

## DATASHEET

## GA109 / GA209 SUPERCAPACITOR

Revision 4.5, May 2020

## Electrical Specifications

The GA109 is a single cell supercapacitor. The GA209 is a dual cell supercapacitor with two GA109 cells in series, so GA209 capacitance = Capacitance of GA109/2 and GA209 ESR = 2 x GA109 ESR.

Table 1: Absolute Maximum Ratings

| Parameter        | Name              |       | Conditions | Min |  | Max  | Units |
|------------------|-------------------|-------|------------|-----|--|------|-------|
| Terminal Voltage | V <sub>peak</sub> | GA109 |            | 0   |  | 2.75 | V     |
|                  |                   | GA209 |            |     |  | 5.5  |       |
| Temperature      | T <sub>max</sub>  |       |            | -40 |  | +70  | °C    |

Table 2: Electrical Characteristics

| Parameter                 | Name             |       | Conditions         | Min | Typical | Max | Units |
|---------------------------|------------------|-------|--------------------|-----|---------|-----|-------|
| Terminal Voltage          | V <sub>n</sub>   | GA109 |                    | 0   |         | 2.5 | V     |
|                           |                  | GA209 |                    | 0   |         | 5.0 |       |
| Capacitance               | C                | GA109 | DC, 23°C           | 106 | 170     | 204 | mF    |
|                           |                  | GA209 |                    | 72  | 90      | 108 |       |
| ESR                       | ESR              | GA109 | DC, 23°C           |     | 50      | 60  | mΩ    |
|                           |                  | GA209 |                    |     | 95      | 114 |       |
| Leakage Current           | I <sub>L</sub>   |       | 2.3V, 23°C, 120hrs |     | 1       | 2   | μA    |
| RMS Current               | I <sub>RMS</sub> |       | 23°C               |     |         | 4.5 | A     |
| Peak Current <sup>1</sup> | I <sub>P</sub>   |       | 23°C               |     |         | 30  | A     |

<sup>1</sup>Non-repetitive current, single pulse to discharge fully charged supercapacitor.

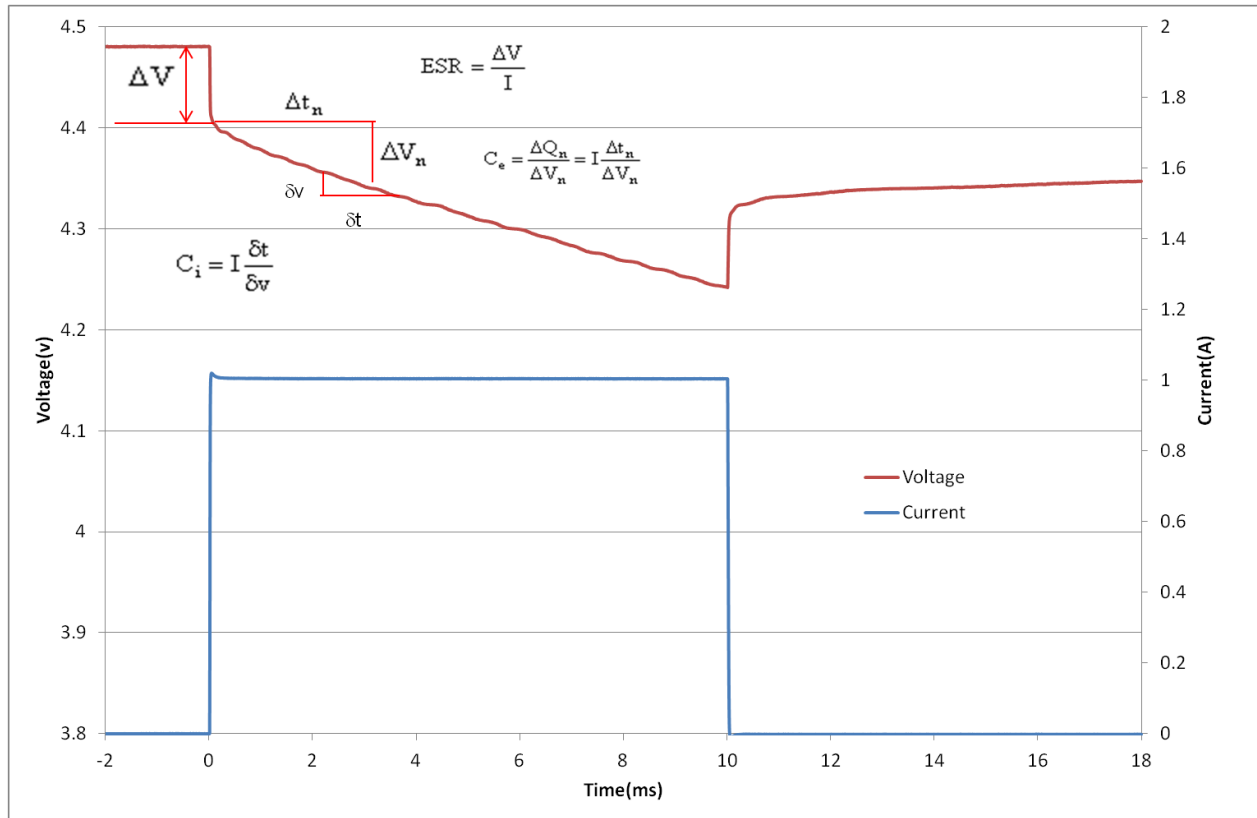
Table 3: Thickness

|        |       |                                                     |        |       |                                                  |
|--------|-------|-----------------------------------------------------|--------|-------|--------------------------------------------------|
| GA109F | 1.0mm | No adhesive tape on underside of the supercapacitor | GA109G | 1.1mm | Adhesive tape on underside, release tape removed |
| GA209F | 2.1mm |                                                     | GA209G | 2.2mm |                                                  |

This datasheet should be read in conjunction with the [CAP-XX Supercapacitor Product Guide](#) which contains information common to our product lines.

## Definition of Terms

In its simplest form, the Equivalent Series Resistance (ESR) of a capacitor is the real part of the complex impedance. In the time domain, it can be found by applying a step discharge current to a charged cell as in Fig. 1. In this figure, the supercapacitor is pre-charged and then discharged with a current pulse,  $I = 1A$  for duration 0.01 secs.



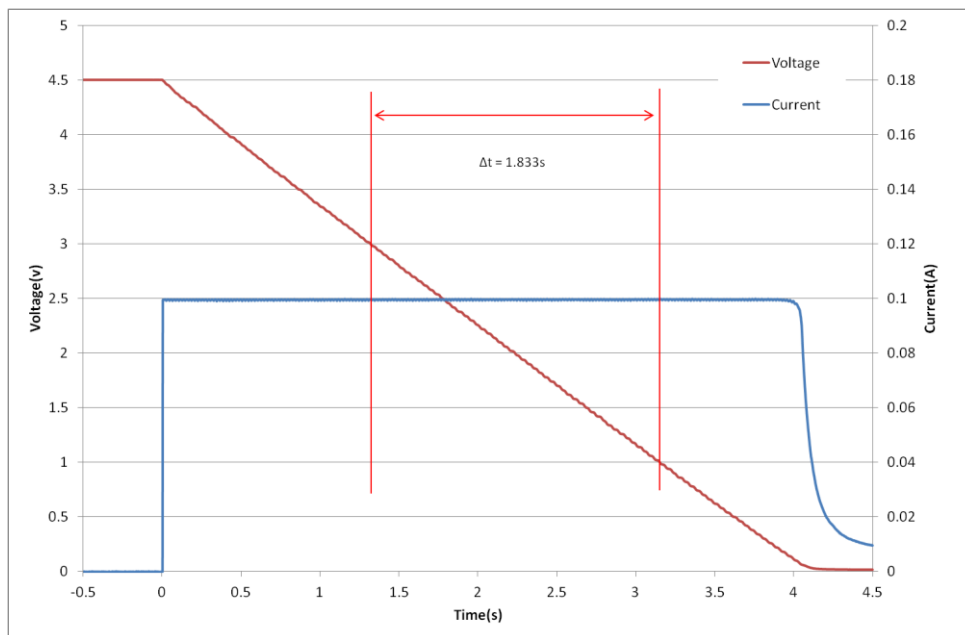
**Fig 1: Effective capacitance, instantaneous capacitance and ESR for a GA209**

The ESR is found by dividing the instantaneous voltage step ( $\Delta V$ ) by  $I$ . In this example  $= (4.48V - 4.409V) / 1.01A = 71m\Omega$ .

The instantaneous capacitance ( $C_i$ ) can be found by taking the inverse of the derivative of the voltage, and multiplying it by  $I$ .

The effective capacitance for a pulse of duration  $\Delta t_n$ ,  $C_e(\Delta t_n)$  is found by dividing the total charge removed from the capacitor ( $\Delta Q_n$ ) by the voltage lost by the capacitor ( $\Delta V_n$ ). For constant current  $C_e(\Delta t_n) = I \times \Delta t_n / \Delta V_n$ .  $C_e$  increases as the pulse width increases and tends to the DC capacitance value as the pulse width becomes very long (~10 secs). After 2msecs, Fig 1 shows the voltage drop  $V_{2ms} = (4.409V - 4.359V) = 50mV$ . Therefore  $C_e(2ms) = 1A \times 2ms / 50mV = 40mF$ . After 10ms, the voltage drop  $= 4.409V - 4.24V = 169mV$ . Therefore  $C_e(10ms) = 1A \times 10ms / 169mV = 59mF$ . The DC capacitance of a GA209 = 80mF. Note that  $\Delta V$ , or  $IR$  drop, is not included because very little charge is removed from the capacitor during this time.  $C_e$  shows the time response of the capacitor and it is useful for predicting circuit behaviour in pulsed applications.

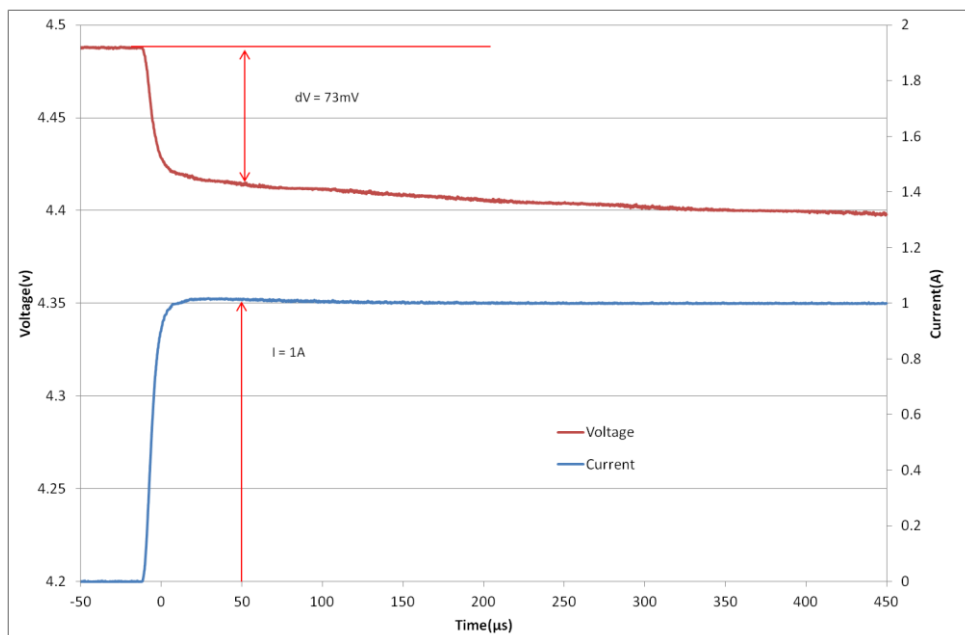
## Measurement of DC Capacitance



**Fig 2: Measurement of DC Capacitance for a GA209**

Fig 2 shows the measurement of DC capacitance by drawing a constant 100mA current from a fully charged supercapacitor and measuring the time taken to discharge from 1.5V to 0.5V for a single cell, or from 3V to 1V for a dual cell supercapacitor. In this case,  $C = 0.1A \times 1.83s / 2V = 91.5mF$ , which is well within the 90mF +/- 20% tolerance for a GA209 cell.

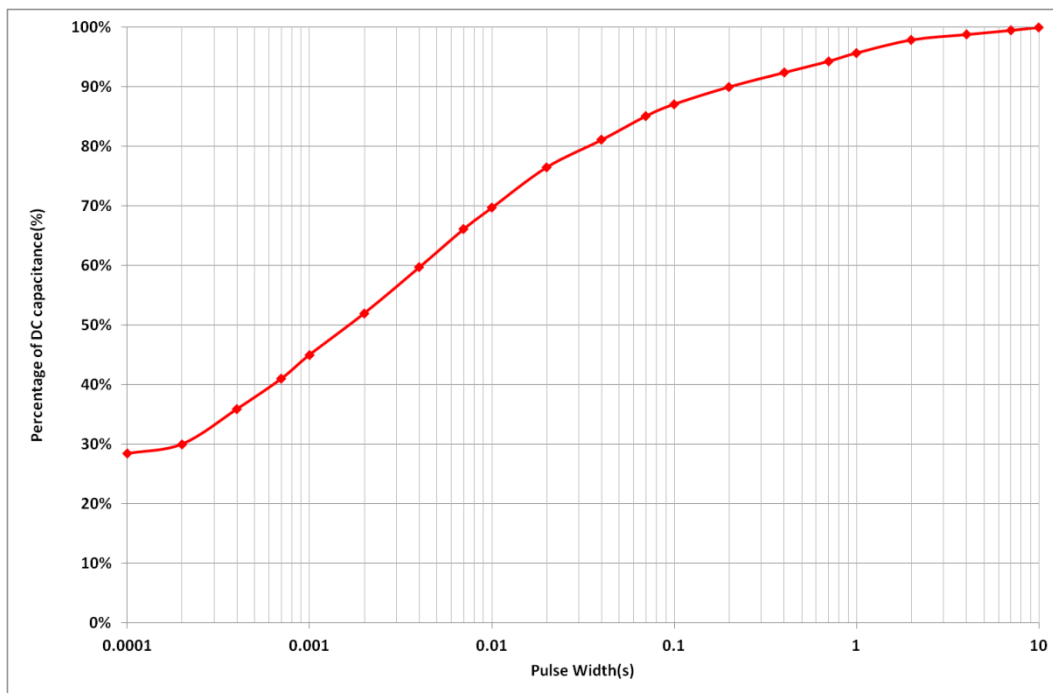
## Measurement of ESR



**Fig 3: Measurement of ESR for a GA209**

Fig 3 shows DC measurement of ESR by applying a step load current to the supercapacitor and measuring the resulting voltage drop. CAP-XX waits for a delay of 50μs after the step current is applied to ensure the voltage and current have settled. In this case the ESR is measured as  $73mV/1A = 73m\Omega$ .

## Effective Capacitance



**Fig 4: Effective Capacitance**

Fig 4 shows the effective capacitance for the GA109, GA209 @ 23°C. This shows that for a 1msec PW, you will measure 45% of DC capacitance or 77mF for a GA109 or 41mF for a GA209. At 10msecs you will measure 70% of the DC capacitance, and at 100msecs you will measure 87% of DC capacitance. Ceffective is a time domain representation of the supercapacitor's frequency response. If, for example, you were calculating the voltage drop if the supercapacitor was supporting 1A for 10msecs, then you would use the  $C_{eff}(10\text{msecs}) = 70\%$  of DC capacitance = 56mF for a GA209, so  $V_{drop} = 1A \times ESR + 1A \times \text{duration}/C = 1A \times 95m\Omega + 1A \times 10ms / 63mF = 255mV$ . The next section on pulse response shows how the effective capacitance is sufficient for even short pulse widths.

## Pulse Response

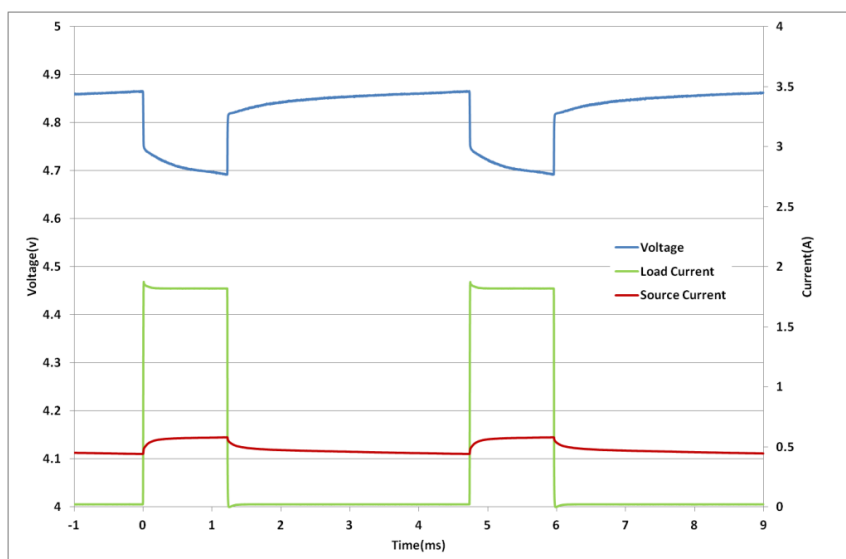
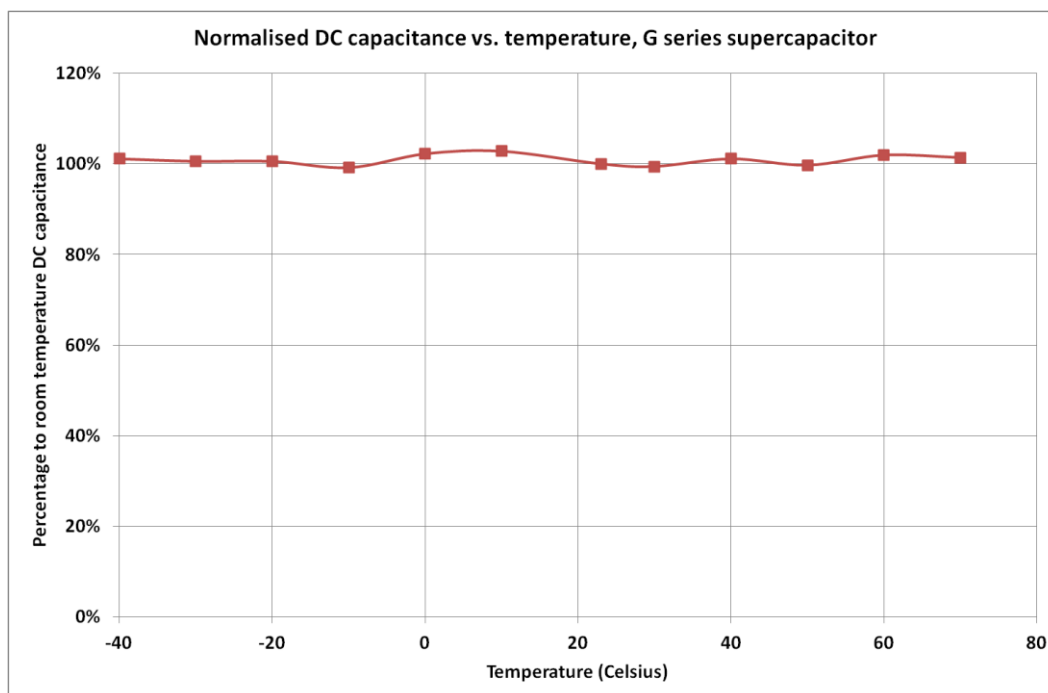


Fig 5 shows that the GA209 supercapacitor does an excellent job supporting a GPRS class 10 pulse train, drawing 1.8A for 1.1ms at 25% duty cycle. The source is current limited to 0.6A and the supercapacitor provides the 1.2A difference to achieve the peak current. At first glance the freq response of Fig 8 indicates the supercapacitor would not support a 1ms pulse, but the  $C_{eff}$  of 41mF coupled with the low ESR supports this pulse train with only ~140mV droop in the supply rail.

**Fig 5: GA209 Pulse Response with GPRS Class 10 Pulse Train**

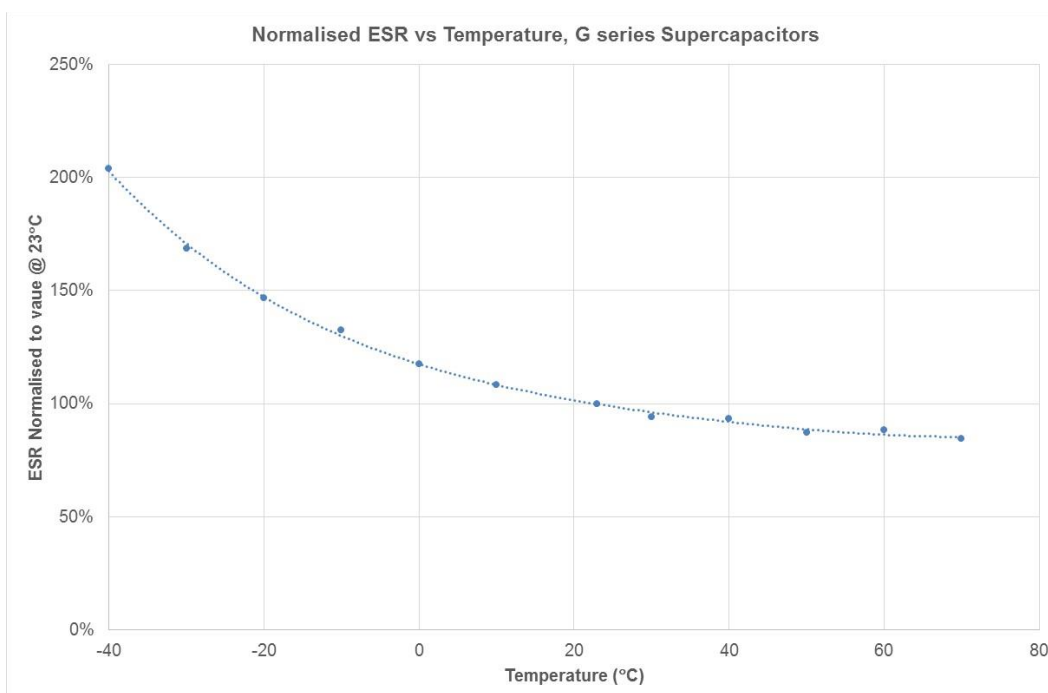
## DC Capacitance variation with temperature



**Fig 6: Capacitance change with temperature**

Fig 6 shows that DC capacitance is approximately constant with temperature.

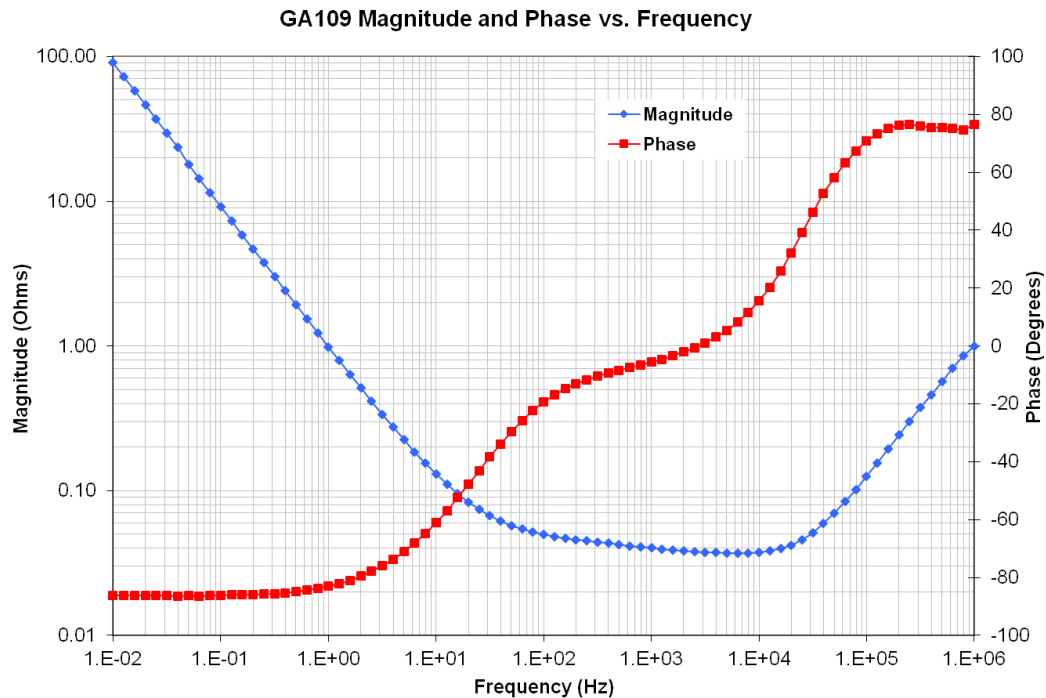
## ESR variation with temperature



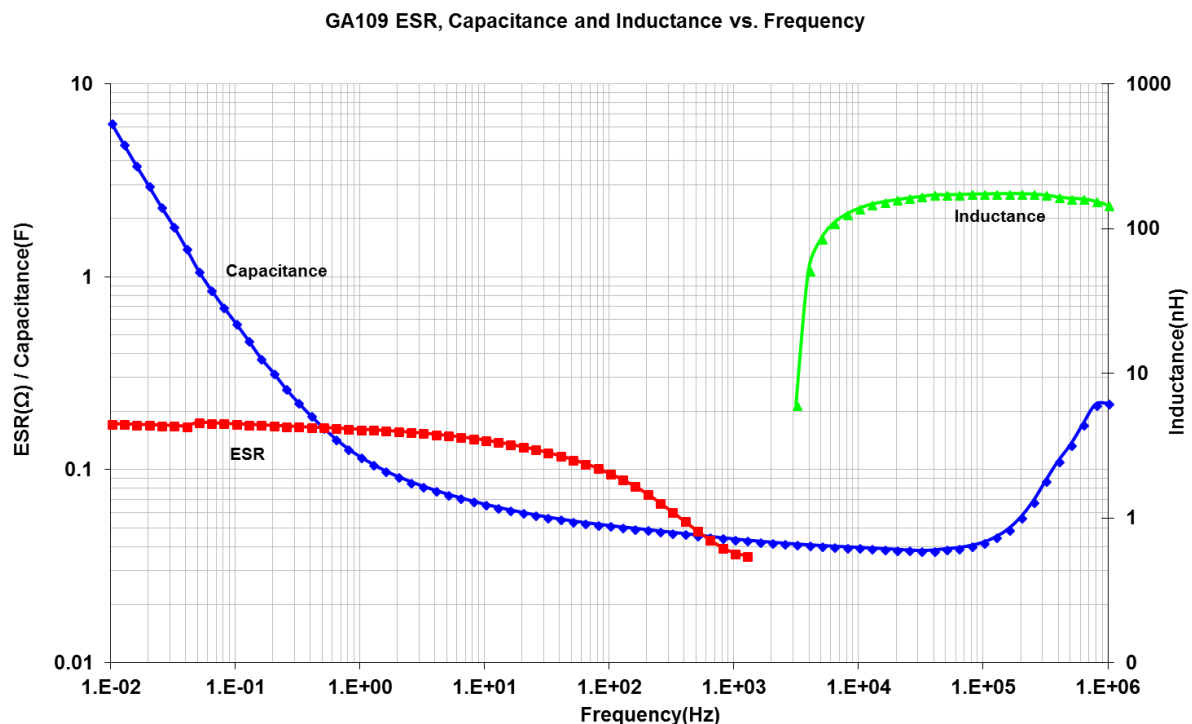
**Fig 7: ESR change with temperature**

Fig 7 shows that ESR at -40°C is ~2 x ESR at room temp, and that ESR at 70°C is ~0.85 x ESR at room temperature.

## Frequency Response



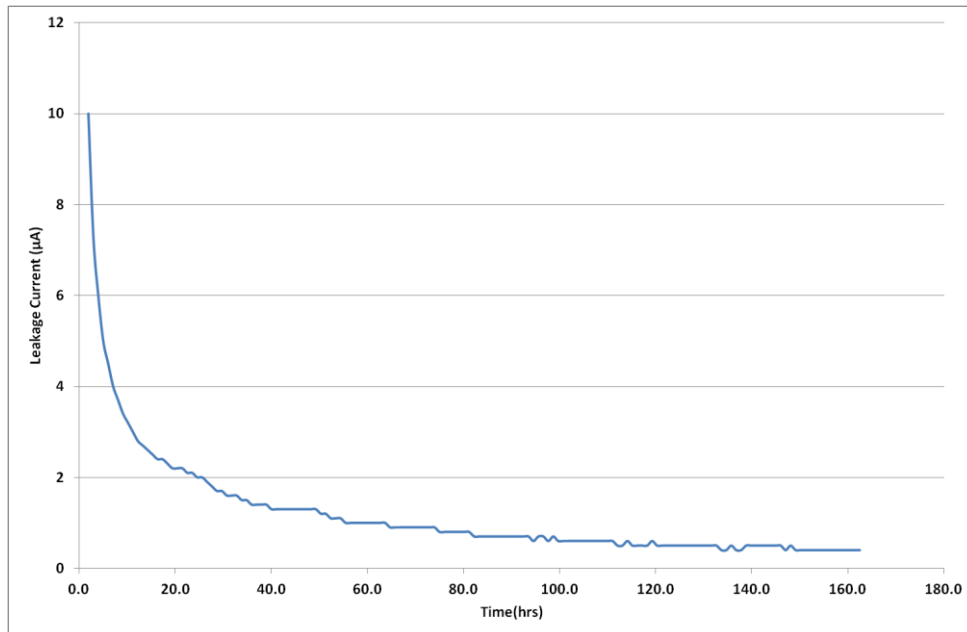
**Fig 8: Frequency Response of Impedance (biased at 2.3V with a 50mV test signal)**



**Fig 9: Frequency Response of ESR, Capacitance & Inductance**

Fig 8 shows the supercapacitor behaves as an ideal capacitor until approx 30 Hz when the magnitude no longer rolls off proportionally to  $1/\text{freq}$  and the phase crosses  $-45^\circ$ . Performance of supercapacitors with frequency is complex and the best predictor of performance is Fig 4 showing effective capacitance as a function of pulsewidth.

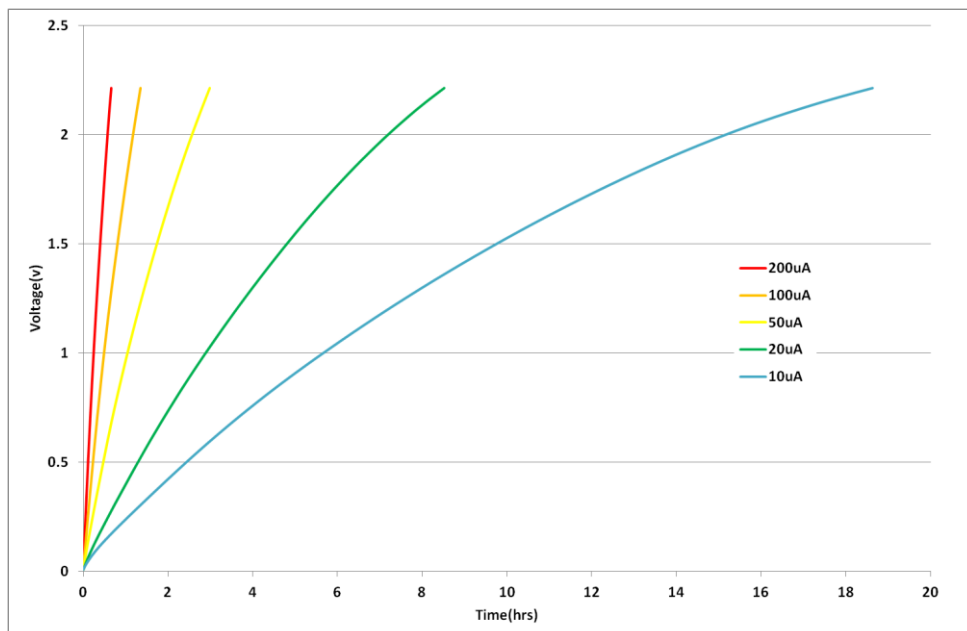
## Leakage Current



**Fig 10: Leakage Current**

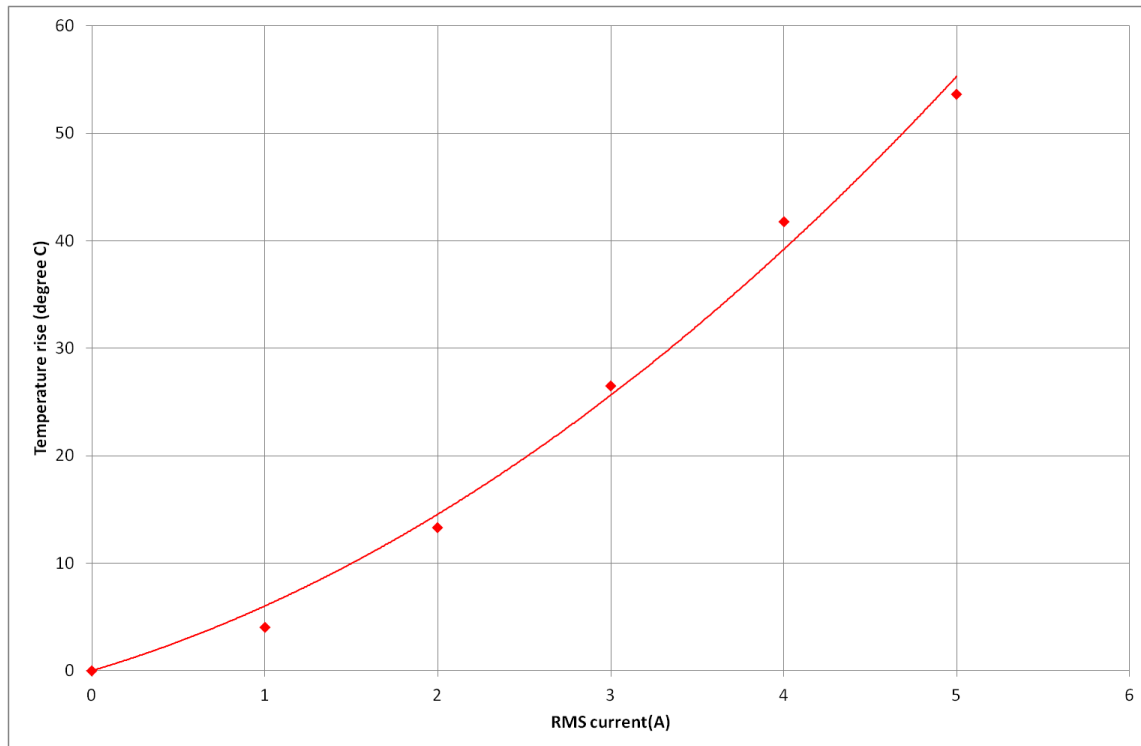
Fig 10 shows the leakage current for GA109 at room temperature. The leakage current decays over time and the equilibrium value leakage current will be reached after ~120hrs at room temperature. The typical equilibrium leakage current is ~0.5µA at room temperature. At 70°C leakage current will be ~5µA.

## Charge Current



**Fig 11: Charging an GA109 with low current**

The corollary to the slow decay in leakage currents shown in Fig 10 is that charging a supercapacitor at very low currents takes longer than theory predicts. At higher charge currents, the charge rate is as theory predicts. For example, it should take  $170\text{mF} \times 2.3\text{V} / 0.00001\text{A} = 10.9\text{hrs}$  to charge a 160mF supercapacitor to 2.3V at 10µA, but Fig 11 shows it took 19hrs. At 50µA charging occurs at a rate close to the theoretical rate.

**RMS Current****Fig 12: Temperature rise in GA209 with RMS current**

Continuous current flow into/out of the supercap 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 12 shows the increase in temperature as a function of RMS current. From this, the maximum RMS current in an application can be calculated, for example, if the ambient temperature is 40°C, and the maximum desired temperature for the supercapacitor is 70°C, then the maximum RMS current should be limited to 3.3 A, which causes a 30°C temperature increase.

## CAP-XX Supercapacitors Product Guide

Refer to the package drawings in the [CAP-XX Supercapacitors Product Guide](#) for detailed information of the product's dimensions, PCB landing placements, active areas and electrical connections, as well for information on endurance and shelf life, transportation and storage, assembly and soldering, safety and RoHS/REACH certification.