DATASHEET

GY13R0 SERIES RADIAL LEADS SUPERCAPACITOR

Revision 3.2, July 2022

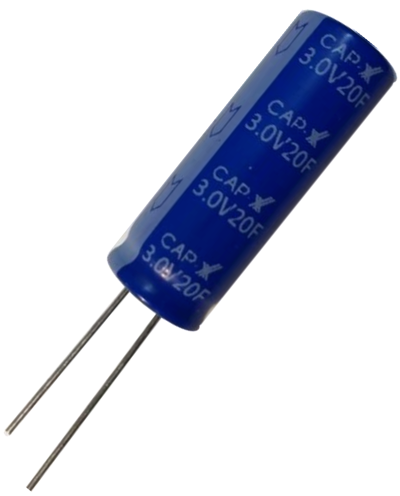
The GY13R0 series of supercapacitors are 3V cylindrical cells offering excellent value with high C and low ESR. They can be placed across a 3V primary battery to provide peak power support without any need for any voltage regulation or cell balancing which lower voltage cells require.

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 3V primary cells and last gasp transmission or activation of a unit into a safe state at end of battery life. These supercapacitors may be placed directly across a 3V battery with no voltage regulation required.
- 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 battery hot swap
- Peak power support for 3V primary cells



1. Electrical Specifications

Part numbering code

G	Y	N	vvv	dd	mmm	S	ccc	R
Model	**Cylindrical**	**# of cells**	**Voltage**	**Diameter (mm)**	**Length (mm)**	**Tolerance**	**Capacitance (µF)**	**Lead format**
		1	3R0 = 3.0V	6C = 6.3 08 = 8.0 10 = 10 1B = 12.5 16 = 16 18 = 18 22 = 22	012 = 12 068 = 68 120 = 120	M ± 20% S +50% /-20% V +30% /-10%	Two digits + number of zeros. 155 = 1500000µF = 1.5F	R = radial

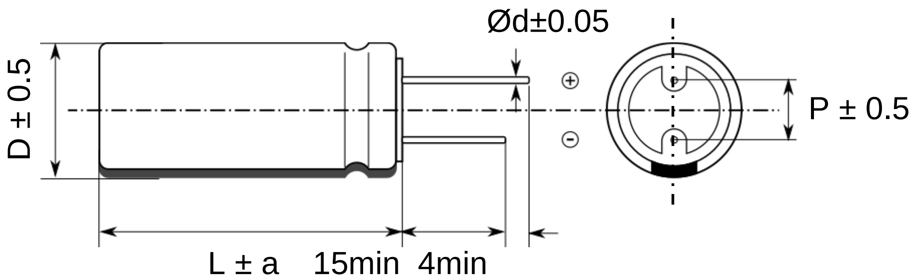
Rated Voltage: 3.0V
Temperature Range: -40°C to +65°C (+85°C @ 2.5V)
Parameters measured at 25°C
Radial leads

CAP-XX Part no.	Cap (F)	DC ESR Max (mΩ)	IL max @ 72 Hrs (µA)	Diameter (mm)	Length (mm)	Mass (gm)
GY13R06C011V105R	1	195	3	6.3	11	0.7
GY13R008011S105R	1	195	3	8	11	0.9
GY13R008014V205R	2	130	6	8	14	1.2
GY13R008018V335R	3.3	85	10	8	18	1.4
GY13R008024V505R	5	80	15	8	24	1.7
GY13R010020S505R	5	45	15	10	20	2.3
GY13R010020V705R	7	45	21	10	20	2.3
GY13R010024V106R	10	40	30	10	24	3
GY13R01B020V106R	10	40	30	12.5	20	3.4
GY13R01B025V156R	15	45	45	12.5	25	4.3
GY13R01B030V206R	20	35	60	12.5	30	5.2
GY13R016025V256R	25	35	75	16	25	7.4
GY13R018040V506R	50	35	150	18	40	13.8
GY13R018040V606R	60	25	180	18	40	13.3
GY13R016050V706R	70	25	210	16	50	16.9
GY13R022045V107R	100	25	300	22	45	22.5
GY13R022055V187R	180	20	540	22	55	27

2. Dimensions (mm)

GY1 Series Shrink Wrap Radial Lead 1F – 180F

ΦD	P	Φd
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

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:

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

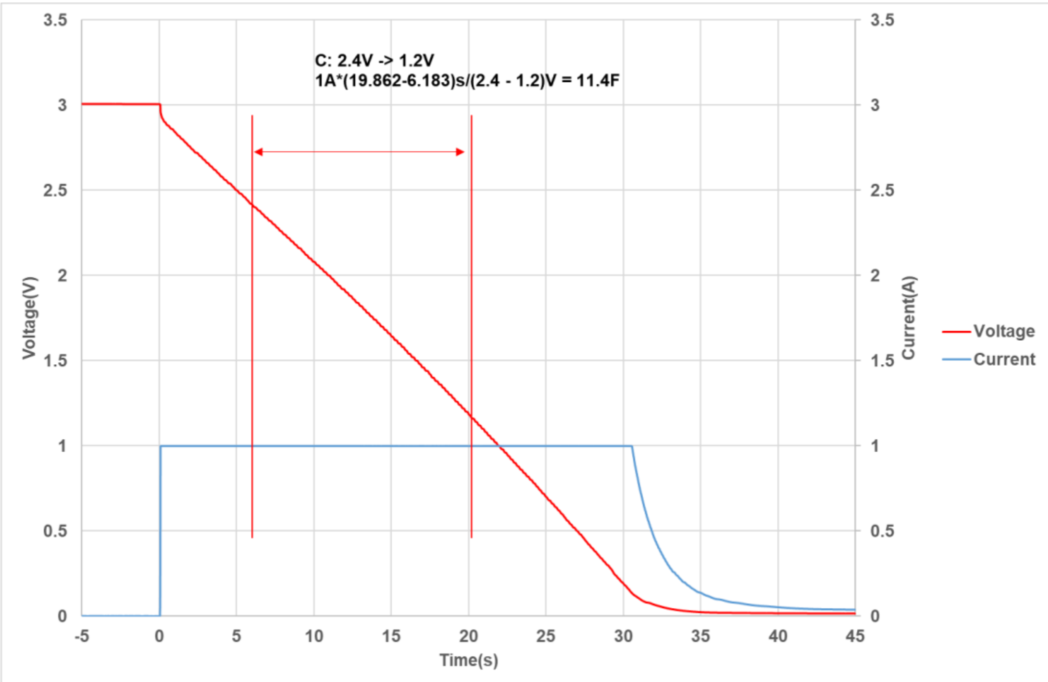


Fig 1: Capacitance measurement

In this case, C = 1A*(19.862-6.183)s/(2.4 - 1.2)V = 11.4F, which is well within the 10F +30% / -10% tolerance for a GY13R010024V106R 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 GY13R010024V106R the ESR is measured as 29mV/1.05A = 27.6mΩ, well below the specified maximum of 40mΩ.

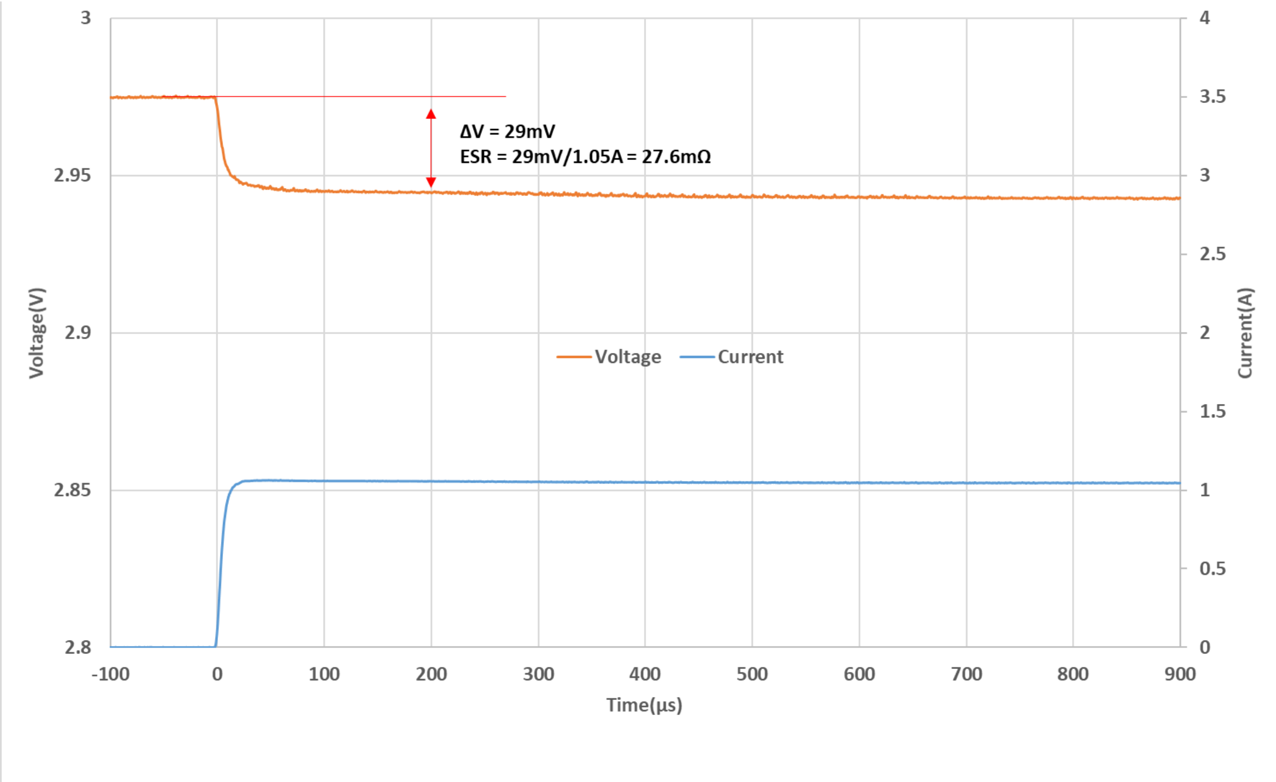


Fig 2: ESR Measurement

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 leakage current for multiple samples of 1F, 2F, 5F and 10F supercapacitors. Leakage current settles to its minimum value after ~120hrs and is typically 2µA/F however the datasheet quotes the maximum values after 72hrs at rated voltage.

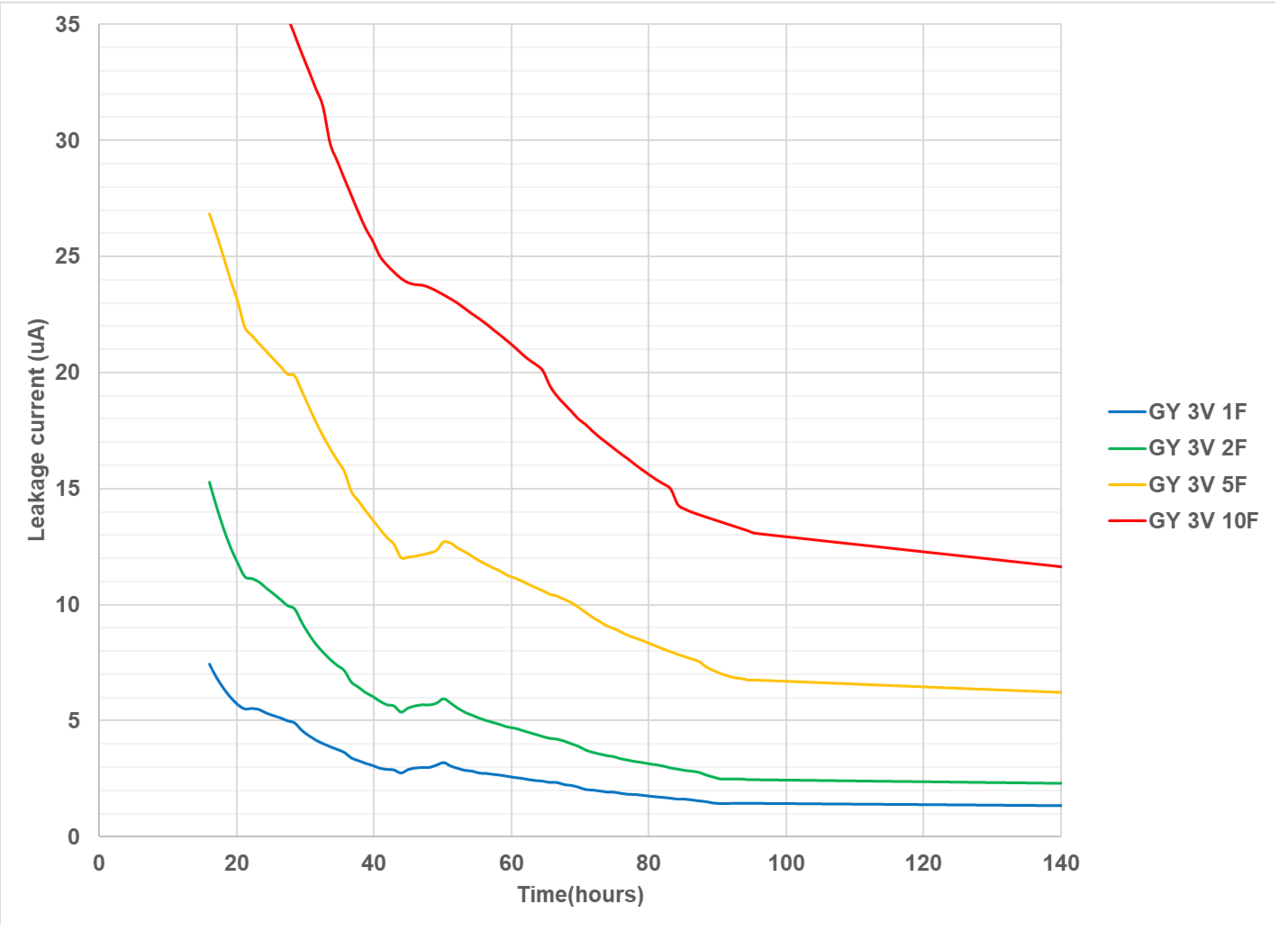


Fig 3: Leakage current measurement

Variation in DC Capacitance and ESR with temperature

Figure 4 shows that DC capacitance does not vary significantly over the operating temperature range of -40°C to +65°C.

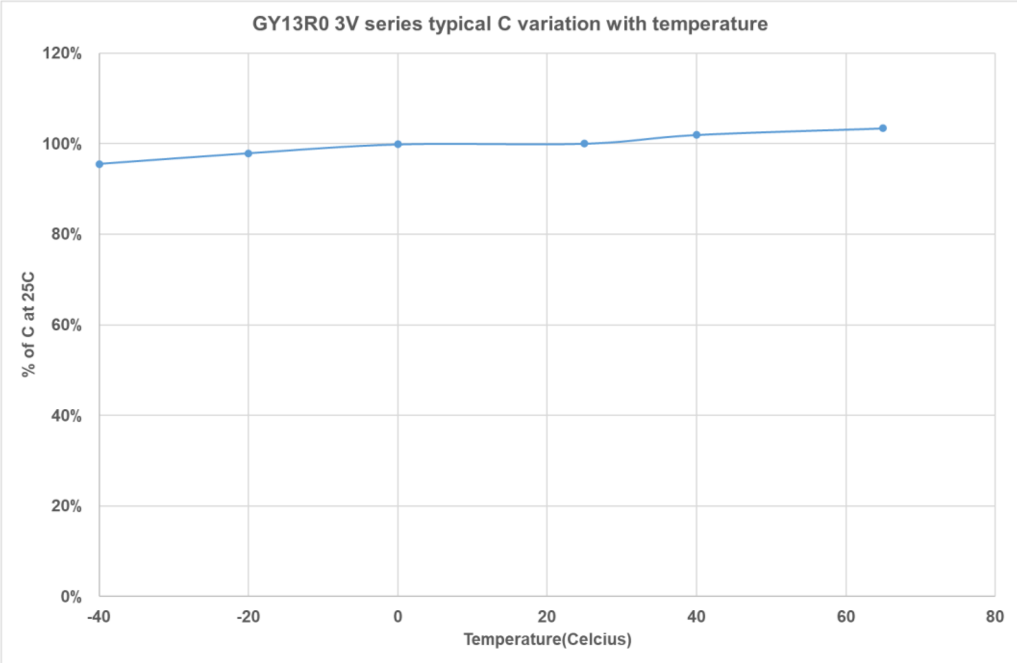


Fig 4: Variation in DC Capacitance over the operating temperature range

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

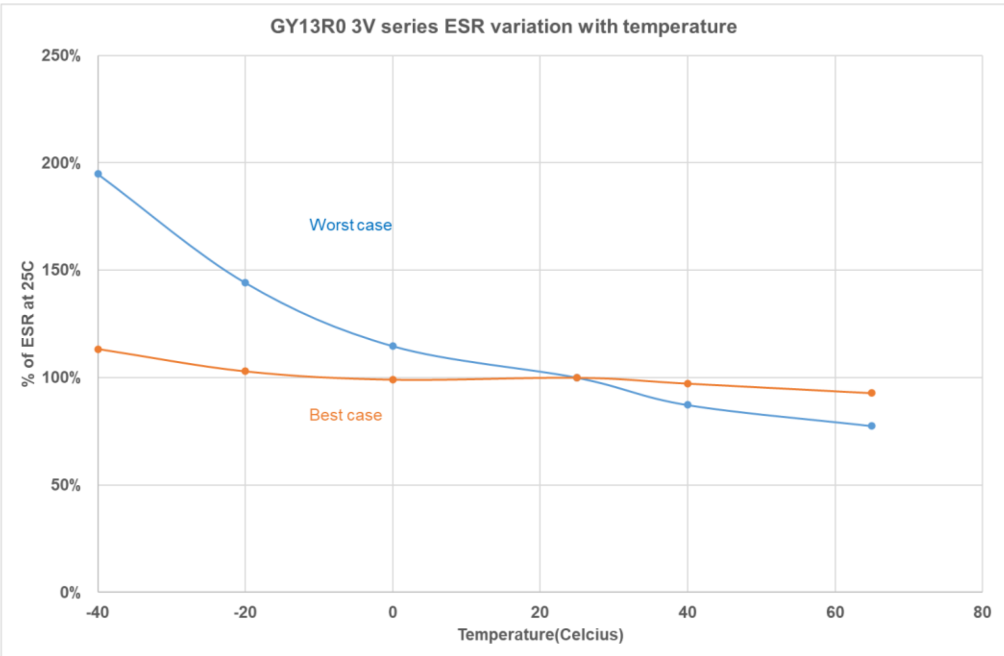


Fig 5: Variation in DC ESR over the operating temperature range

From Figure 5, ESR_{DC} at -40°C is between ~1.1x to 1.8x the ESR_{DC} at room temperature. ESR_{DC} at 65°C is 70% to 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.

Peak Current

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

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

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 3V 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	56	3.2
5	78	41	2.9
2	33	15	2
1	30	10	1.1

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 =

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

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 =

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

Maximum Continuous Current

Continuous current flow into/out of the supercapacitor will cause self-heating, which limits the maximum continuous current the supercapacitor can withstand. This is measured by a current square wave with 50% duty cycle, charging the supercapacitor to rated voltage, V_R, at a constant current, and then discharging the supercapacitor to a half rated voltage $V_R/2$ 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 GY13R0 series supercapacitors.

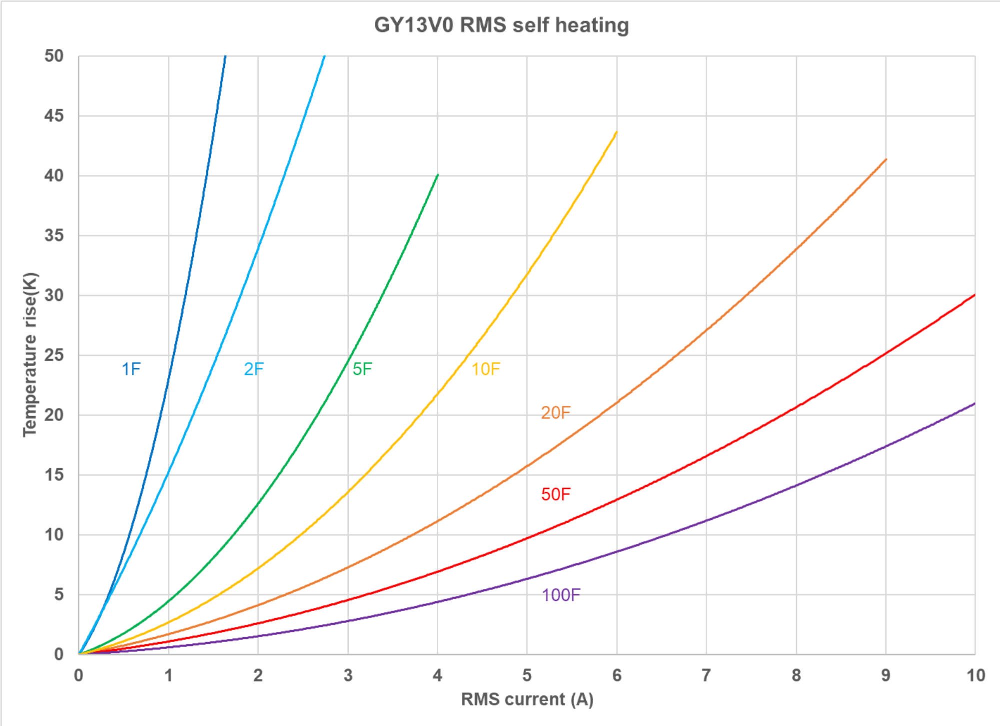


Fig 6: Self heating with RMS current for various supercapacitors

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 65°C, then the maximum RMS current for a 10F supercapacitor should be limited to 4.4A, which causes a 25°C temperature increase.

Effective capacitance (Ceff)

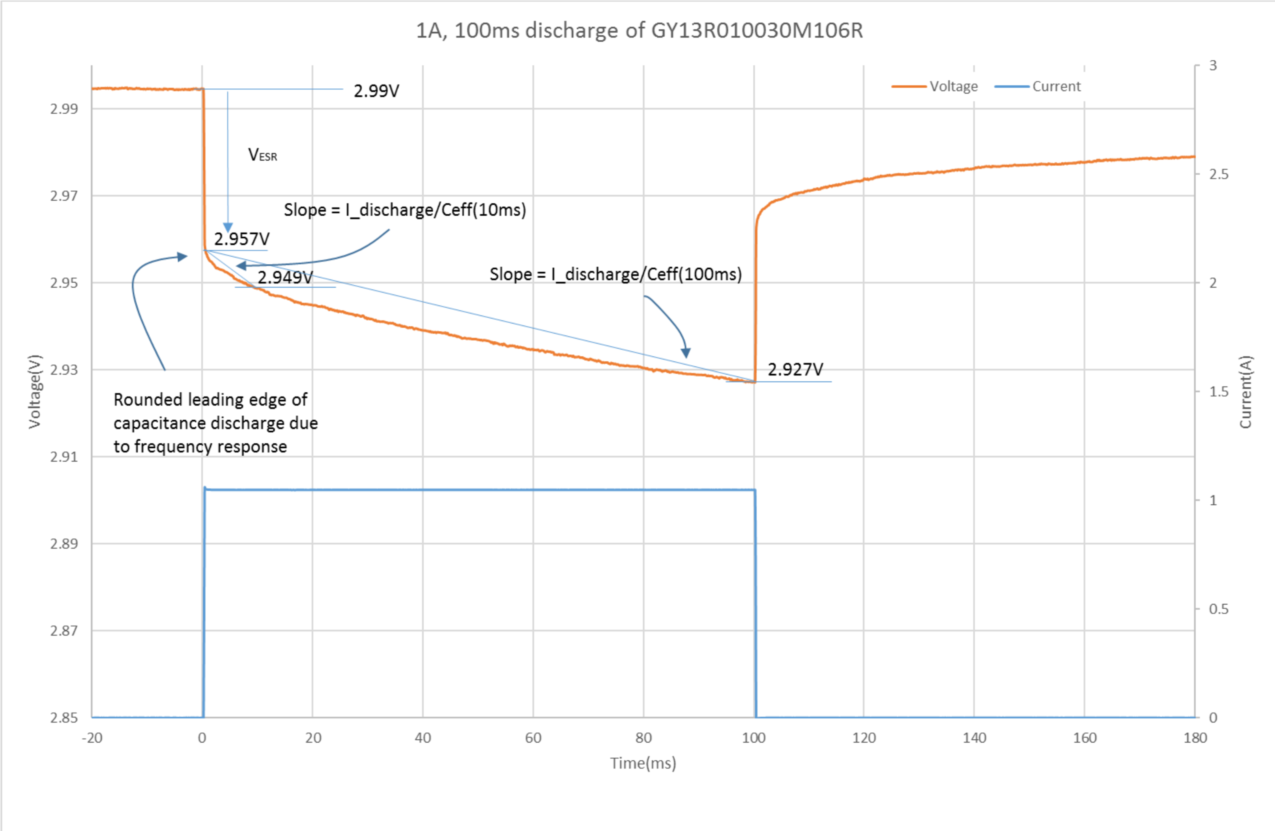


Fig 7: Discharge pulse illustrating the concept of Ceff

In Fig 7, consider the voltage drop due to capacitance for the 10F GY13R010030M106R after 10ms = 2.957– 2.949V = 8mV. Therefore Ceff(10ms) = Discharge_Current x 10ms/Voltage drop(10ms) = 1.05A x 0.01s/0.008V = 1.3F or 13% of DC Capacitance. The voltage drop due to capacitance after 100ms = 2.957V – 2.927V = 30mV. Ceff(100ms) = 1.05A x 0.1s/0.03V = 3.5F or 35% of DC capacitance. Fig 10 shows Ceff as a % of DC capacitance for the GY13R0 series of supercapacitors.

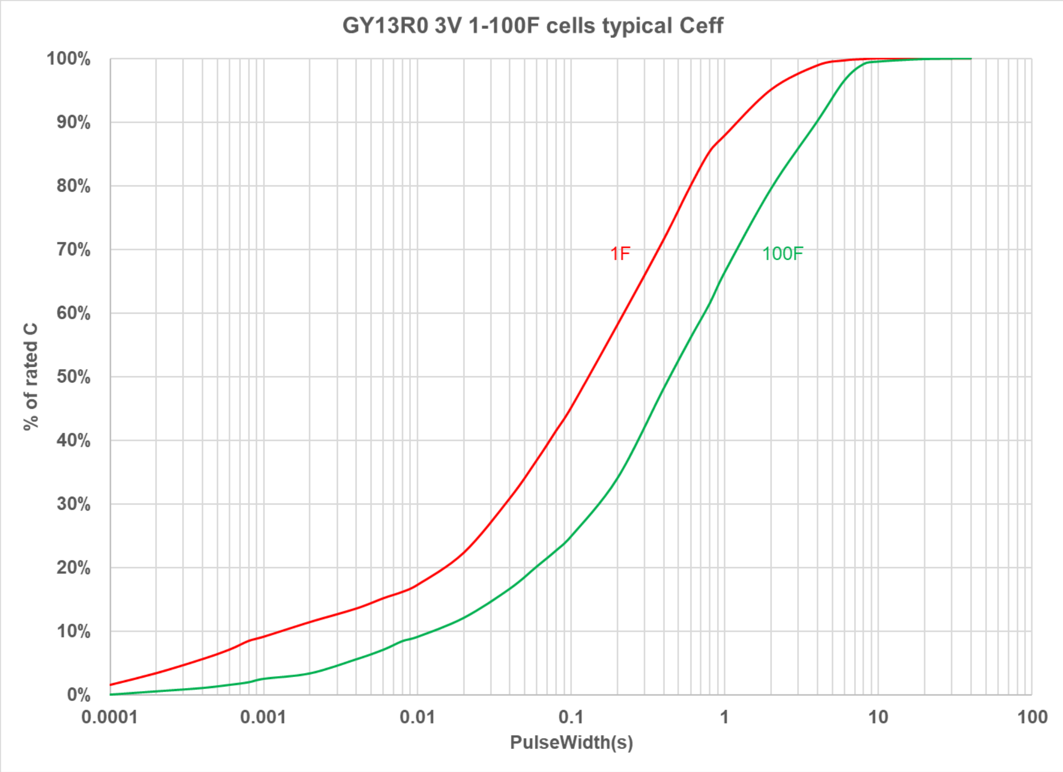


Fig 8: Typical range of effective capacitance for GY13R0 series supercapacitors

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 cells in series

In many applications where voltage > 3V is required, 2 or more supercapacitor cells need to be connected in series. 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 3 cells in series were at 8V and there was over-voltage protection circuits that prevented each cell from exceeding 3V, then module could have 2 cells at 2.5V and the other at 3V. The cell at 3V will age faster than the cells at 2.5V shortening life compared to life if all cells were held at 2.67V.

Refer to the Application Whitepaper on Supercapacitor Cell Balancing under the DESIGN AIDS section of the CAP-XX website, www.cap-xx.com .

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 180F, so stored energy = ½ x 180 x 3^2 /3600 = 0.225Wh. Under regulation UN3499 there is no restriction on shipping these supercapacitors. Their shipping description is “Electrical Capacitors” with harmonized shipping code 8532.29.0040.