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GY13R0 SERIES SUPERCAPACITORS
with radial leads
Datasheet Rev1.1, November 2018

1. Electrical Specifications

The GY13R0 series of supercapacitors are cylindrical cells offering excellent value with high C and low ESR.

Part numbering code

G	Y	N	vvv	dd	mmm	S	ccc	R
Model	**Cylindrical**	**no of cells** 1	**Voltage** 3R0 = 3.0V	**Diameter** 6C = 6.3mm 08 = 8.0mm 10 = 10mm 1B = 12.5mm 16 = 16mm 18 = 18mm	**Length (mm)** 012 = 12mm 016=16mm 068 = 68mm 120 = 120mm	**Tolerance** M ± 20% S +30% /-10% V +25% / -5%	**µF** Two digits + number of zeros. Eg 155 = 1500000µF = 1.5F	**Lead format** R = radial S = 2 solder pins W = 4 Cu tabs

Rated Voltage: 3.0V
Temperature Range: -40°C to +65°C
Parameters measured at 25ºC
Radial leads

CAP-XX Part no.	Cap(F)	ESR Max @ 1KHz (mΩ)	ESR Max @ DC (mΩ)	Diameter (mm)	Length (mm)	DCL max @ 72 Hrs (µA)	Mass (gm)	Power Density (W/kg)	Energy Density (Wh/kg)
GY13R008012S105R	1	180	863	8	12	6	0.8	1492	1.49
GY13R008016S205R	2	100	360	8	16	10	1.1	2808	2.34
GY13R008020S335R	3.3	95	280	8	20	12	1.2	3118	3.33
GY13R008025S505R	5	85	220	8	25	15	1.7	2888	3.68
GY13R010020S505R	5	70	170	10	20	15	2.1	3013	2.96
GY13R010030M106R	10	50	75	10	30	30	3.1	4691	4.07
GY13R01B020M106R	10	50	75	12.5	20	30	3.4	4265	3.7
GY13R01B030M156R	15	40	60	12.5	30	50	4.3	4147	4.32
GY13R01B035M156R	15	34	58	12.5	35	60	6.0	3103	3.13
GY13R016025M256R	25	27	50	16	25	60	7.2	2987	4.32
GY13R016030M306R	30	20	40	16	30	70	8.2	3288	4.57
GY13R018040M506R	50	18	20	18	40	75	12.7	4266	4.94

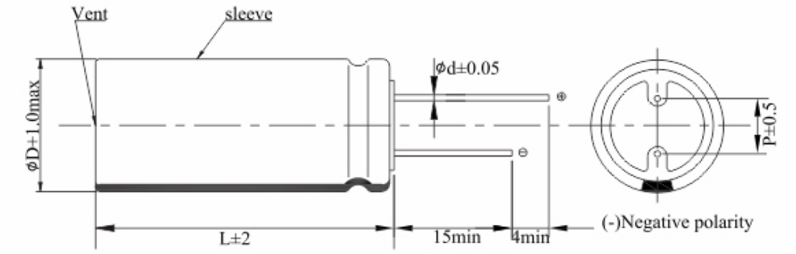
Applications:

- Energy Harvesting for wireless sensors
- Peak power support for GSM/GPRS transmission
- Last gasp power for remote meter status transmission
- 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

2. Dimensions (mm)

GY13R0 Series Shrink Wrap Radial

ΦD	P	Φd
8	3.5	0.6
10	5.3	0.6
12.5	5.3	0.6
16,18	7.7	0.8



3. 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 30 minutes and then discharged at constant current. The time taken to discharge from 0.8 x VR to 0.4 x VR is measured to calculate capacitance as:

$I = 4 \times V_R \times C$ (mA)
$V_1 = 0.8 \times V_R$
$V_2 = 0.4 \times V_R$
$C = I \times (T_1 - T_2)/(V_1 - V_2)$

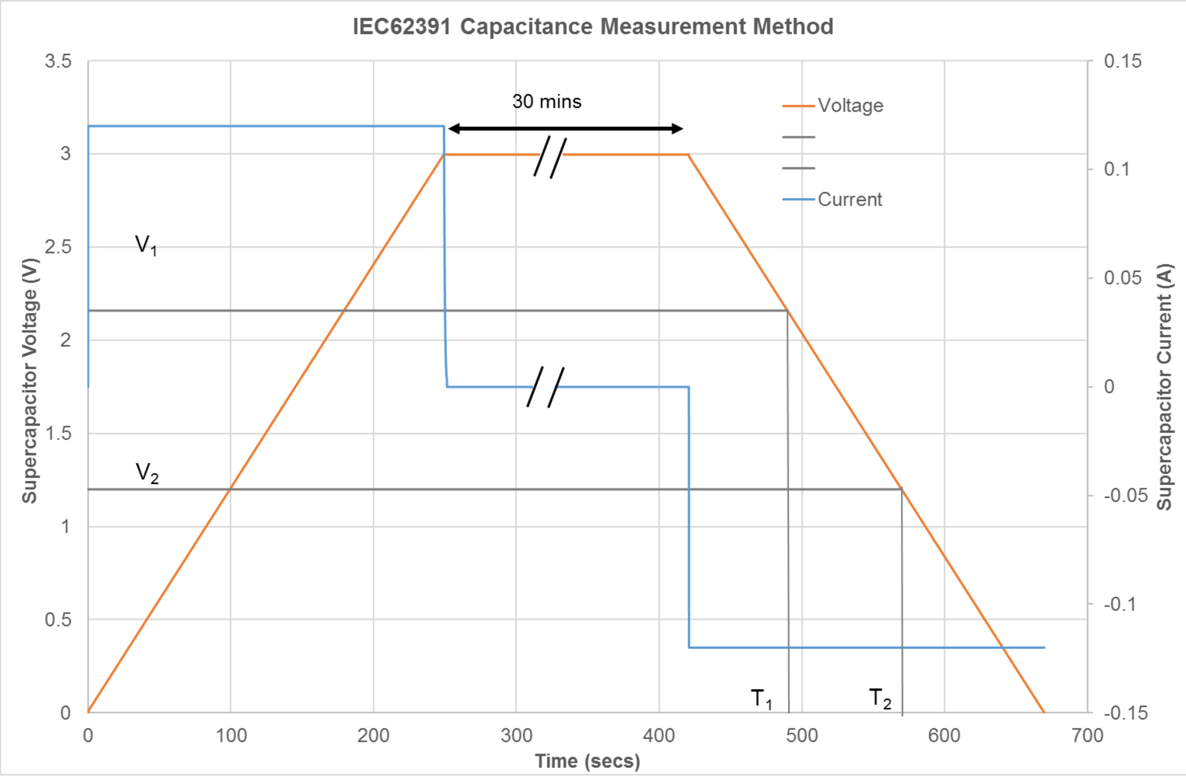


Fig 1: Capacitance measurement

4. Measurement of ESR

Equivalent Series Resistance (ESR) is measured at 25°C using the 6 step method shown in Fig 2. The measurement is carried out over 2 cycles measuring the difference in voltage from when discharge current is applied to when no current is applied. Referring to Fig 2:

$I_1 = I_2 = 75mA/F$

$ESR_{DC} = (ESR_{DC1} = ESR_{DC2})/2$

$ESR_{DC1} = (V_5 – V_4)/I_2$

$ESR_{DC2} = (V_{11} – V_{10})/I_2$

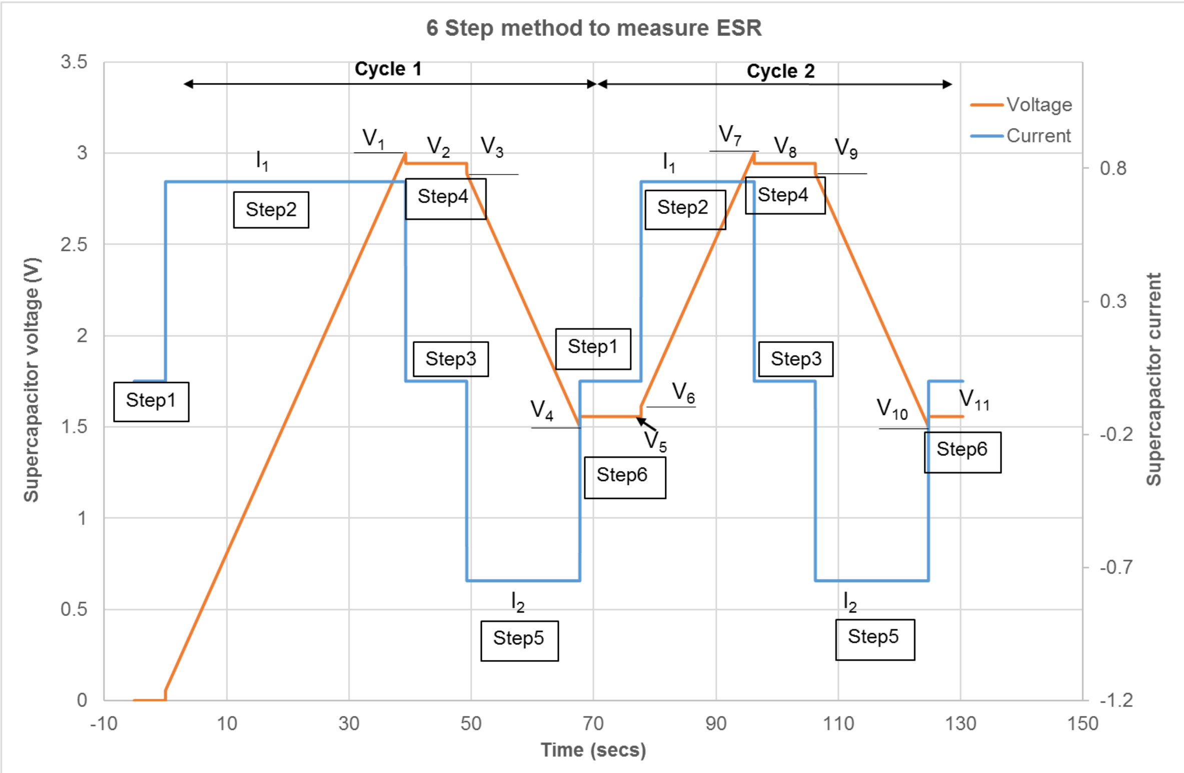


Fig 2: ESR Measurement

5. 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, 5F, 10F and 20F supercapacitors. Leakage current is typically 2µA/F but the datasheet quotes the maximum values after 72hrs at rated voltage.

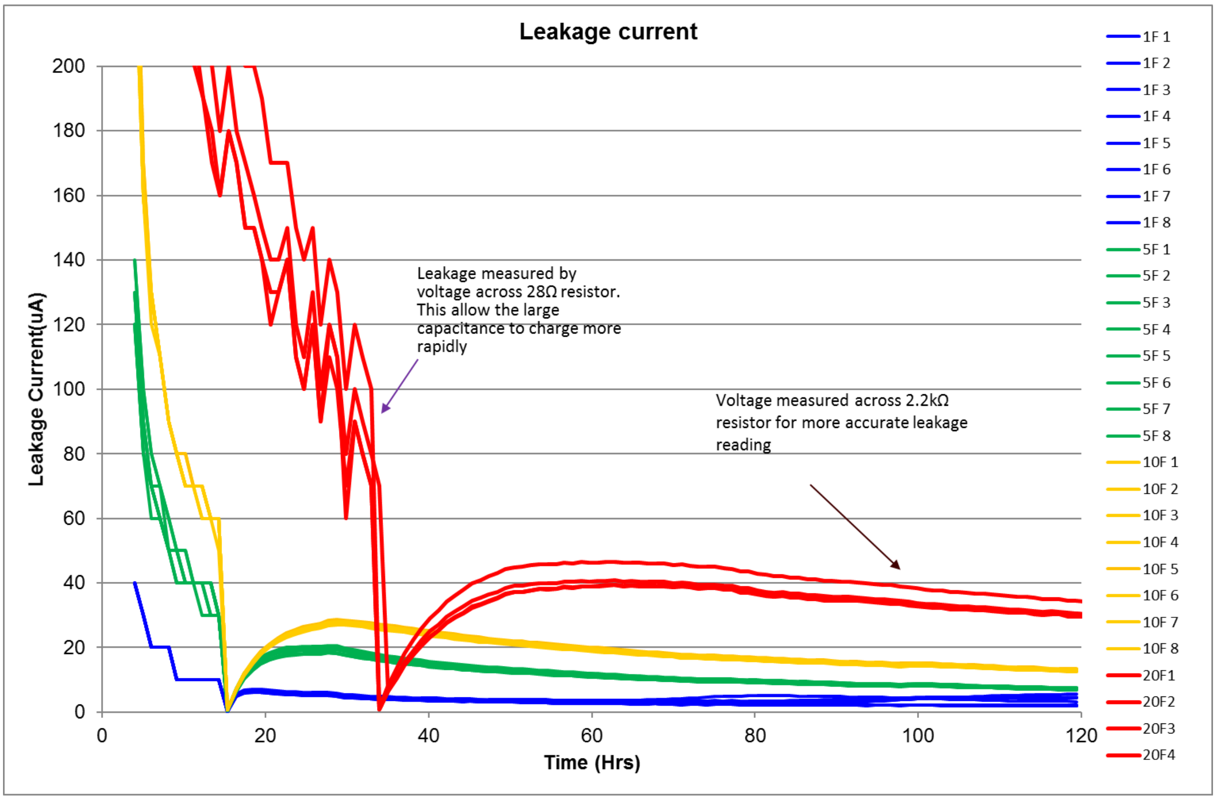


Fig 3: Leakage current measurement

6. 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 +60°C.

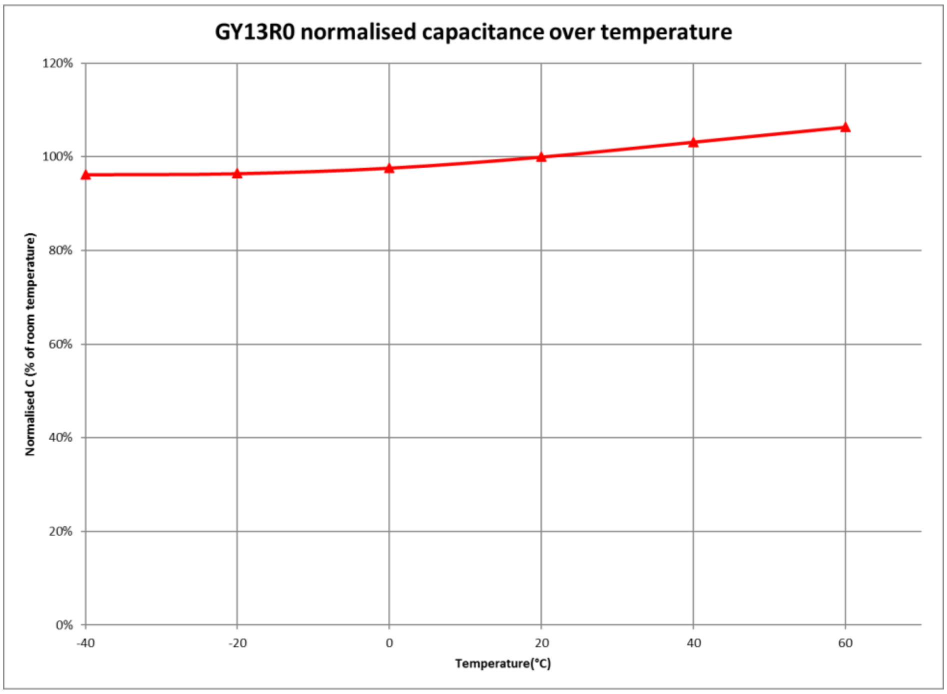


Fig 4: Variation in DC Capacitance over the operating temperature range

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

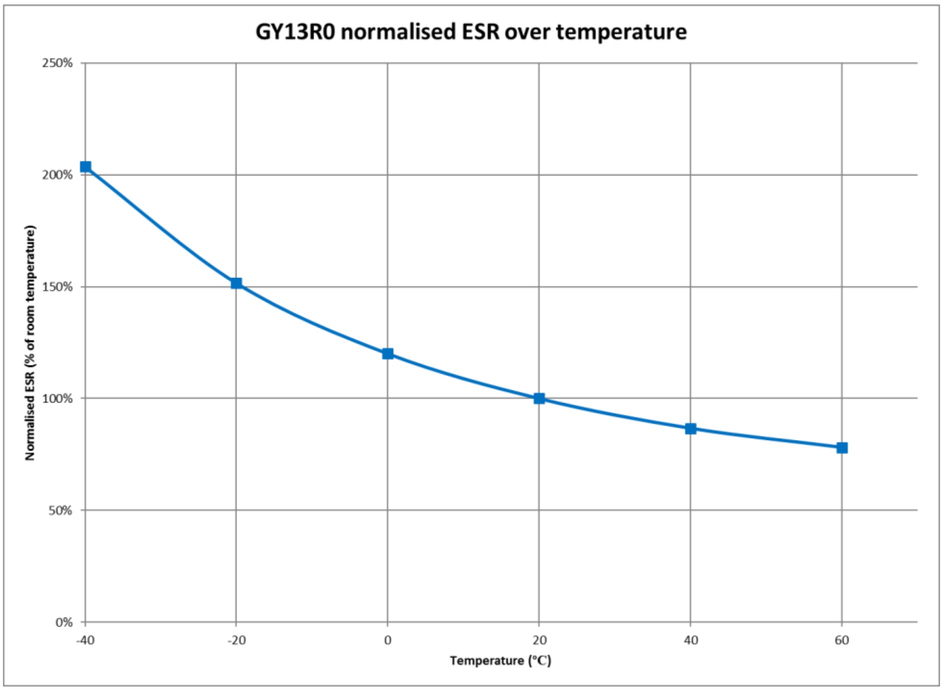


Fig 5: Variation in DC ESR over the operating temperature range

From Figure 5, ESR_{DC} at -40°C is double the ESR_{DC} at room temperature. ESR_{DC} at 60°C is ~75% 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.

7. 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)
20	56	45	1.5
10	40	30	2
5	33	22	1.5
1	16	8	2.5

Parts in the GY13R0 series with C > 20F will have peak current > 56A. 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 =

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

For constant power where I increases as V decreases to keep V x I = constant, there is no closed form solution. Use the Fixed Power worksheet in the file BackupPower_VoltageDecay simulator on the CAP-XX website to determine the min voltage after applying a constant power for a given time.

8. 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 a lower 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 supercapacitors.

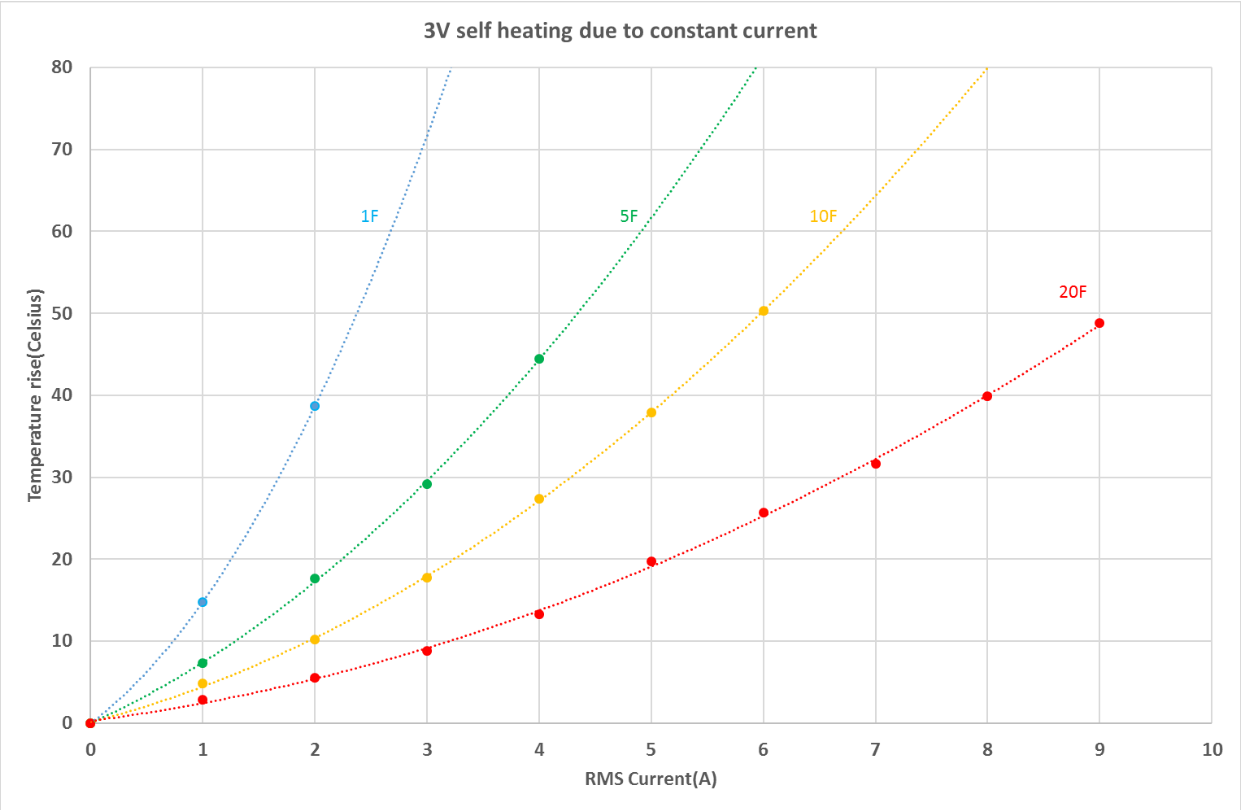


Fig 6: Self heating with RMS current for various supercapacitors

Supercapacitors with C > 20F will have a lesser temperature increase than the curve for the 20F supercapacitor in Fig 6. For other value of capacitance, please interpolate between the curves shown. 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 3.7A, which causes a 25°C temperature increase.

9. Frequency Response and effective capacitance (Ceff)

Figure 7 show the frequency response for the 10F, GY13R010030S106R supercapacitor which is typical of the GY series.

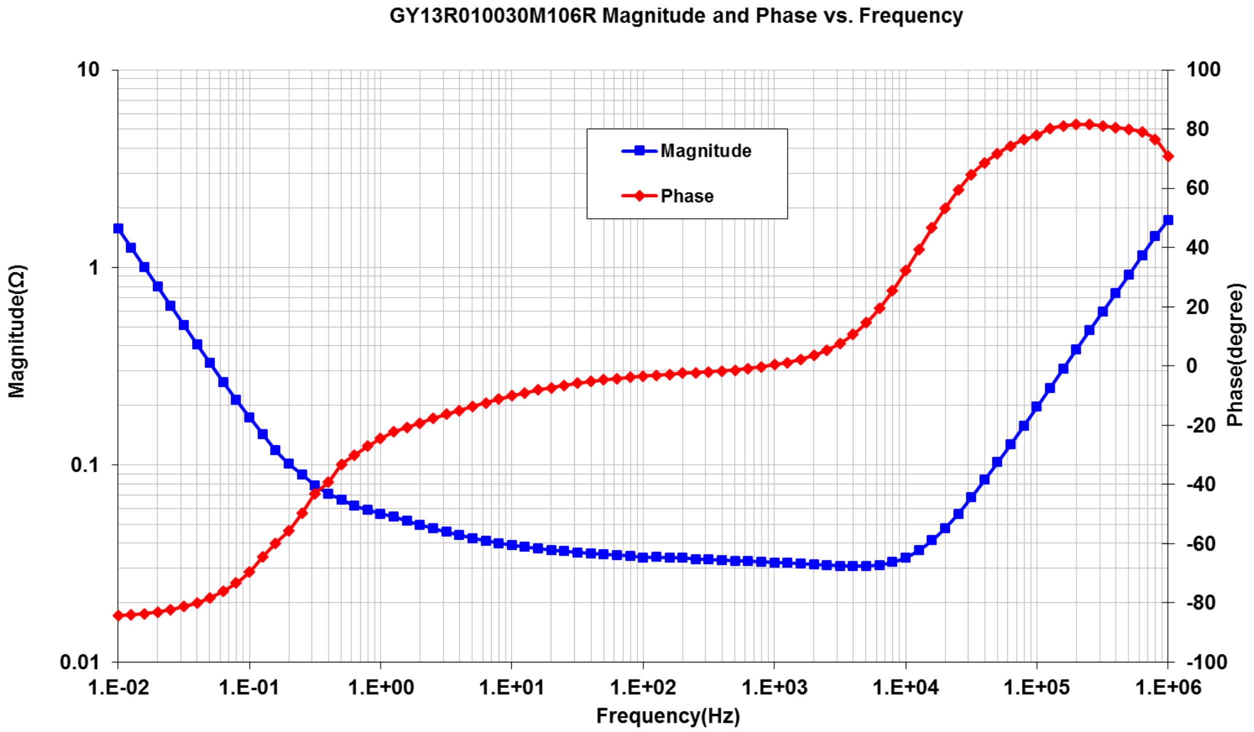


Fig 7: Magnitude and Phase Frequency Response for 10F cell, GY12R710030S106R

The magnitude curve shows capacitance starts to roll off at ~0.3Hz, while the phase curve crosses -45° at ~0.3Hz. This may lead to a false conclusion that the GY supercapacitor range cannot support short pulses. However, Fig 8 shows this 10F cell supporting a class 10 GPRS pulse train with 1.15ms pulses and a 4.6ms period. The supercapacitor has much lower ESR_{DC} than the charging source, so during the 1A pulse, the charging source is supplying 0.4A and the supercapacitor is supplying 0.6A. In between pulses the charging source is supplying 260mA. The I_discharge waveform has 1.15ms pulses at 25% duty cycle which has significant components at the 10^{th} harmonic or ~2.2KHz. That these pulses are square indicates that the supercapacitor has excellent pulse response despite the frequency response of Fig 7. This is explained by the concept of effective capacitance or Ceff. Consider the 1A, 100ms pulse of Figure 9. The voltage drop from 2.696V to 2.662V is the voltage drop due to ESR = Discharge_Current x ESR_{DC}. From this we can determine ESR_{DC} = (2.99V – 2.957V)/1.05A = 31mΩ. The voltage drop from 2.957V to 2.949V is due to capacitance discharge. Since Discharge_Current is constant, this should be a straight line, shown in Fig 9 as the slope = Discharge_Current/Ceff(100ms). The rounded leading edge of the voltage drop resulting from capacitance discharge is due to the frequency response of the supercapacitor. CAP-XX has created the concept of effective capacitance for a given pulsewidth, Ceff(pulsewidth) to translate this frequency response to the time domain and enable easy calculation of voltage drop for a given pulsewidth.

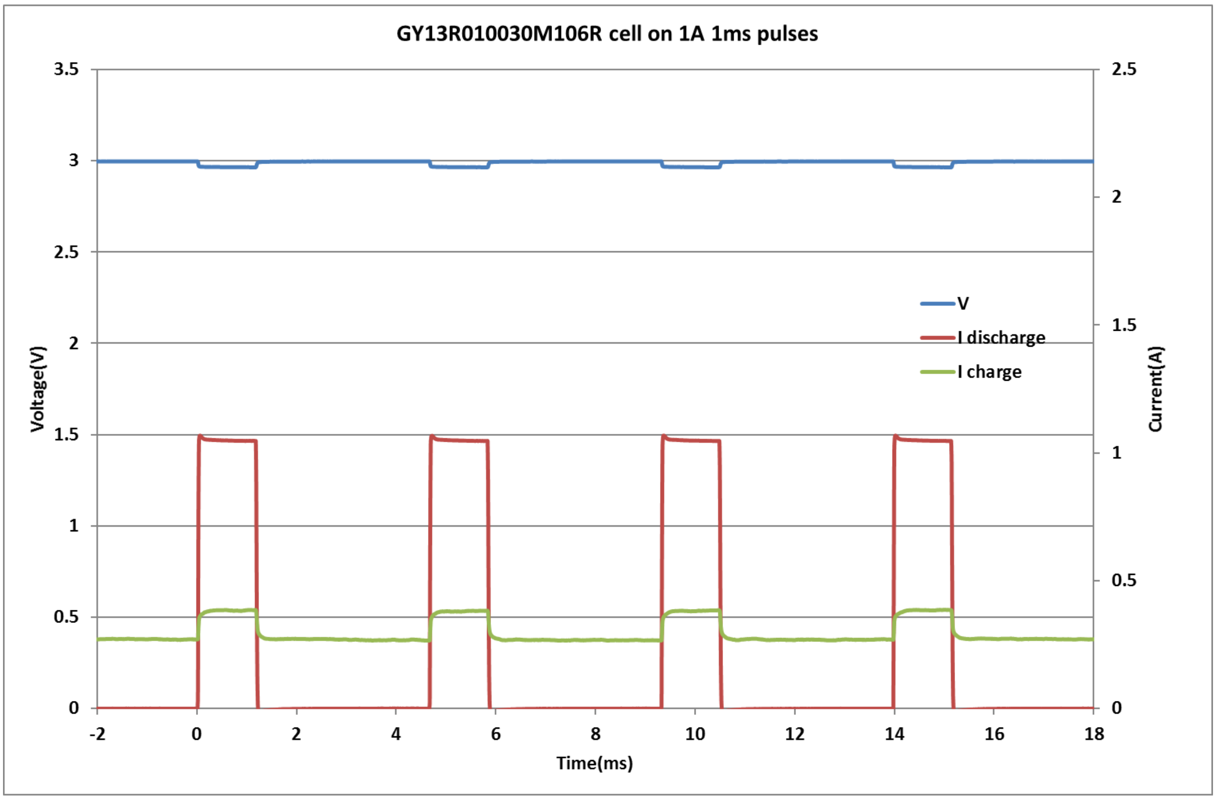


Fig 8: Pulse response of a GY13R010030M106R

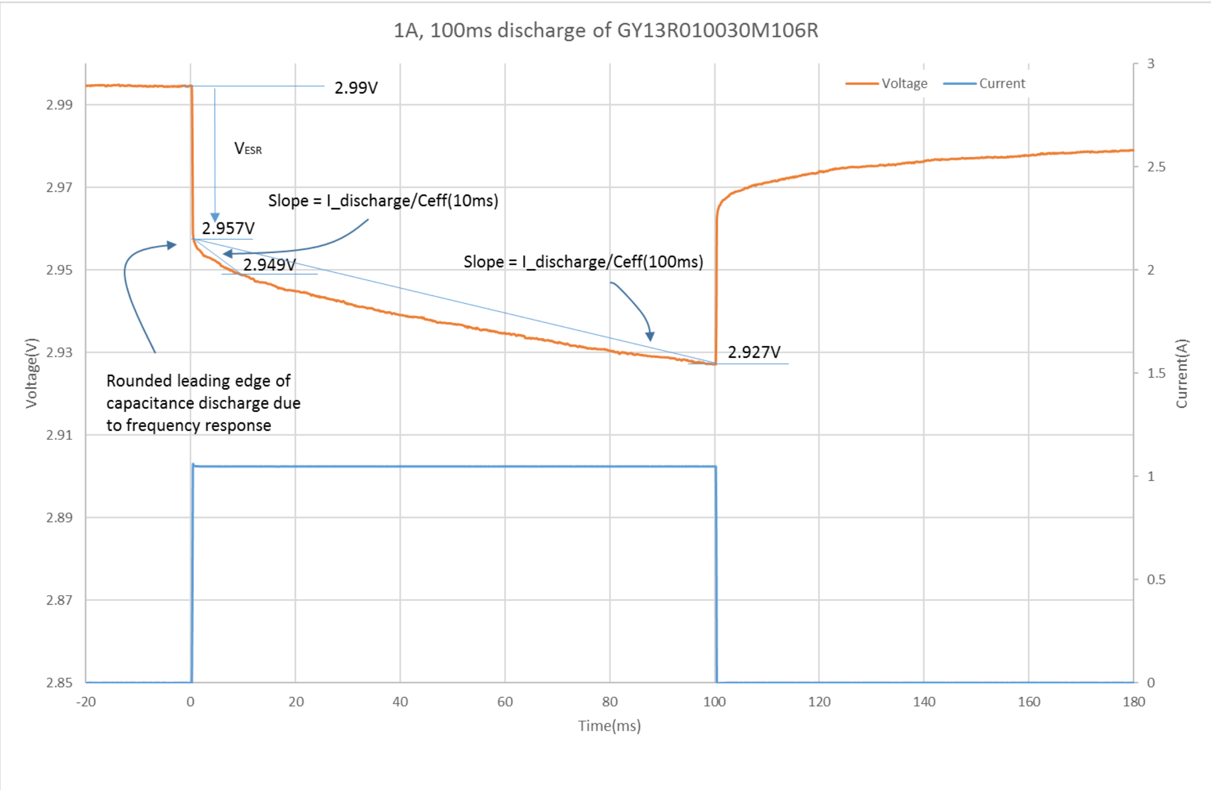


Fig 9: Discharge pulse illustrating the concept of Ceff

In Fig 9, consider the voltage drop due to capacitance 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. The voltage drop due to capacitance after 100ms = 2.957V – 2.927V = 30mV. Ceff(100ms) = 1.05A x 0.1s/0.03V = 3.5F. Fig 10 shows Ceff as a % of DC capacitance for the GY13R0 series of supercapacitors.

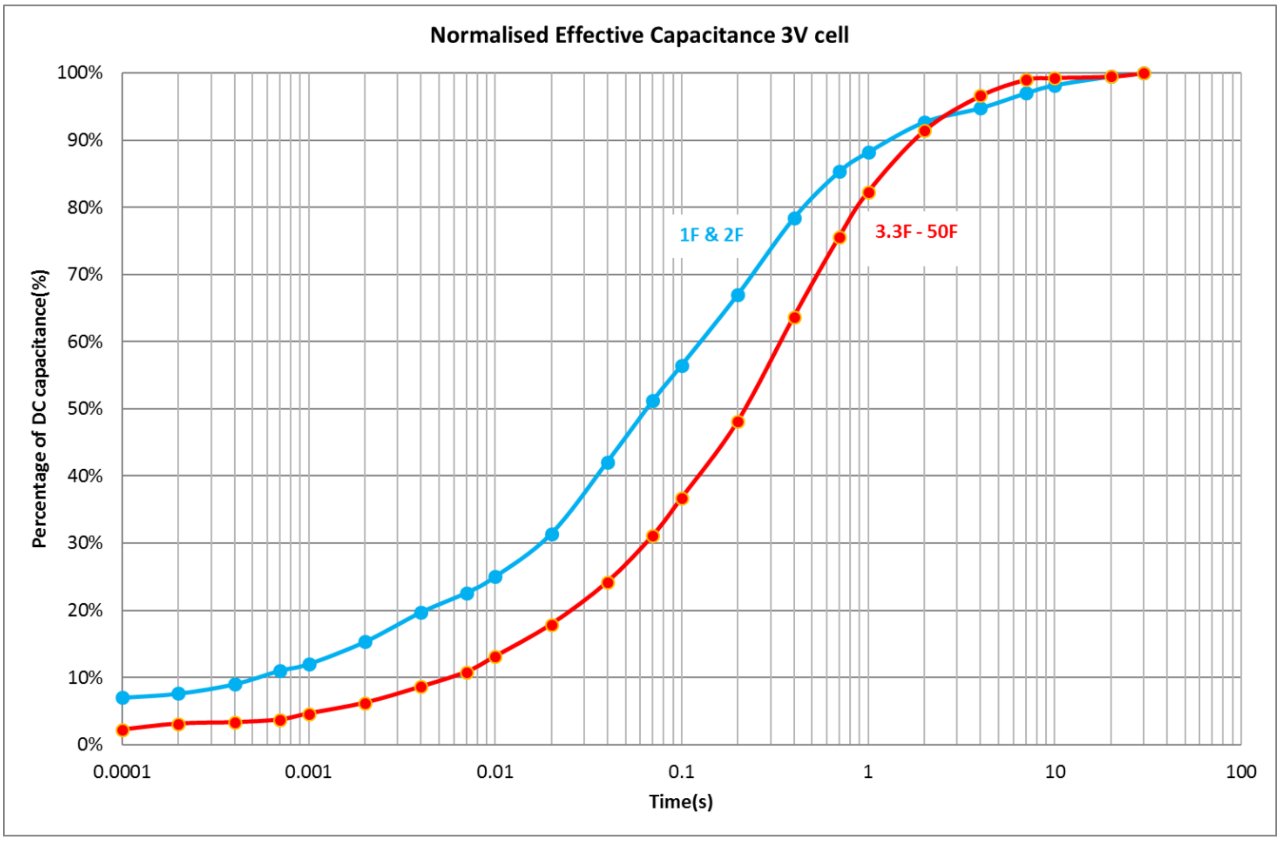


Fig 10: Normalised effective capacitance for GY series supercapacitors

From Fig 10, for parts in the range 3.3F – 50F, Ceff(1ms) = 4% x DC capacitance. In the case of Fig 8, with 1.15ms, 1.05A pulses supported by a GY13R010030M106R, Ceff = 4% x 10F = 0.4F. Therefore, the voltage drop during the pulse = 1.15ms x 1.05A / 0.4F = 3mV. This explains Fig 8 where the pulses are square.

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

Vdrop = I_{DISCH} x ESR_{DC} + I_{DISCH} x T/Ceff(T)

Where Ceff(T) = DC capacitance x % at time T read from Fig 10.

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

10. Operating Life

Supercapacitors slowly age over time with a loss of capacitance and increase in ESR. The rate of ageing depends on the operating voltage and temperature. Figs 11 and 12 show the estimates time to decrease C or increase ESR by 30% and 50% at 3V and 2.7V per cell for temperatures ranging from room temperature (23°C) to 60°C. You can extrapolate the curves in Figs 11 & 12 for lower temperatures or to up to 65°C and interpolate for other voltages. The supercapacitor life will depend on the rate of C loss / ESR increase, the initial C and ESR of the supercapacitor, and the minimum C / maximum ESR that still supports your application. You can increase life in your application by simply starting with a higher C / lower ESR supercapacitor.

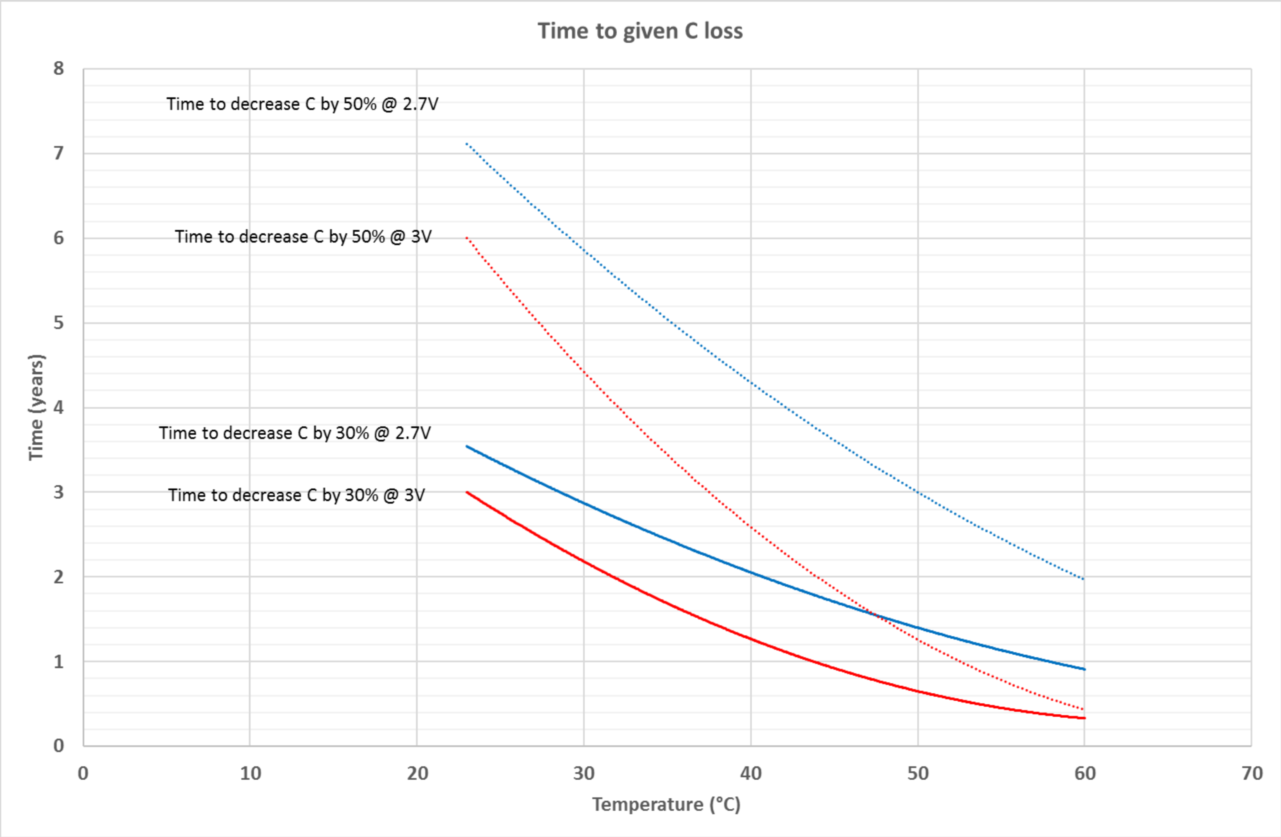


Fig 11: C loss at 3.0V and 2.7V as a function of temperature

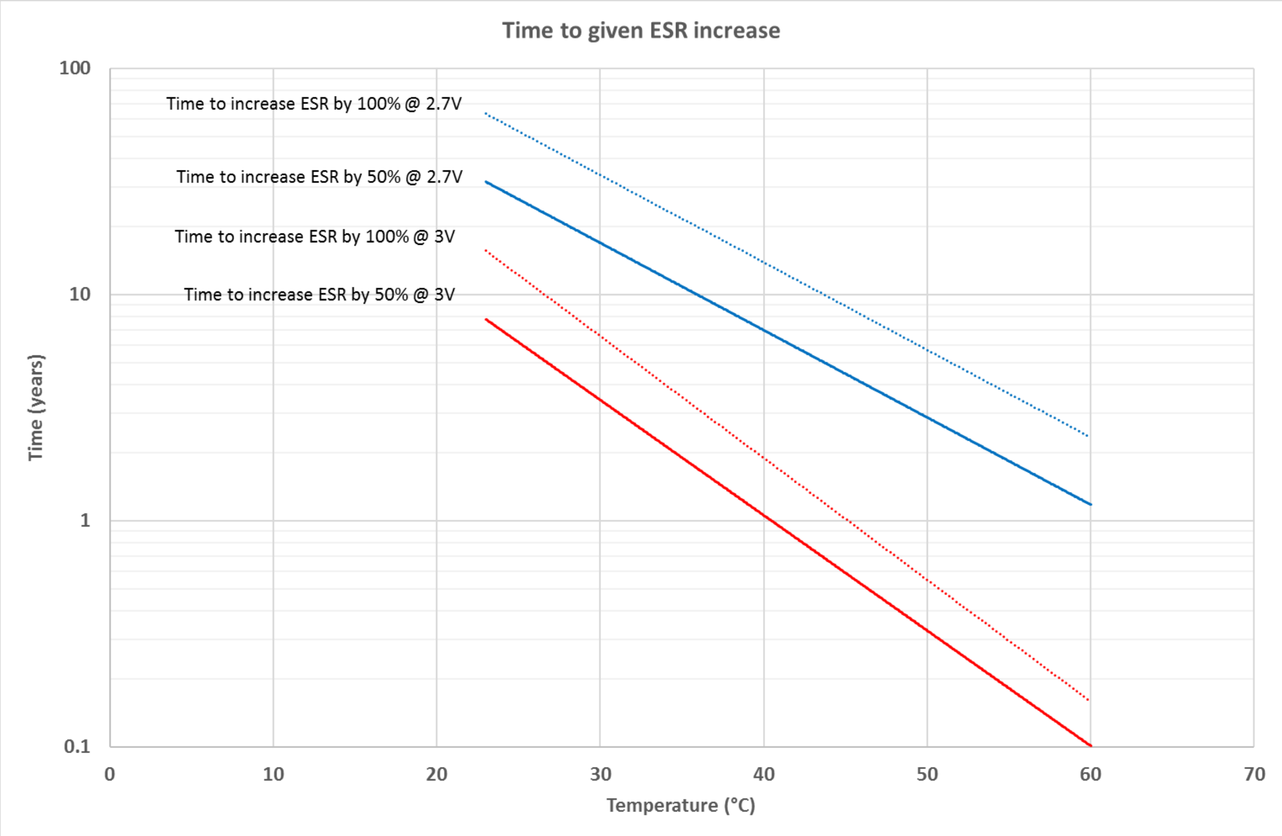


Fig 12: ESR rise at 3.0V and 2.7V as a function of temperature

11. Vibration

Test parameters

Amplitude	1.5mm
Frequency	10 – 55Hz
Direction	X, Y, Z axis, 2hrs in each direction
Test Duration	6 hours

Acceptance criteria

Capacitance	≥ 70% of initial value
ESR	≤ 2 x initial value
Appearance	No remarkable defects

12. 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

13. 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 solder temperatures.

Solder temperature (°C)	Suggested solder time(s)	Maximum solder time (s)
220	7	9
240	7	9
250	5	7
260	3	4

Reflow Soldering:
Infrared or conveyor over reflow techniques can be used on these supercapacitors but do not reflow solder in a standard reflow oven.

14. 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 3^2 /3600 = 0.0625Wh. Under regulation UN3499 there is no restriction on shipping these supercapacitors. Their shipping description is “Electrical Capacitors” with harmonized shipping code 8532.29.0040.