DATASHEET

# HY SERIES RADIAL LEAD SUPERCAPACITOR

Revision 4.1, May 2023

The HY series of supercapacitors are high temperature (85°C) cylindrical cells offering excellent value. They are available as single cells, or dual cell modules with a choice of cell balancing options.

## Features:

- High power output to support peak current loads
- On-board energy storage to handle power surges (high capacitance and energy density)
- Long cycle life
- Wide temperature range (-40°C to +85°C)

## Applications:

- Energy Harvesting for wireless sensors
- Peak power support for GSM/GPRS transmission
- Peak power support for low power batteries such as Lithium Thionyl Chloride batteries during automatic meter reading data transmission and last gasp transmission at end of battery life
- Peak power support for locks & actuators
- Peak power support for portable drug delivery systems
- Short term bridging power for power interruptions or battery hot swap

# Electrical Specifications

## Single cells

### Part numbering code

| H | Y | N | vvv | dd | lll | S | ccc | R |
|---|---|---|---|---|---|---|---|---|
| **Model** | **Cylindrical** | **# of cells** | **Voltage** | **Diameter (mm)** | **Length (mm)** | **Tolerance** | **Capacitance (µF)** | **Lead format** |
| High temp | | 1 | 2R7 = 2.7V | 6C = 6.3<br>08 = 8.0<br>10 = 10<br>1B = 12.5<br>16 = 16<br>18 = 18 | 012 = 12<br>040 = 40 | M ± 20%<br>S +50% /-20%<br>V +30% / -10%<br>P +80% / -20% | Two digits + number of zeros.<br>155<br>= 1500000µF<br>= 1.5F | R = radial |

Rated Voltage: 2.7V (Surge 2.85V)
Temperature Range: -40°C to +85°C
Parameters measured at 25°C

| CAP-XX Part no. | Cap (F) | DC ESR Max (mΩ) | AC ESR Max @ 1KHz (mΩ) | IL max @ 72 Hrs (µA) | Diameter (mm) | Length (mm) | Mass (gm) |
|---|---|---|---|---|---|---|---|
| HY12R708014V105R | 1 | 560 | 400 | 2 | 8 | 14 | 0.9 |
| HY12R708014V205R | 2 | 225 | 160 | 4 | 8 | 14 | 1 |
| HY12R708020V305R | 3 | 110 | 80 | 6 | 8 | 20 | 1.4 |
| HY12R708020V335R | 3.3 | 110 | 80 | 7 | 8 | 20 | 1.4 |
| HY12R710020V505R | 5 | 110 | 80 | 10 | 10 | 20 | 2.2 |
| HY12R710025V705R | 7 | 85 | 60 | 14 | 10 | 25 | 2.7 |
| HY12R710025V106R | 10 | 125 | 90 | 20 | 10 | 25 | 2.8 |
| HY12R710030V106R | 10 | 70 | 50 | 20 | 10 | 30 | 3.2 |
| HY12R71B020V106R | 10 | 70 | 50 | 20 | 12.5 | 20 | 3.4 |
| HY12R71B025V156R | 15 | 50 | 35 | 35 | 12.5 | 25 | 4.3 |
| HY12R71B030V206R | 20 | 40 | 28 | 47 | 12.5 | 30 | 5.2 |
| HY12R716025V256R | 25 | 35 | 25 | 75 | 16 | 25 | 7.4 |
| HY12R718040V506R | 50 | 30 | 20 | 150 | 18 | 40 | 13.8 |

## Dual Cell Modules

### Part numbering code

| H | Y | N | vvv | tt | ll | S | ccc | R | B |
|---|---|---|---|---|---|---|---|---|---|
| **Model** | **Cylindrical** | **# of cells** | **Voltage** | **Module thickness (mm)** | **Length (mm)** | **Tolerance** | **Cap. (µF)** | **Lead format** | **Balancing** |
| High Temp | | 2 | 5R5 = 5.5V | 8E = 8.5<br>11 = 11 | 13 = 13<br>37 = 37 | M ± 20%<br>S +50% /-20%<br>V +30% / -10%<br>P +80% / -20% | Two digits + number of zeros. | R= radial leads<br>T= Wire & connector<br>B= Bent radial lead | R = Resistor[1]<br>N = No balancing |

Notes:
[1]R = A pair of balancing 0402 resistors are used. Value can be chosen during ordering. This is for the guarantee of longevity in harsh environments.

Rated Voltage: 5.5V (Surge 5.7V)
Temperature Range: -40°C to +85°C
Parameters measured at 25°C

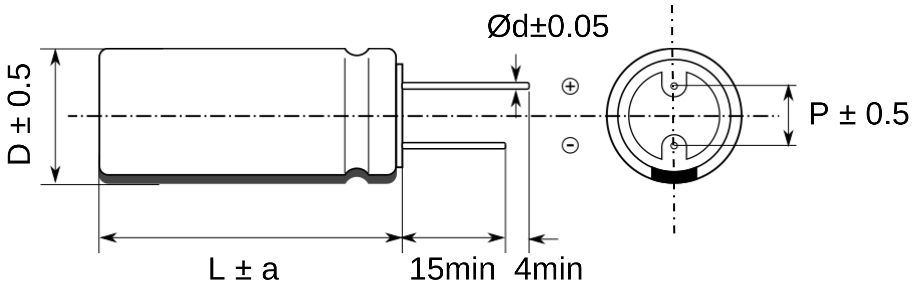
| CAP-XX Part no. | Cap (F) | DC ESR Max (mΩ) | AC ESR Max (mΩ) | IL max @ 72 Hrs (µA) | Thick x Width (mm) | Length (mm) |
|---|---|---|---|---|---|---|
| HY25R58E16V504RN | 0.5 | 1120 | 800 | 2 | 8.5 x 17 | 16 |
| HY25R58E16V105RN | 1 | 475 | 340 | 4 | 8.5 x 17 | 16 |
| HY25R58E22V155RN | 1.5 | 250 | 180 | 6 | 8.5 x 17 | 22 |
| HY25R58E27V255RN | 2.5 | 560 | 400 | 10 | 8.5 x 17 | 27 |
| HY25R51122V255RN | 2.5 | 250 | 180 | 10 | 11 x 22 | 22 |
| HY25R58E32V355RN | 3.5 | 310 | 220 | 14 | 8.5 x 17 | 32 |
| HY25R51122V355RN | 3.5 | 250 | 180 | 14 | 11 x 22 | 22 |
| HY25R51127V355RN | 3.5 | 195 | 140 | 14 | 11 x 22 | 27 |
| HY25R51127V505RN | 5 | 280 | 200 | 20 | 11 x 22 | 27 |
| HY25R51323V505RN | 5 | 170 | 120 | 20 | 13 x 26 | 23 |
| HY25R51133V505RN | 5 | 170 | 120 | 20 | 11 x 22 | 33 |
| HY25R51327V505RN | 5 | 170 | 120 | 20 | 13 x 26 | 27 |
| HY25R51327V755RN | 7.5 | 125 | 90 | 30 | 13 x 26 | 27 |
| HY25R51333V755RN | 7.5 | 125 | 90 | 30 | 13 x 26 | 33 |
| HY25R51724V106RN | 10 | 105 | 76 | 40 | 17 x 34 | 24 |
| HY25R51327V106RN | 10 | 105 | 76 | 40 | 13 x 26 | 27 |
| HY25R51333V106RN | 10 | 105 | 76 | 40 | 13 x 26 | 33 |
| HY25R51729V126RN | 12.5 | 100 | 70 | 50 | 17 x 34 | 29 |
| HY25R51735V156RN | 15 | 100 | 70 | 60 | 17 x 34 | 35 |
| HY25R51735V176RN | 17.5 | 85 | 62 | 70 | 17 x 34 | 35 |
| HY25R51739V206RN | 20 | 85 | 62 | 80 | 17 x 34 | 39 |
| HY25R51843V256RN | 25 | 85 | 60 | 100 | 18 x 36 | 43 |

Notes:
1. For a possible module consisting of 2 single cells listed on page 2, but not shown in the table above, please contact CAP-XX.

# Dimensions (all units in mm)

## HY1 Series Radial Lead 1F – 50F

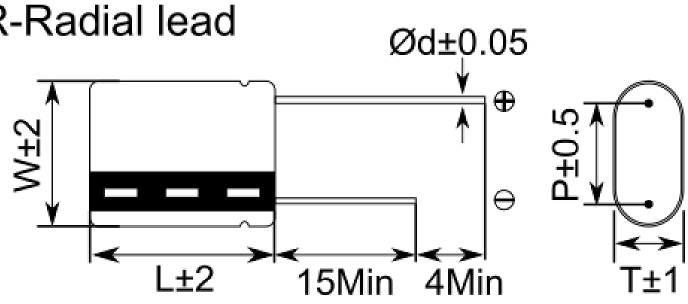
| ΦD | P | a | Φd |
|---|---|---|---|
| 8 | 3.5 | 1.5 | 0.6 |
| 10 | 5 | 2 | 0.6 |
| 12.5 | 5 | 2 | 0.6 |
| 16 | 7.5 | 2 | 0.8 |
| 18 | 7.5 | 2 | 0.8 |



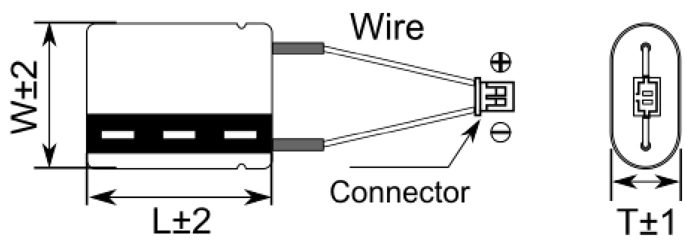

## HY2 Series, 0.5F – 25F

| T | P | Φd |
|---|---|---|
| 8.5 | 12 | 0.6 |
| 11 | 15.5 | 0.6 |
| 13 | 18 | 0.6 |
| 17 | 24 | 0.8 |
| 18 | 26 | 0.8 |

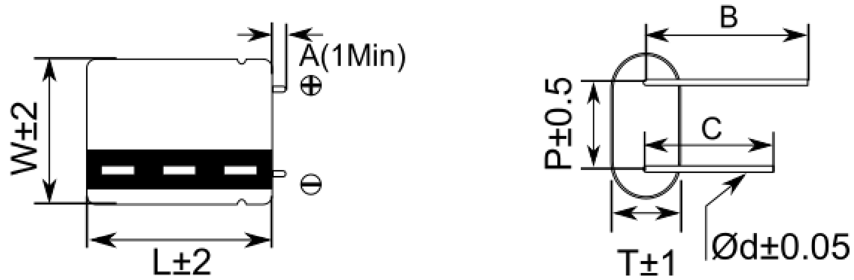
R-Radial lead




T-Wire & connector




B-Bent lead




Note: the colour of the shrink wrap on HY product may be either Blue or Black.

Limited customisations on connector PN (default 1.25mm pitch A1251), wire and lead length (A, B & C) are possible. Please contact sales.

# Measurement of capacitance

Capacitance is measured at 25°C using the method specified by IEC62391 shown in Fig 1. This measures DC capacitance. The capacitor is charged to rated voltage, $V_R$, at constant current, held at rated voltage for at least 30 minutes and then discharged at constant current. The time taken to discharge from 0.8 x $V_R$ to 0.4 x $V_R$ is measured to calculate capacitance as:

$$C = I \times (T_1 - T_2)/(V_1 - V_2)$$

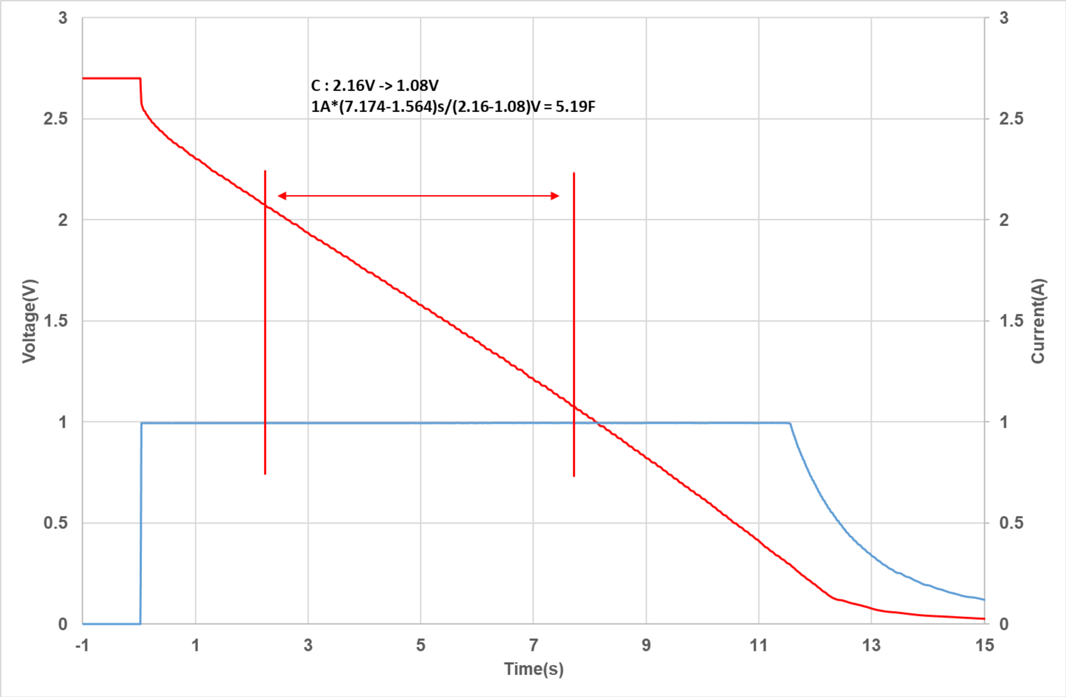



**Fig 1: HY12R708024V505R Capacitance measurement**

In this case, C = 1A*(7.174-1.564)s/(2.16-1.08)V = 5.19F, which is well within the 5F +30% / - 10% tolerance for a HY12R708024V505R cell.

# Measurement of DC ESR

Equivalent Series Resistance (ESR) is measured at 25°C by applying a step load current to the supercapacitor and measuring the resulting voltage drop. CAP-XX waits for a delay of 200µs after the step current is applied to ensure the voltage and current have settled. In this case, for a HY12R708024V505R the ESR is measured as 94mV/1.2A = 78.3mΩ, less than the 85mΩ maximum specified.

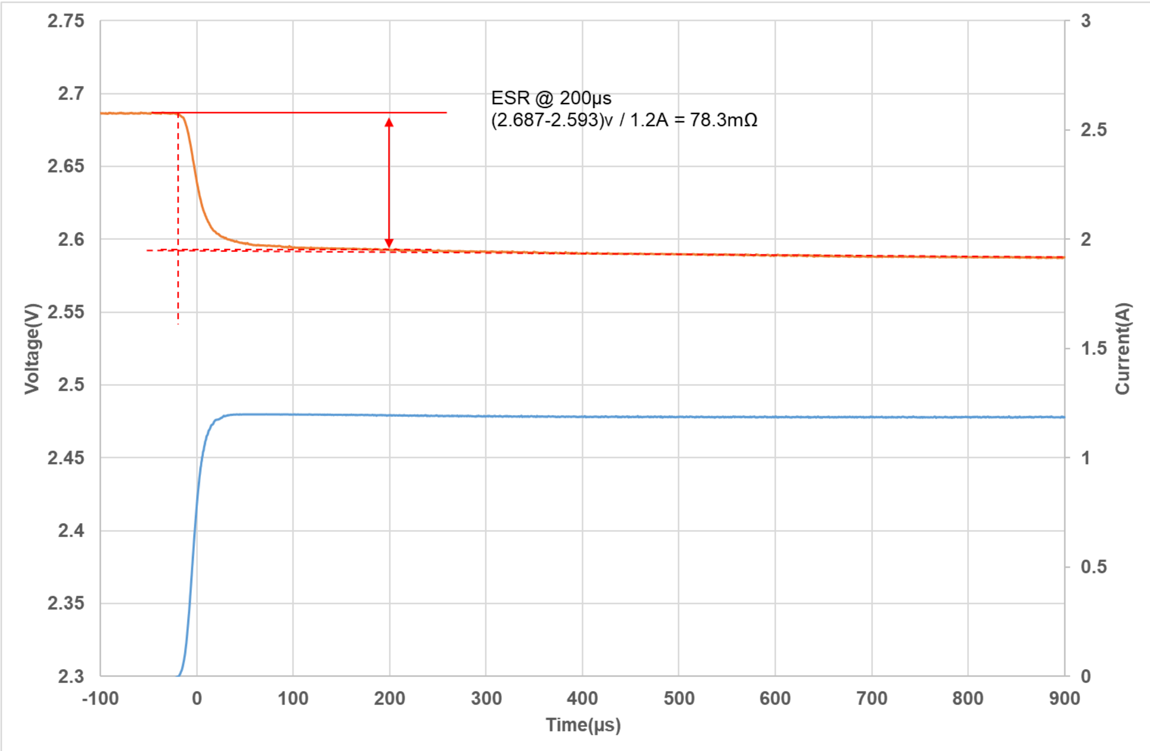



**Fig 2: HY12R708024V505R ESR Measurement**

## Measurement of Leakage Current

Leakage current is measured by holding the supercapacitor at rated voltage at 25°C and measuring the current drawn through a high value resistor, typically 1KΩ or 2.2KΩ. The leakage current decays over time as shown in Fig 3 which shows the average leakage current for HY series supercapacitors. Fig3 shows that the long-term equilibrium leakage current is typically < 1µA/F but the datasheet quotes the maximum values after 72hrs at rated voltage.

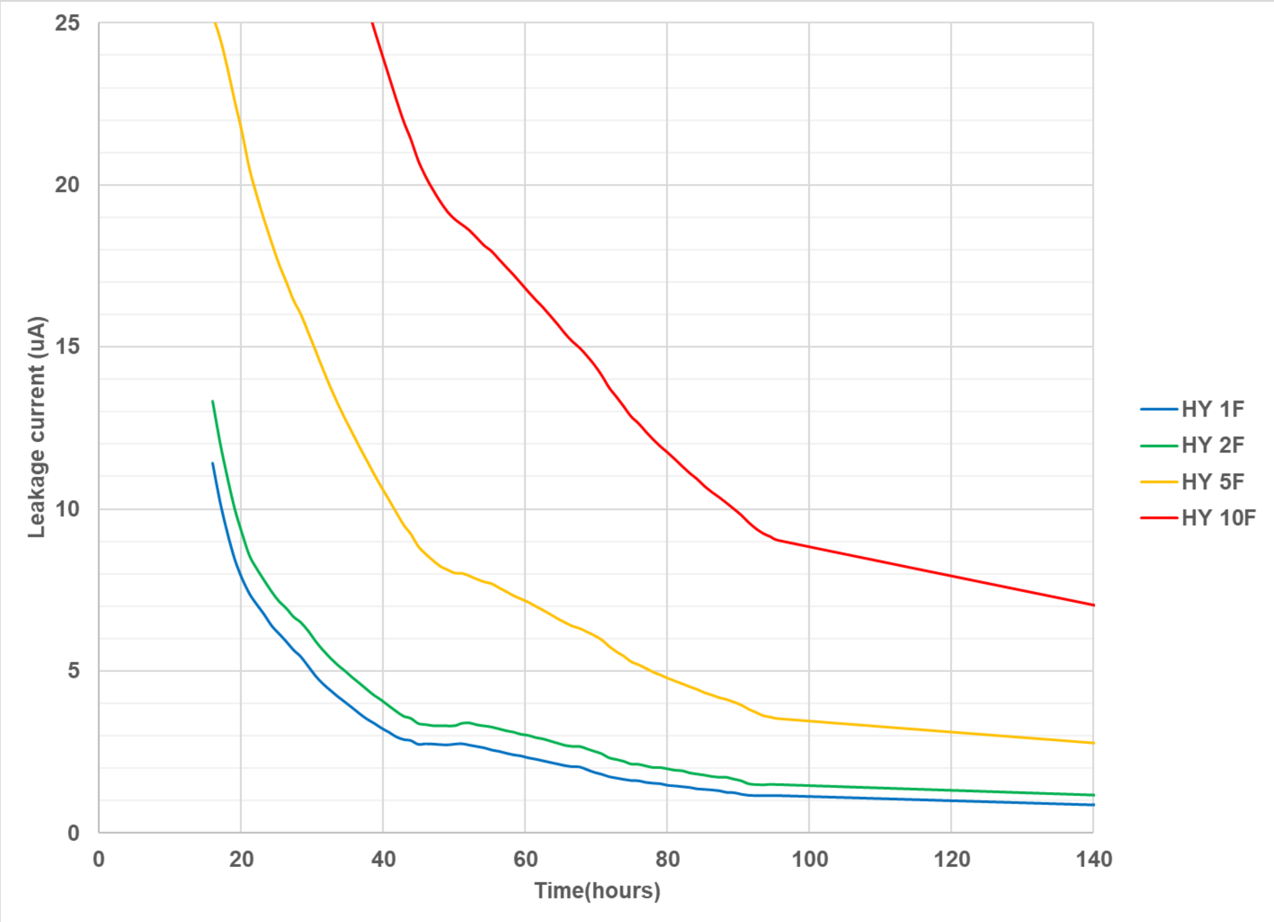



**Fig 3: Leakage current measurement**

## Variation in DC Capacitance and ESR with temperature

Figure 4 shows that DC capacitance does not vary with significantly over the operating temperature range of -40°C to +85°C.

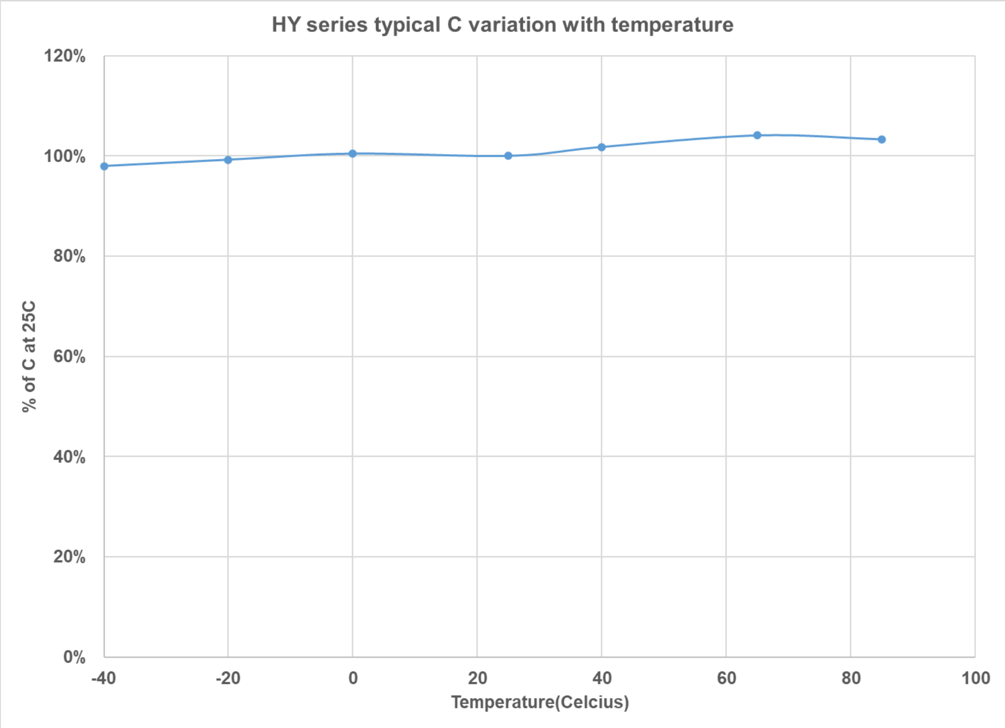



**Fig 4: Typical variation in DC Capacitance over the operating temperature range**

Figure 5 shows variation in DC ESR over the operating temperature range.

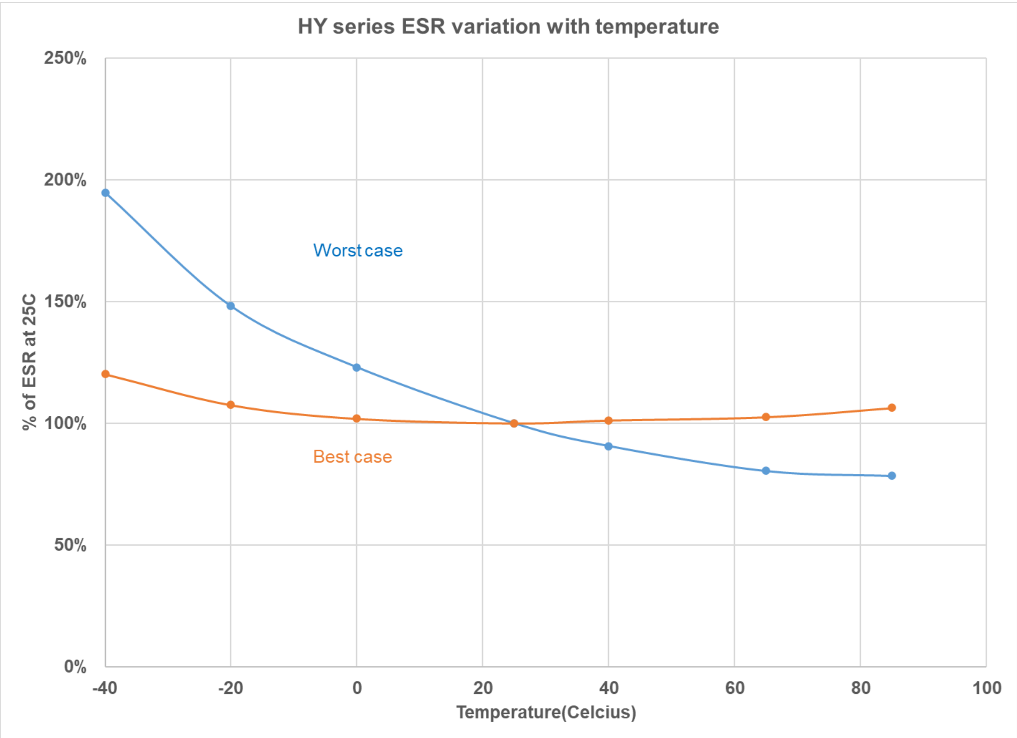



**Fig 5: Typical variation in DC ESR over the operating temperature range**

From Figure 5, $ESR_{DC}$ at -40°C varies from ~1.2 to 1.9 x $ESR_{DC}$ at room temperature. $ESR_{DC}$ at 85°C is 70% to 105% of $ESR_{DC}$ at room temperature. The variation in ESR with temperature is due to the change in the mobility of ions in solution in the electrolyte.

# Peak Current

Peak current is limited by Vrated/(ESR + $R_L$) where $R_L$ is the load resistance including parasitic resistance such as PCB traces. The current then decays and is given by:

$$[Vrated/(ESR + R_L)].e^{-t/[(ESR+RL).C]}$$

where t = time in seconds. At high peak current, the supercapacitor discharges rapidly so that self heating due to the high current is negligible. Table 1 Shows short circuit current for a range of supercapacitors initially charged to 2.7V at the instant the short circuit is applied and after 100ms. It also shows the temperature increase recorded due to the short circuit.

**Table 1:**

| Capacitance (F) | Instantaneous peak current (A) | Current after 100ms (A) | Temperature rise (°C) |
|---|---|---|---|
| 10 | 92 | 49 | 3 |
| 5 | 80 | 38 | 2.1 |
| 2 | 36 | 14 | 1.3 |
| 1 | 28 | 9 | 1 |

In all cases the temperature rise is not significant. A one-time peak current pulse is only limited by the $ESR_{DC}$ + Load resistance, not by any thermal limitations.
The voltage drop when a constant current pulse of duration $\tau$ is applied =

$$V_{INIT} – V_{FINAL} = I.ESR_{DC} + I.\tau/C$$

Where:

- I = constant current
- $\tau$ = duration of constant current
- $V_{INIT}$ = the initial voltage when the current pulse is first applied
- $V_{FINAL}$ = the supercapacitor voltage at the end of the pulse

Re-arranging terms, the maximum current that can be sustained for a time $\tau$, when the supercapacitor is initially charged to rated voltage, $V_R$, and discharged to $V_{MIN}$, the minimum voltage that supports the given application =

$$I_{MAX} = \frac{V_R - V_{MIN}}{ESR_{DC} + \frac{\tau}{C}}$$

## Maximum Continuous Current

Continuous current flow into/out of the supercapacitor will cause self-heating, which limits the maximum continuous current the supercapacitor can handle. This is measured by a current square wave with 50% duty cycle, charging the supercapacitor to rated voltage at a constant current, and then discharging the supercapacitor to half rated voltage at the same constant current value. For a square wave with 50% duty cycle, the RMS current is the same as the current amplitude. Fig 6 shows the increase in temperature above ambient temperature as a function of RMS current for various supercapacitors.

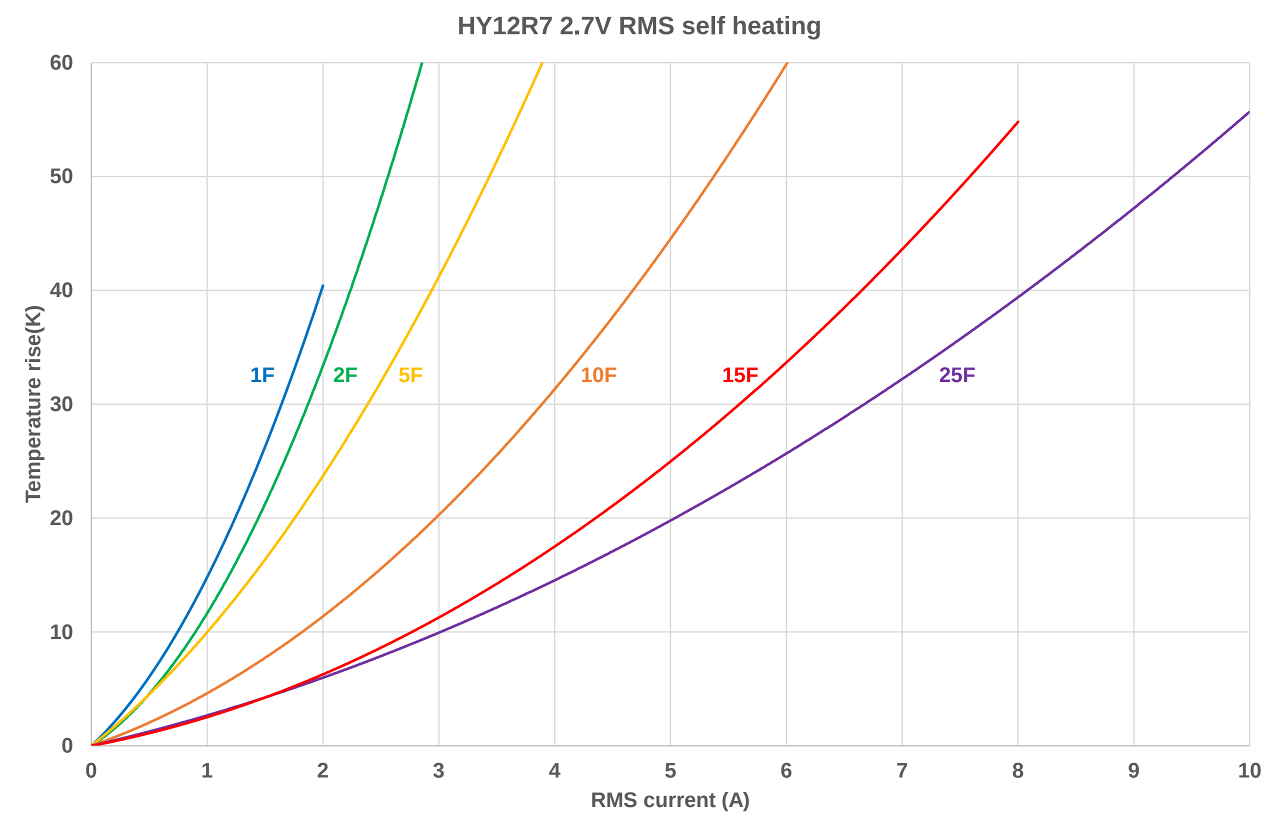



**Fig 6: Self heating with RMS current for HY series supercapacitors**

From Fig 6, the maximum RMS current in an application can be calculated. For example, if the ambient temperature is 40°C, and the maximum operating temperature for the supercapacitor is 85°C, then the maximum RMS current for a 10F supercapacitor should be limited to 5A, which causes a 45°C temperature increase.

# Effective capacitance (Ceff)

Effective capacitance is the capacitance seen for short pulse widths. Due to a supercapacitor's frequency response, for shorter pulse widths there will be less capacitance available than the DC capacitance. In Fig 7, consider the voltage drop due to capacitance after 10ms = 2.662V – 2.654V = 8mV. Therefore Ceff(10ms) = Discharge_Current x 10ms/Voltage drop(10ms) = 1.05A x 0.01s/0.008V = 1.3F. The voltage drop due to capacitance after 100ms = 2.662V – 2.636V = 26mV, hence Ceff(100ms) = 1.05A x 0.1s/0.026V = 4.0F. Fig 8 shows Ceff as a % of DC capacitance for the HY series of supercapacitors.

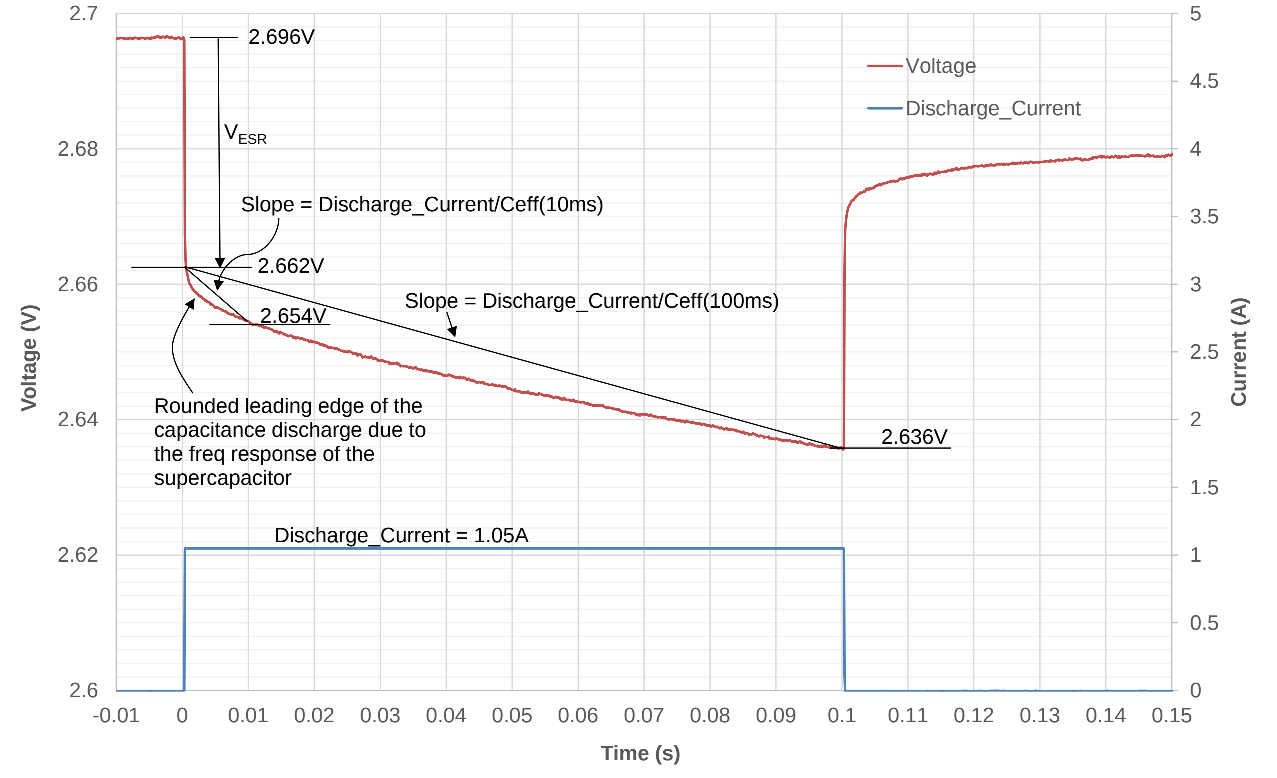



**Fig 7: Discharge pulse illustrating the concept of Ceff**

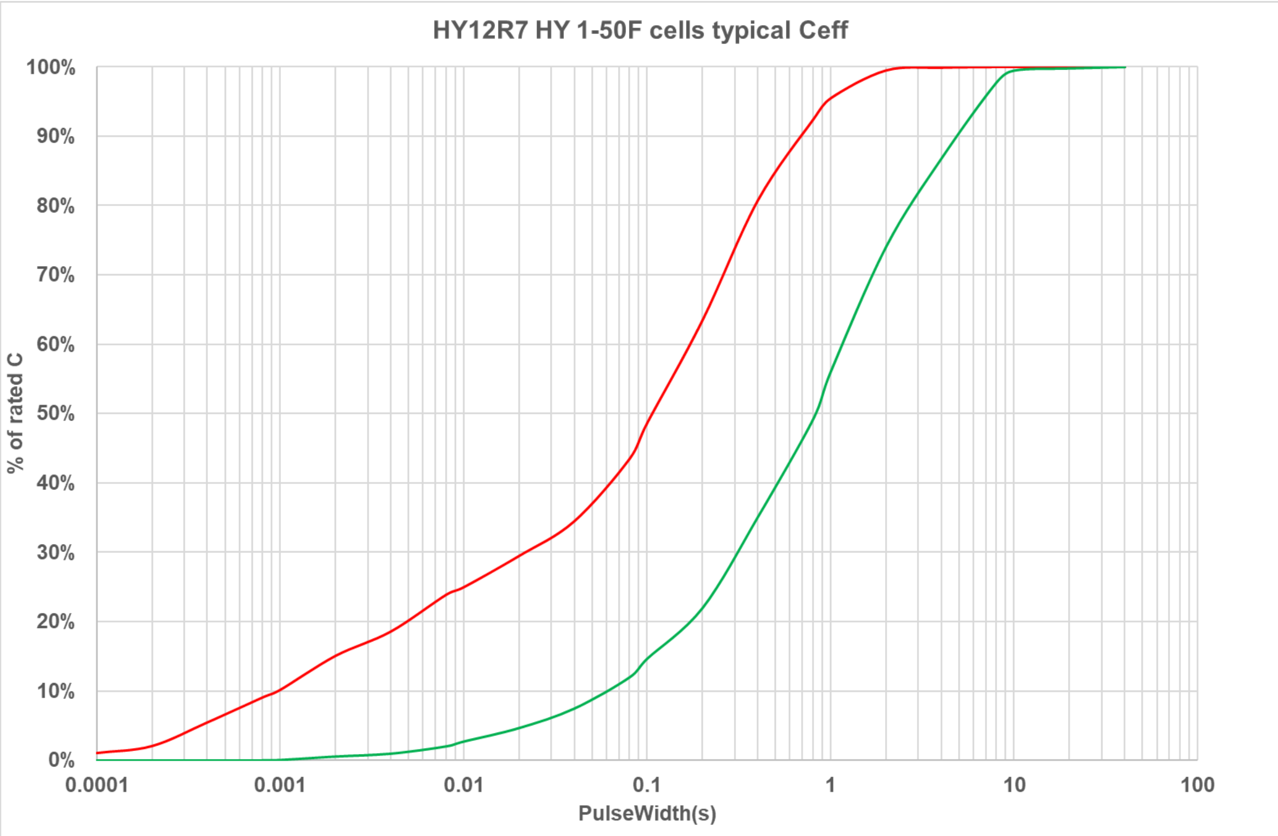



**Fig 8: Typical range of effective capacitance for HY 2.7V series supercapacitors**

For any given pulse width, T, with a constant discharge current $I_{DISCH}$, the voltage drop is given by:

Vdrop = $I_{DISCH}$ x ESR + $I_{DISCH}$ x T/Ceff(T)

Where Ceff(T) = DC capacitance x % at time T read from Fig 8.

Shorter pulses need less capacitance to support them, so the supercapacitors can support short pulses despite their frequency response.

## Balancing options

In many applications a voltage > 2.7V but ≤ 5.5V is required. For these applications 2 supercapacitor cells are connected in series in dual cell modules such as the CAP-XX HY2 series which is rated to 5.5V.

Our experimental data shows in most cases these dual cylindrical cells modules self-balance sufficiently to ensure long life. However, under harsh operating condition, such as large temperature swing, high charge/discharge current, CAP-XX recommend the use of a balancing solution to ensure longevity.

In the HY2 series modules there is a PCB connecting the 2 cells. The voltage between the 2 cells must be balanced. This PCB can have one of two balancing options:

1. Option “R” as the last character in the HY2 series part number.
   A pair of balancing resistors are fitted, one resistor across each cell. The balancing resistors increase leakage current drawn by the module. Thus the value of the resistor should be carefully chosen by the customer during ordering.

2. Option “N” as the last character in the HY2 series part number.
   No balancing is included.

If the application uses a supercapacitor charging IC that has an integrated supercapacitor midpoint balancing circuit, or there is a balancing circuit on the PCB, then order 2 x HY1 cells and place them in series. This makes the midpoint available to your balancing circuit. The dimensions of 2 HY1 cells placed next to each other are the same as a shrink wrapped HY2 series cell, refer to Dimensions on page 4 of this datasheet. Refer to the Application Whitepaper on Supercapacitor Cell Balancing under the DESIGN AIDS section of the CAP-XX website, www.cap-xx.com for more information on cell balancing.

## Storage

CAP-XX recommends storing supercapacitors in their original packaging in an air conditioned room, preferably at < 30°C and < 50% relative humidity. CAP-XX supercapacitors can be stored at any temperature not exceeding their maximum operating temperature but storage at continuous high temperature and humidity is not recommended and will cause premature ageing.

Do not store supercapacitors in the following environments:

- High temperature / high humidity
- Direct sunlight
- In direct contact with water, salt, oil or other chemicals
- In direct contact with corrosive materials, acids, alkalis or toxic gases
- Dusty environment
- In environments subjected to shock and vibration

## Soldering

When soldering it is important to not over-heat the supercapacitor to not adversely affect its performance. CAP-XX recommends that only the leads come in contact with solder and not the supercapacitor body.

Hand Soldering
Heat transfers from the leads into to the supercapacitor body, so the soldering iron temperature should be < 350°C soldering time should be kept to the minimum possible and be less than 4 seconds.

Wave Soldering
The PCB should be pre-heated only from the bottom and for < 60 secs with temperature ≤ 100°C on the top side of the board for PCBs ≥ 0.8mm thick. The table below lists suggested solder temperatures.

| Solder temperature °C | Suggested solder time (s) |
|---|---|
| 220 | 7 |
| 240 | 7 |
| 250 | 5 |
| 260 | 3 |

Reflow Soldering
Infrared or conveyor oven soldering techniques can be used providing the supercapacitor body is not subject to temperatures > 85°C. Do not use a standard reflow oven.

## Transportation

All the supercapacitor cells in this datasheet store < 0.3Wh energy. The energy in watt-hours is calculated as: ½ x Capacitance x $V_{rated}^2$/3600. The largest cell in this range is 50F, so stored energy = ½ x 50 x $2.7^2$ /3600 = 0.0506Wh. Under regulation UN3499 there is no restriction on shipping these supercapacitors. Their shipping description is “Electrical Capacitors” with harmonized shipping code 8532.29.0040.