DATASHEET

GY SERIES RADIAL LEAD SUPERCAPACITOR

Revision 3.3, June 2022

The GY series of supercapacitors are 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

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 to ride through power Interruptions or for battery hot swap

Electrical Specifications

Single cells

Part numbering code

G	Y	N	vvv	dd	lll	S	ccc	R
Model	**Cylindrical**	**# of cells**	**Voltage**	**Diameter (mm)**	**Length (mm)**	**Tolerance**	**Capacitance (µF)**	**Lead format**
		1	2R7 = 2.7V	05 = 5 6C = 6.3 08 = 8.0 10 = 10 1B = 12.5 18 = 18 22 = 22	012 = 12 068 = 68 120 = 120	M ± 20% S +50% /-20% V +30% /-10%	Two digits + number of zeros. e.g. 155 = 1500000µF = 1.5F	R = radial

Rated Voltage: 2.7V

Temperature Range: -40°C to +70°C

Parameters measured at 25°C

CAP-XX Part no.	Cap (F)	DC ESR Max (mΩ)	IL max @ 72 Hrs (µA)	Diameter (mm)	Length (mm)	Mass (gm)
GY12R705012V504R	0.5	570	1	5	12	0.4
GY12R76C012V804R	0.8	440	2	6.3	12	0.7
GY12R76C011V105R	1	190	2	6.3	11	0.7
GY12R708012V105R	1	250	2	8	12	0.9
GY12R708011V205R	2	190	4	8	11	1
GY12R708014V205R	2	130	4	8	14	1.2
GY12R708014V335R	3.3	130	7	8	14	1.4
GY12R708020V335R	3.3	95	7	8	20	1.4
GY12R708024V505R	5	75	10	8	24	1.7
GY12R710020S505R	5	45	10	10	20	2
GY12R710020V705R	7	45	14	10	20	2.3
GY12R710024V106R	10	40	20	10	24	2.7
GY12R71B020V106R	10	40	20	12.5	20	3.4
GY12R71B025V156R	15	40	30	12.5	25	4.3
GY12R71B034V206R	20	40	40	12.5	34	5.6
GY12R716020V206R	20	40	40	16	20	5.9
GY12R716025V256R	25	35	55	16	25	7.4
GY12R716030V306R	30	25	60	16	30	8.4
GY12R716035V406R	40	25	80	16	35	9.9
GY12R718040V506R	50	20	100	18	40	13.6
GY12R718040V606R	60	20	120	18	40	13.6
GY12R718050V706R	70	25	140	18	50	16.9
GY12R718060V107R	100	25	200	18	60	20.3
GY12R722045V107R	100	20	200	22	45	22.5
GY12R722045V127R	120	20	240	22	45	22.5
GY12R722055V187R	180	20	360	22	55	27.0

Dual Cell Modules

Part numbering code

G	Y	N	vvv	tt	ll	S	ccc	R	B
Model	**Cylindrical**	**# of cells**	**Voltage**	**Module thickness (mm)**	**Length (mm)**	**Tolerance**	**Cap. (µF)**	**Lead & package format**	**Balancing**
		2	5R5 = 5.5V	8E = 8.5 11 = 11 13 = 13 17 = 17	17 = 17 44 = 44	M ± 20% S +50% /-20% V +30% /-10%	Two digits + number of zeros.	R= shrink wrap, radial leads – see dwg	R = Resistor[1] A = Active[2]

[1] R pair of balancing resistors, 0402 resistors, nominal value stated in table below

[2] A = CAP-XX active balancing circuit which draws < 1µA.

Rated Voltage: 5.5V
Temperature Range: -40°C to +70°C
Parameters measured at 25°C

CAP-XX Part no.[1]	**Cap (F)**	**DC ESR Max (mΩ)**	**IL max[2] @ 72 Hrs (µA) with resistor 220KΩ balancing resistors B=R**	**IL max[3] @ 72 Hrs (µA) with active balancing B=A**	**Thick x Width (mm)**	**Length (mm)**
GY25R50614V224RR	0.22	1130	14	NA	6 x 12	14
GY25R50713V474RR	0.47	380	15	NA	7 x 14	13
GY25R58E14V474RR	0.47	500	15	3	8.5 x 17	14
GY25R58E13V105RR	1	380	17	5	8.5 x 17	13
GY25R58E16V105RR	1	250	17	5	8.5 x 17	16
GY25R58E22V155RR	1.5	190	20	8	8.5 x 17	22
GY25R58E16V155RR	1.5	250	20	8	8.5 x 17	16
GY25R58E26V255RR	2.5	150	23	11	8.5 x 17	26
GY25R51122S255RR	2.5	90	23	11	11 x 22	22
GY25R51122V355RR	3.5	90	27	15	11 x 22	22
GY25R51126V505RR	5	80	33	21	11 x 22	26
GY25R51322V505RR	5	75	33	21	13 x 26	22
GY25R51327V755RR	7.5	75	43	31	13 x 26	27
GY25R51336V106RR	10	75	53	41	13 x 26	36
GY25R51722V106RR	10	75	53	41	17 x 34	22
GY25R51727V126RR	12.5	70	68	56	17 x 34	27
GY25R51732V156RR	15	45	73	61	17 x 34	32
GY25R51737V206RR	20	45	93	81	17 x 34	37
GY25R51942V256RR	25	40	113	101	19 x 38	42
GY25R51942V306RR	30	40	133	121	19 x 38	42
GY25R51952V356RR	35	45	153	141	19 x 38	52
GY25R51962V506RR	50	45	213	201	19 x 38	62

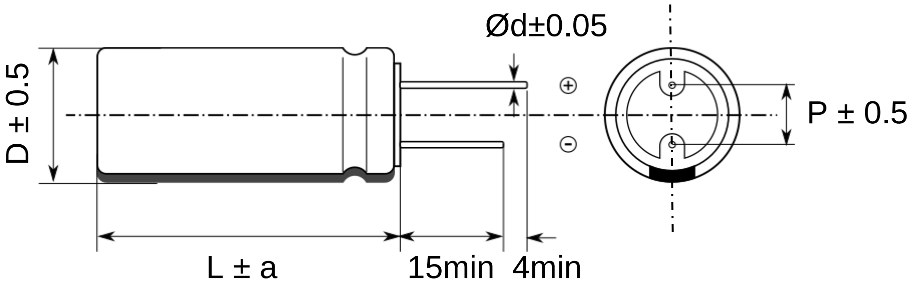
Notes:

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.
2. Includes balancing current through 220KΩ resistors at 2.75V/cell. If cell voltage is reduced, e.g. 1.8V/cell, then balancing current is reduced by (2.75V-1.8V)/220KΩ = 4µA, so for example, the leakage current with balancing resistors for the HY25R50713V474RR at 3.6V would reduce from 15µA to 11µA.
   If a different value of balancing resistor is desired, please contact CAP-XX.
3. Cell leakage current + 1µA for the active balance circuit.

Dimensions (all units in mm)

GY1 Series Shrink Wrap Radial Lead 0.5F – 180F

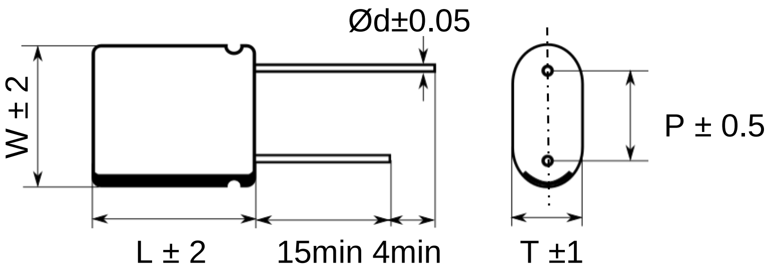
ΦD	P	Φd
5	2.0	0.5
6.3	2.5	0.5
8	3.5	0.6
10	5	0.6
12.5	5	0.6
16	7.5	0.8
18	7.5	0.8
22	10	1



ΦD ≤ 18	a = 2
ΦD = 22	a = 3.5

GY2 Series Shrink Wrap, 0.22F – 50F

Cell dia.	T	W	P	Φd
5	6	12	7.5	0.5
6.3	7	14	8.8	0.5
8	8.5	17	12	0.6
10	11	22	15.5	0.6
12.5	13	26	18	0.6
16	17	34	24	0.8
18	19	38	26	0.8



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:

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

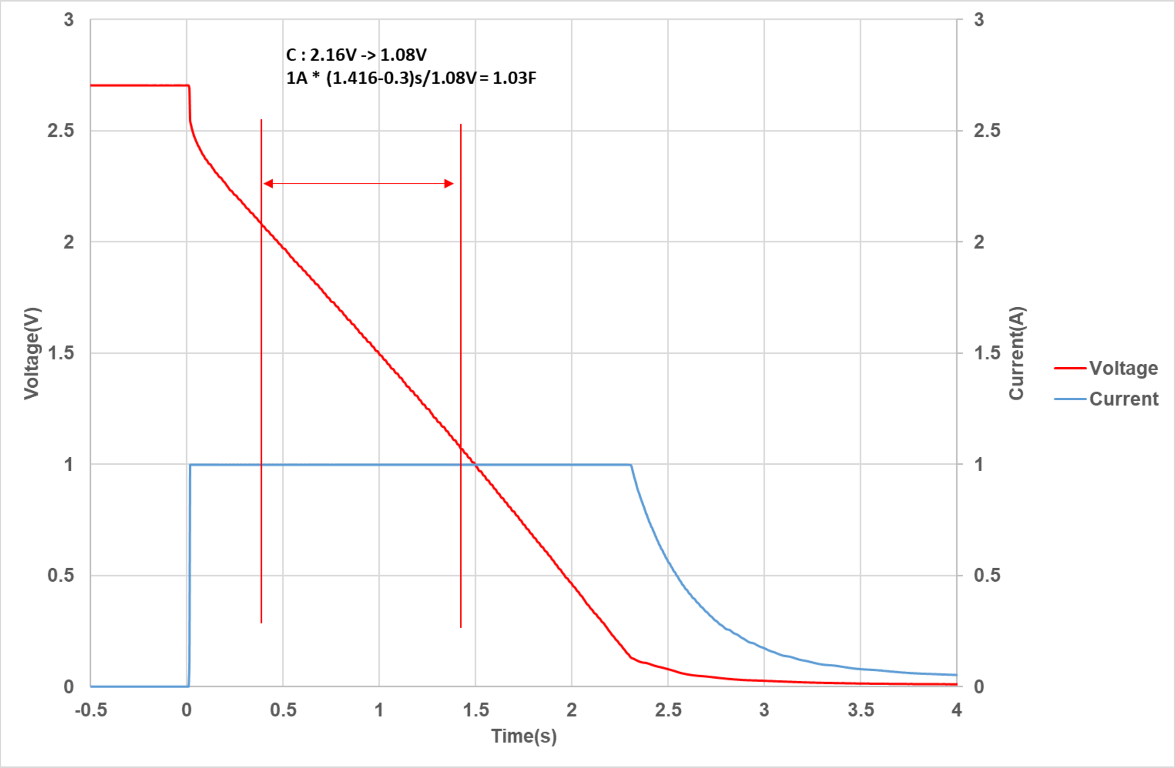


Fig 1: GY12R708012V105R Capacitance measurement

In this case, C = 1A x (1.416-0.3)s /(2.16 – 1.08)V = 1.03F, which is well within the 1F +30% / -10% tolerance for a GY12R708012V105R cell.

Measurement of 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 GY12R708012V105R the ESR is measured as 140mV/1A = 140mΩ which is well below the specified maximum of 250mΩ.

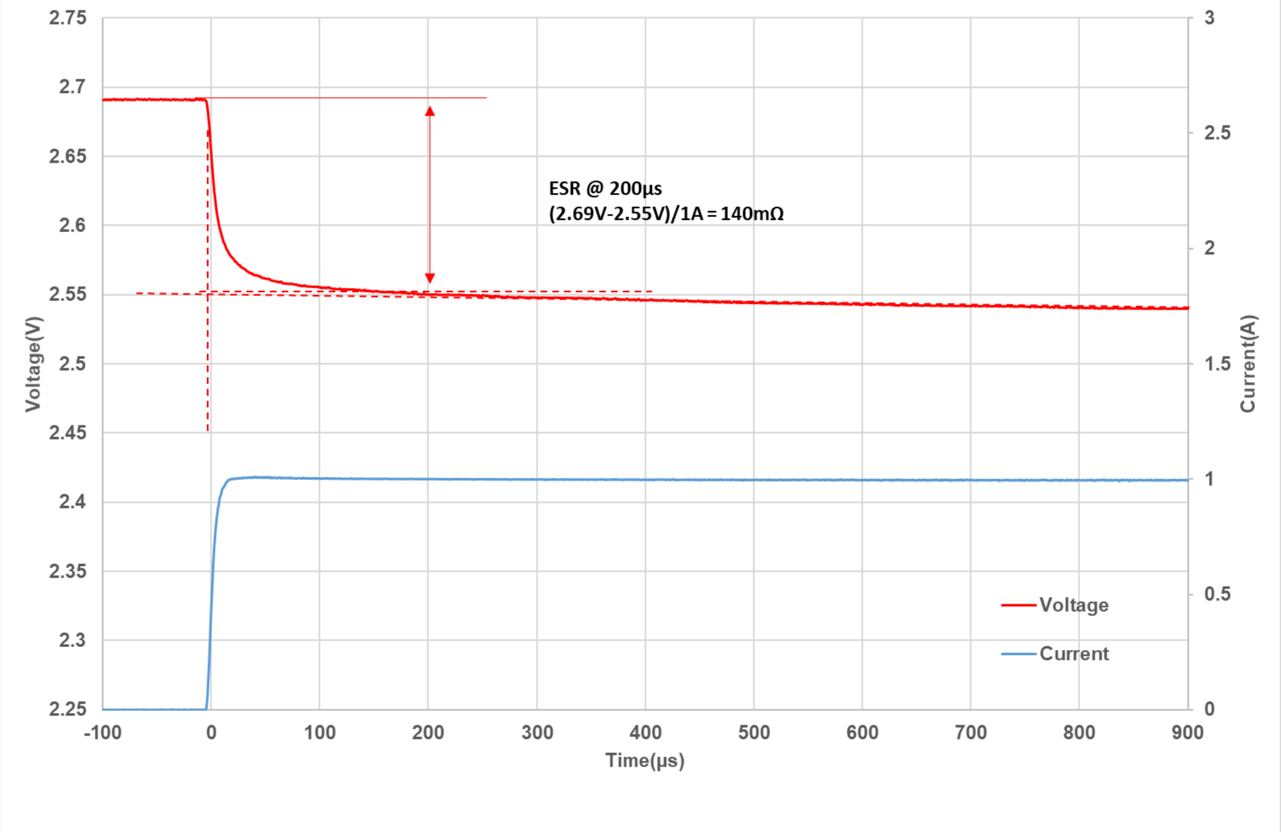


Fig 2: GY12R708012V105R ESR Measurement

Measurement of Leakage Current

Leakage current is measured by holding the supercapacitor at rated voltage at 25°C and charging it through a low value current limit resistor, in this case, 28Ω. After the current through the 28Ω resistor has decayed the supercapacitor is then held on charge with a higher value sense resistor, typically 1KΩ or 2.2KΩ, and the voltage is measured across this resistor to determine leakage current. The leakage current decays over time as shown in Fig 3 which shows the average leakage current for 4 samples each of 1F, 2F, 5F and 10F supercapacitors. The datasheet quotes the maximum values after 72hrs. Leakage current decays to its final equilibrium value after ~120hrs, typically ~1µA/F as shown in Fig 3.

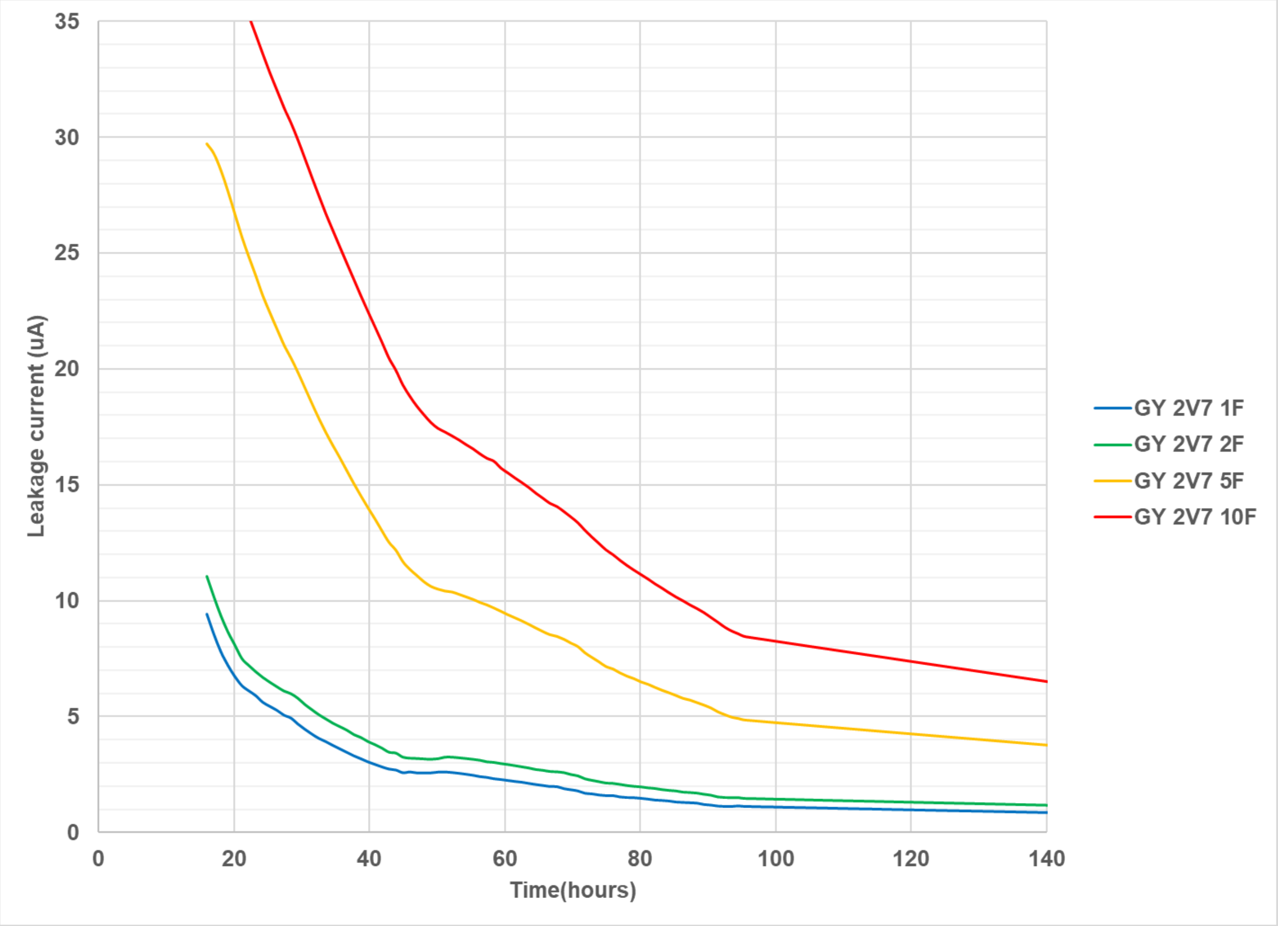


Fig 3: Leakage current measurement

Variation in DC Capacitance and ESR with temperature

Figure 4 shows that DC capacitance does not vary significantly over the operating temperature range of -40°C to +70°C.

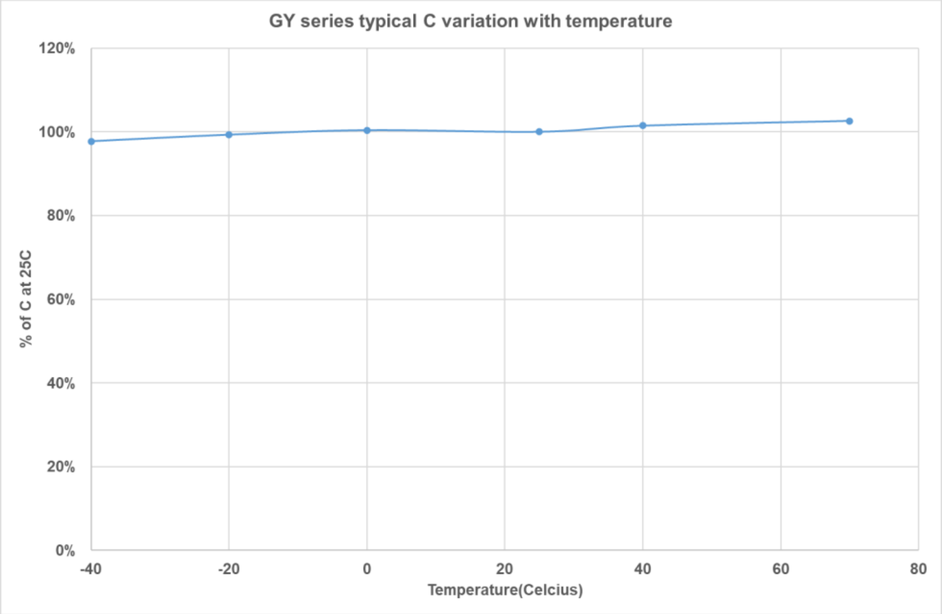


Fig 4: Typical variation in Capacitance over the operating temperature range

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

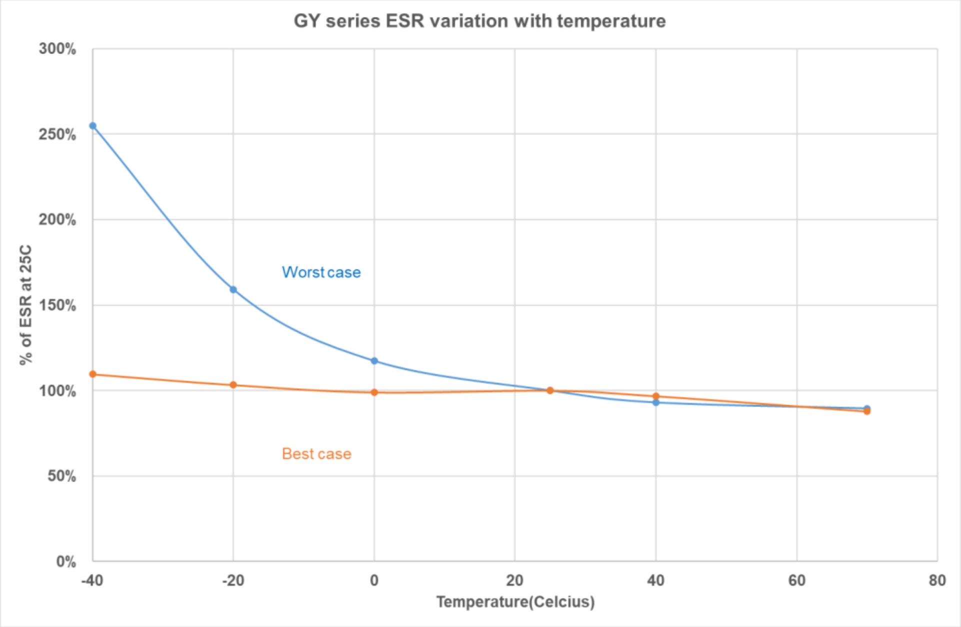


Fig 5: Typical variation in DC ESR over the operating temperature range

From Figure 5, ESR_{DC} at -40°C varies from ~2.6x to 1.1x ESR_{DC} at room temperature depending on the part. ESR_{DC} at 70°C is ~90% 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 and the characteristics of the activated carbon used in that part.

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:

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

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	78	40	3.7
5	51	30	2.6
2	35	14	1.6
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 τ is applied =

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

Where:

I = constant current
τ = duration of constant current
V_{INIT} = the initial voltage when the current pulse is first applied
V_{FINAL} = the supercap voltage at the end of the pulse

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

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

Note that if the duration of the constant current, τ, is short then you will need to use Ceff(τ) accurately determine the voltage drop, or the max current for a given voltage drop over time τ. Please see the section on Effective Capacitance in this datasheet.

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 as a function of RMS current for various GY12R7 series supercapacitors.

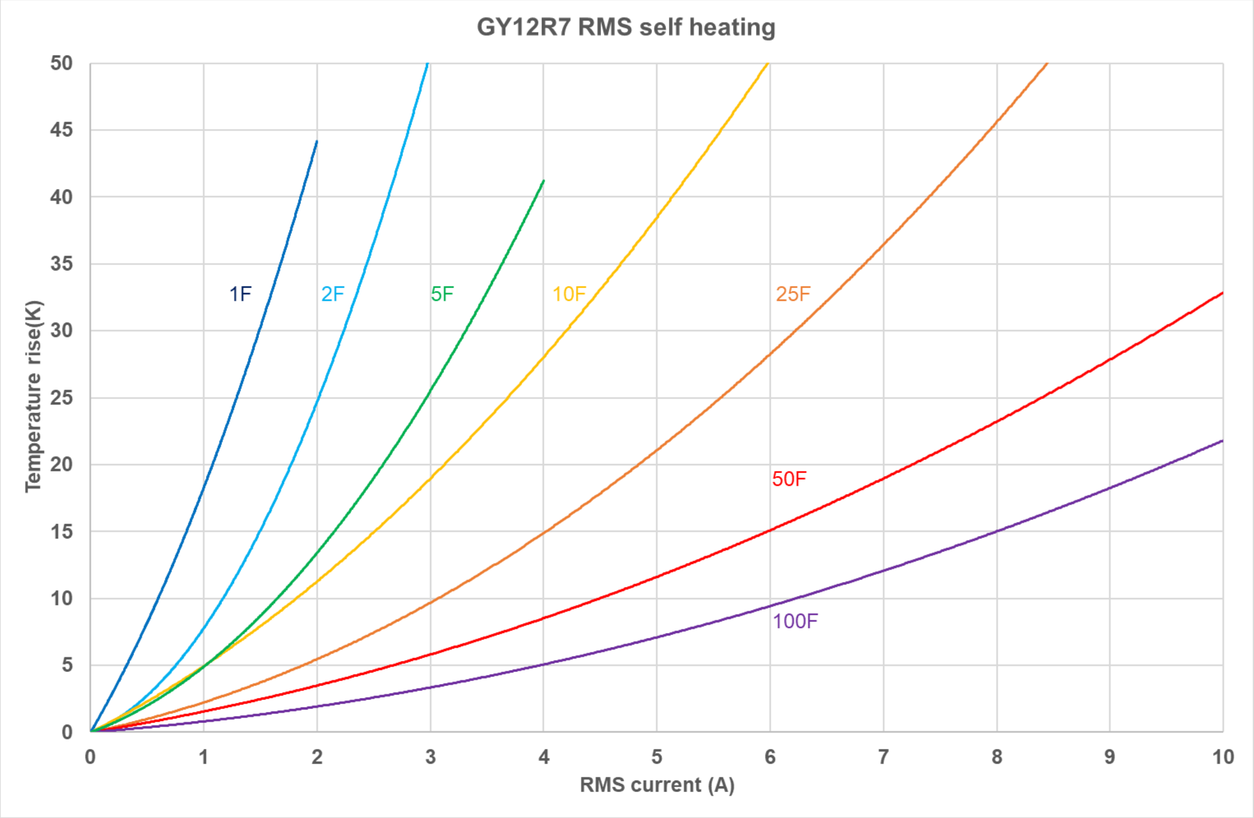


Fig 6: Self heating with RMS current for various supercapacitors

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 70°C, then the maximum RMS current for a 10F supercapacitor should be limited to 4.2A, which causes a 30°C temperature increase.

Effective capacitance (Ceff)

Effective capacitance is the capacitance seen for short pulse widths. Due to the 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 GY series of supercapacitors.

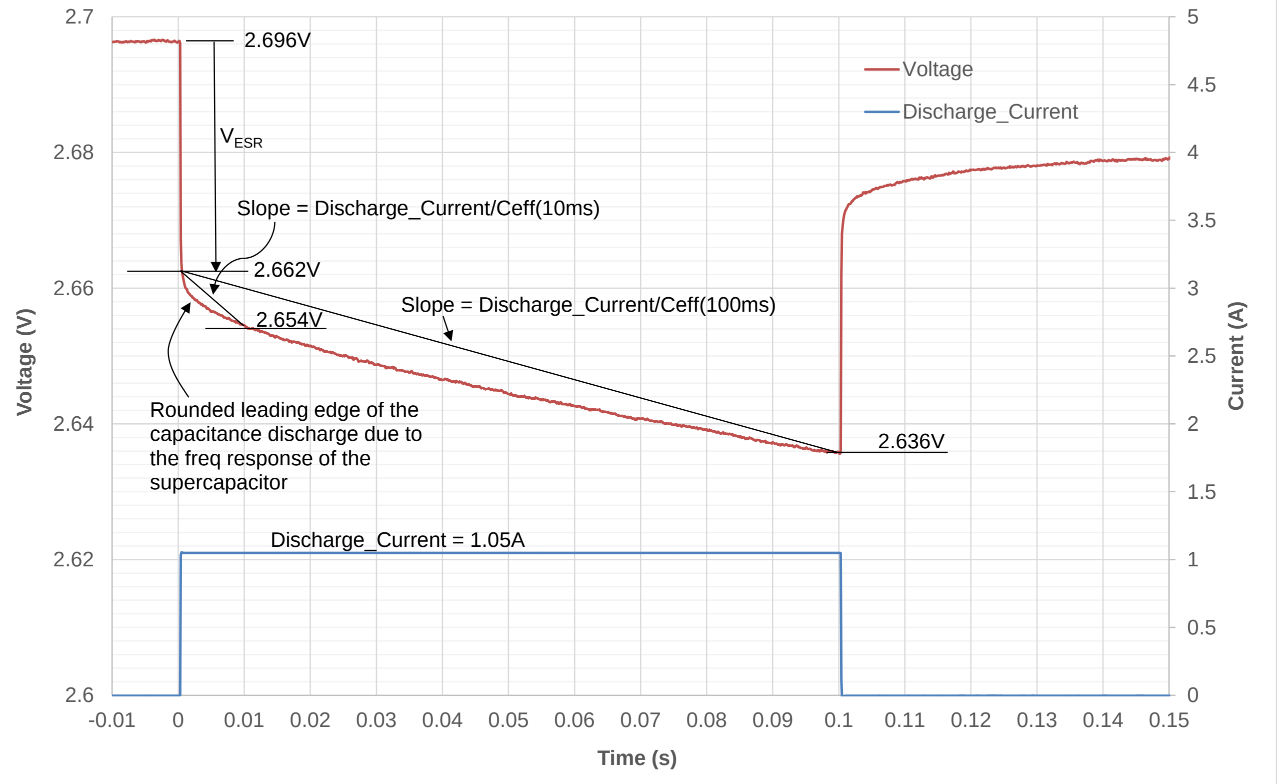


Fig 7: Discharge pulse illustrating the concept of Ceff

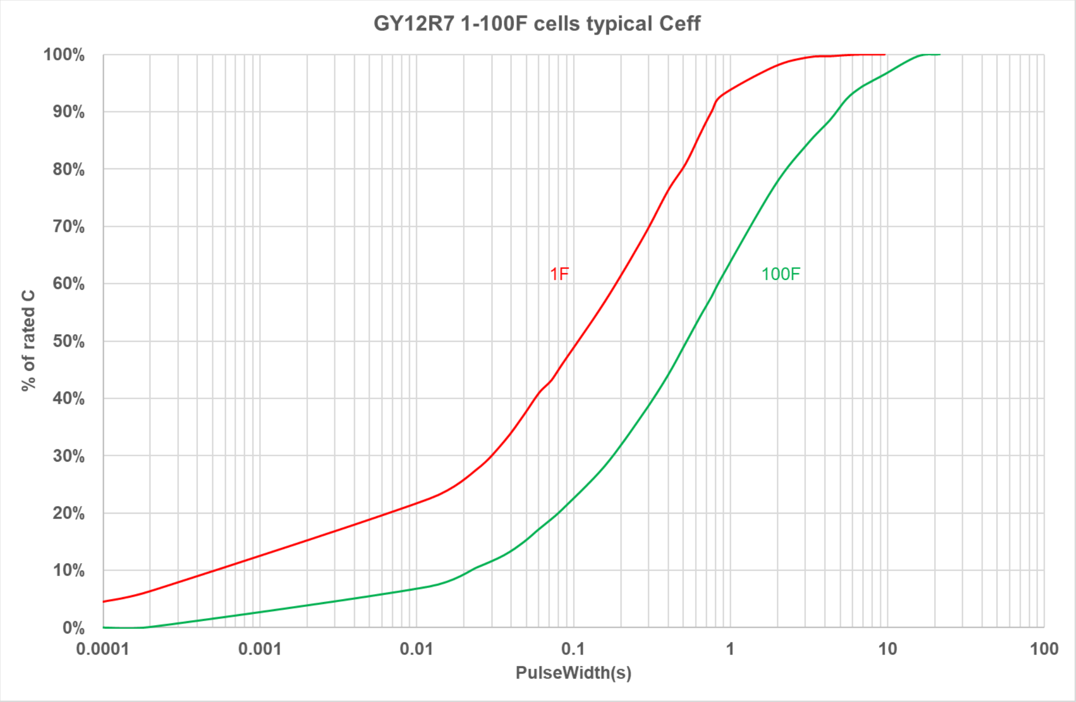


Fig 8: Typical effective capacitance range for GY 2.7V series supercapacitors

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 slow 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 GY2 series which is rated to 5.5V. These cells should have a balancing circuit to ensure that the cell voltages remain approximately equal or the cell with the lower C will have a higher voltage across it, causing it to age faster than its companion cell, hence losing even more C until it goes over voltage. This is a reason why a balancing circuit should aim to maintain the voltage across each cell equal, rather than just prevent over-voltage. As an example, if the dual cell module was at 5.0V and there was over-voltage protection circuits that prevented each cell from exceeding 2.7V, then module could have one cell at 2.7V and the other at 2.3V. The cell at 2.7V will age faster than the cell at 2.3V and will age faster than if both cells were held at 2.5V shortening module life.

In the GY2 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 GY2 series part number.
   A pair of 220KΩ balancing resistors are fitted, one resistor across each cell. The balancing resistors increase leakage current drawn by the module. The dual cell module table shows the leakage current including the current drawn by the balancing resistors when the module is at 5.5V. In this case the balancing resistors draw 2.75V/220KΩ =12.5µA.

2. Option “A” as the last character in the GY2 series part number.
   An op amp maintains the midpoint voltage = ½ the supercapacitor module terminal voltage. This solution maintains the midpoint voltage very accurately, responds more quickly as the supercapacitor charges and discharges and only adds ~1µA to leakage current.
   This option is only available as a special order. Minimum order quantity will apply.

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 GY1 cells and place them in series. This makes the midpoint available to your balancing circuit. The dimensions of 2 GY1 cells placed next to each other are the same as a shrink wrapped GY2 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 > 65°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 100F, so stored energy = ½ x 100 x 2.7^2 /3600 = 0.101Wh. Under regulation UN3499 there is no restriction on shipping these supercapacitors. Their shipping description is “Electrical Capacitors” with harmonized shipping code 8532.29.0040.