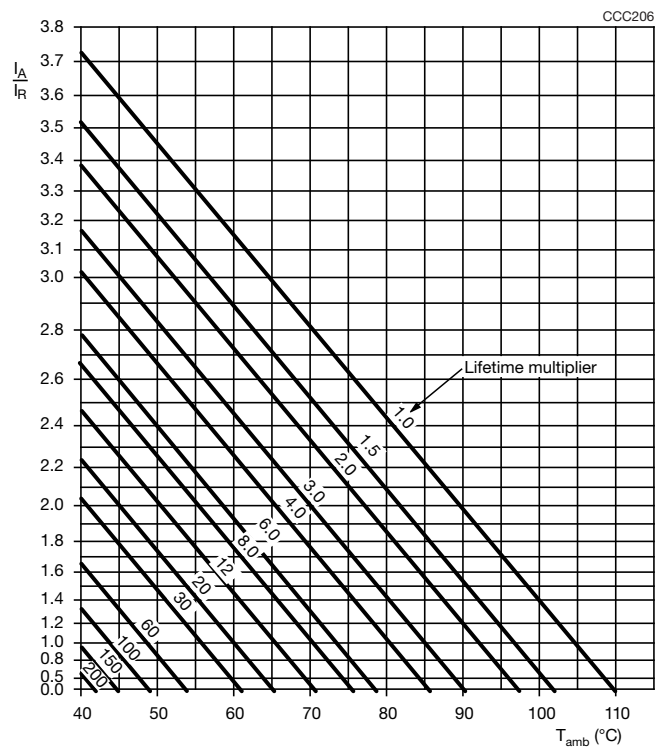
**RIPPLE CURRENT AND USEFUL LIFE**

Table 7

| ENDURANCE TEST DURATION AND USEFUL LIFE |                         |                           |   |
|---|-------------------------|---------------------------|---|
| LIFE CODE                               | ENDURANCE AT 105 °C (h) | USEFUL LIFE AT 105 °C (h) | USEFUL LIFE AT 40 °C 1.8 x I <sub>R</sub> APPLIED (h) |
| L1                                      | 1000                    | 1500                      | 75 000  |
| L2                                      | 2500                    | 3000                      | 150 000   |
| L3                                      | 3000                    | 4000                      | 200 000   |
| L4                                      | 4000                    | 5000                      | 250 000   |
| L5                                      | 5000                    | 6000                      | 300 000   |

**Note**

- Multiplier of useful life code: CCC206



$I_A$  = Actual ripple current at 100 Hz  
 $I_R$  = Rated ripple current at 100 Hz, 105 °C

Fig. 5 - Multiplier of useful life as a function of ambient temperature and ripple current load

Table 8

| MULTIPLIER OF RIPPLE CURRENT (I <sub>R</sub> ) AS A FUNCTION OF FREQUENCY |                |      |      |      |      |        |          |
|---|----------------|------|------|------|------|--------|----------|
| U <sub>R</sub> (V)  | FREQUENCY (Hz) |      |      |      |      |        |          |
|   | 50             | 100  | 300  | 1000 | 3000 | 10 000 | ≥ 30 000 |
| 400   | 0.75           | 1.00 | 1.30 | 1.60 | 1.90 | 2.20   | 2.50     |
| 450   | 0.75           | 1.00 | 1.30 | 1.60 | 1.90 | 2.20   | 2.50     |



Table 9

| TEST PROCEDURES AND REQUIREMENTS            |   |  |  |
|---|---|--|--|
| TEST  |   | PROCEDURE<br>(quick reference)   | REQUIREMENTS   |
| NAME OF TEST                                | REFERENCE                                 |  |  |
| Mounting                                    | IEC 60384-18, subclause 4.3               | Shall be performed prior to tests mentioned below; reflow soldering; for maximum temperature load refer to chapter "Mounting"                      | $\Delta C/C: \pm 5 \%$<br>$\tan \delta \leq \text{spec. limit}$<br>$I_{L2} \leq \text{spec. limit}$  |
| Endurance                                   | IEC 60384-18 / CECC 32300, subclause 4.15 | $T_{amb} = 105 \text{ }^\circ\text{C}$ ; $U_R$ applied; for test duration see Table 7  | $U_R \geq 400 \text{ V}$ ; $\Delta C/C: \pm 20 \%$<br>$\tan \delta \leq 2 \times \text{spec. limit}$<br>$I_{L2} \leq \text{spec. limit}$   |
| Useful life                                 | CECC 30301, subclause 1.8.1               | $T_{amb} = 105 \text{ }^\circ\text{C}$ ; $U_R$ and $I_R$ applied; for test duration see Table 7  | $\Delta C/C: \pm 50 \%$<br>$\tan \delta \leq 3 \times \text{spec. limit}$<br>$I_{L2} \leq \text{spec. limit}$<br>no short or open circuit<br>total failure percentage: $\leq 1 \%$ |
| Shelf life<br>(storage at high temperature) | IEC 60384-18 / CECC 32300, subclause 4.17 | $T_{amb} = 105 \text{ }^\circ\text{C}$ ; no voltage applied; 1000 h<br>after test: $U_R$ to be applied for 30 min, 24 h to 48 h before measurement | For requirements see "Endurance test" above  |
| Reverse voltage                             | IEC 60384-18 / CECC 32300, subclause 4.16 | $T_{amb} = 105 \text{ }^\circ\text{C}$ :<br>125 h at $U = -1.0 \text{ V}$ ,<br>followed by 125 h at $U_R$  | $\Delta C/C: \pm 15 \%$<br>$\tan \delta \leq 1.5 \times \text{spec. limit}$<br>$I_{L2} \leq \text{spec. limit}$  |

Statements about product lifetime are based on calculations and internal testing. They should only be interpreted as estimations. Also due to external factors, the lifetime in the field application may deviate from the calculated lifetime. In general, nothing stated herein shall be construed as a guarantee of durability.



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