

## GA109 / GA209 SUPERCAPACITOR

Datasheet Rev3.0, April 2013

This Datasheet should be read in conjunction with the CAP-XX Supercapacitors Product Guide which contains information common to our product lines.

**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		2.5	V
		GA209				5.0	
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		2.3	V
		GA209		0		4.5	
Capacitance	C	GA109	DC, 23°C	128	160	192	mF
		GA209		64	80	96	
ESR	ESR	GA109	DC, 23°C	52	65	78	mΩ
		GA209		104	130	156	
Leakage Current	I <sub>L</sub>		2.3V, 23°C 120hrs		1	2	μA
RMS Current	I <sub>RMS</sub>		23°C			4	A
Peak Current <sup>1</sup>	I <sub>p</sub>		23°C			30	A

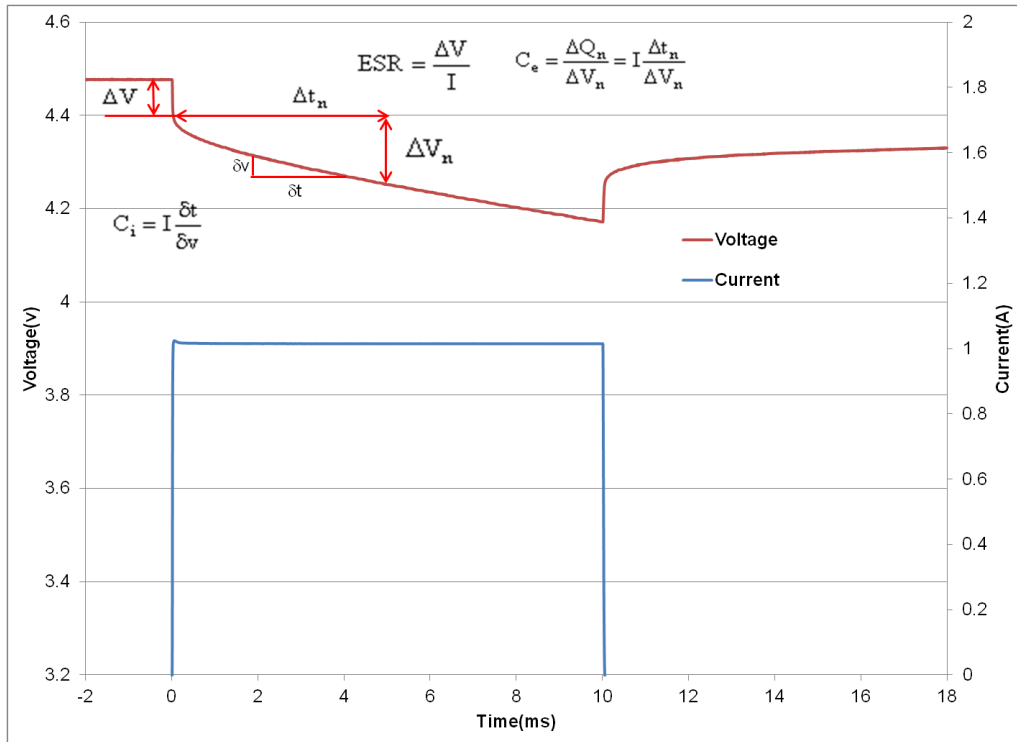
<sup>1</sup>Non-repetitive current, single pulse to discharge fully charged supercapacitor.

**Table 3: Thickness**

GA109F	1.10mm	No adhesive tape on underside of the supercapacitor	GA109G	1.20mm	Adhesive tape on underside, release tape removed
GA209F	2.20mm		GA209G	2.30mm	

## 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,  $I = 1\text{A}$  for duration  $0.01\text{ secs}$ .



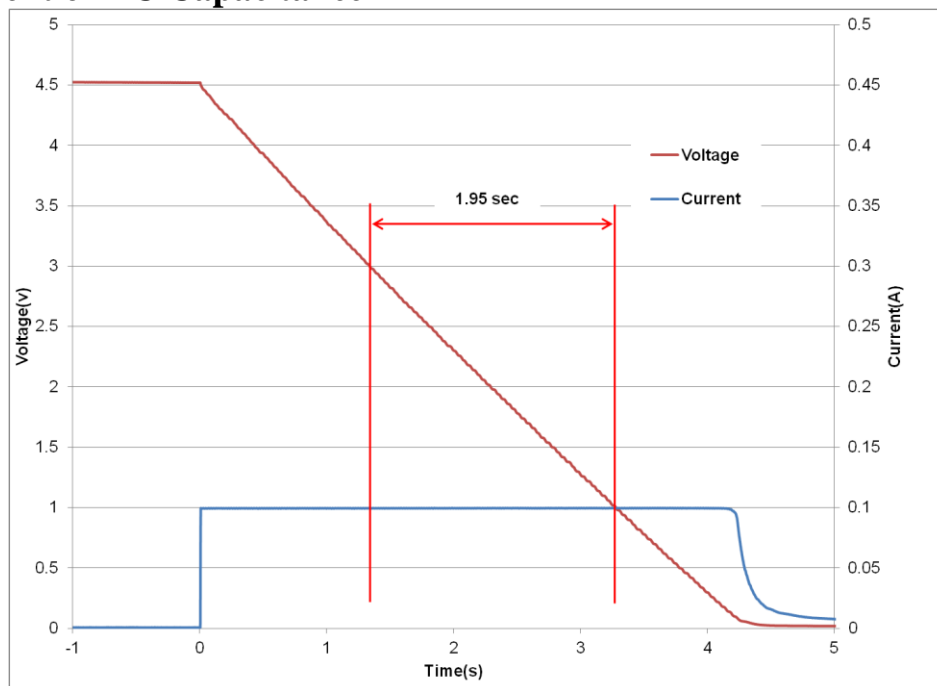
**Figure 1: Effective capacitance, instantaneous capacitance and ESR for a GA209**

The ESR is found by dividing the instantaneous voltage step ( $\Delta V$ ) by  $I$ . In this example  $= (4.477\text{V} - 4.409\text{V}) / 1.01\text{A} = 67.3\text{m}\Omega$ .

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 ( $\sim 10\text{ secs}$ ). After 2msecs, Fig 1 shows the voltage drop  $V_{2\text{ms}} = (4.409\text{V} - 4.311\text{V}) = 98\text{mV}$ . Therefore  $C_e(2\text{ms}) = 1.01\text{A} \times 2\text{ms} / 98\text{mV} = 20.6\text{mF}$ . After 10ms, the voltage drop  $= 4.409\text{V} - 4.173\text{V} = 236\text{mV}$ . Therefore  $C_e(10\text{ms}) = 1.01\text{A} \times 10\text{ms} / 236\text{mV} = 42.8\text{mF}$ . The DC capacitance of a GA209  $= 80\text{mF}$ . 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 behavior in pulsed applications.

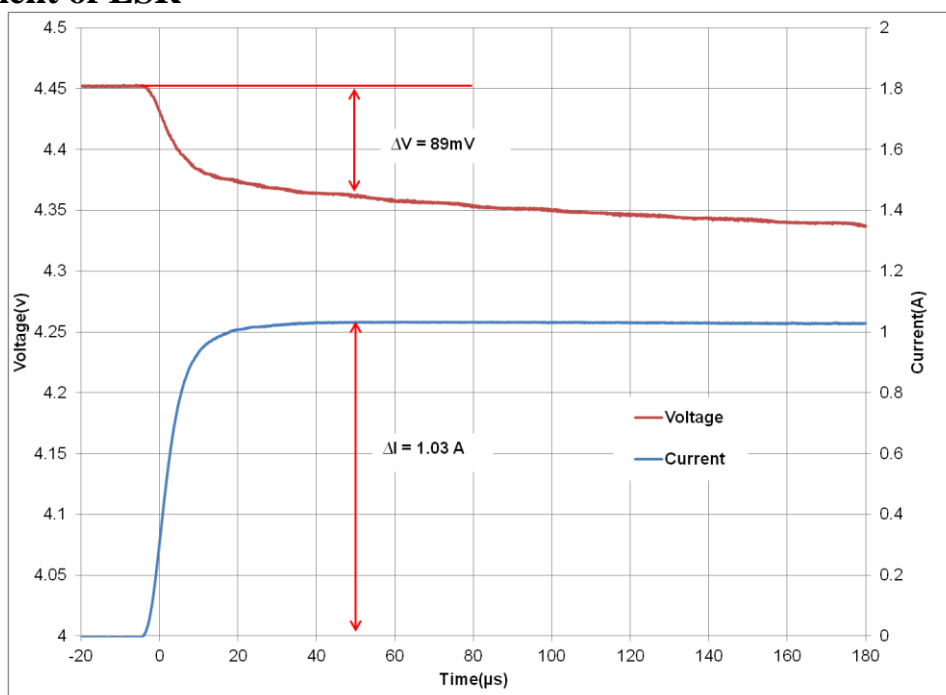
## Measurement of DC Capacitance



**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,  $C = 0.095\text{A} \times 1.95\text{s} / 2\text{V} = 92.6\text{mF}$ , which is well within the 80mF +/- 20% tolerance for a GA209 cell.

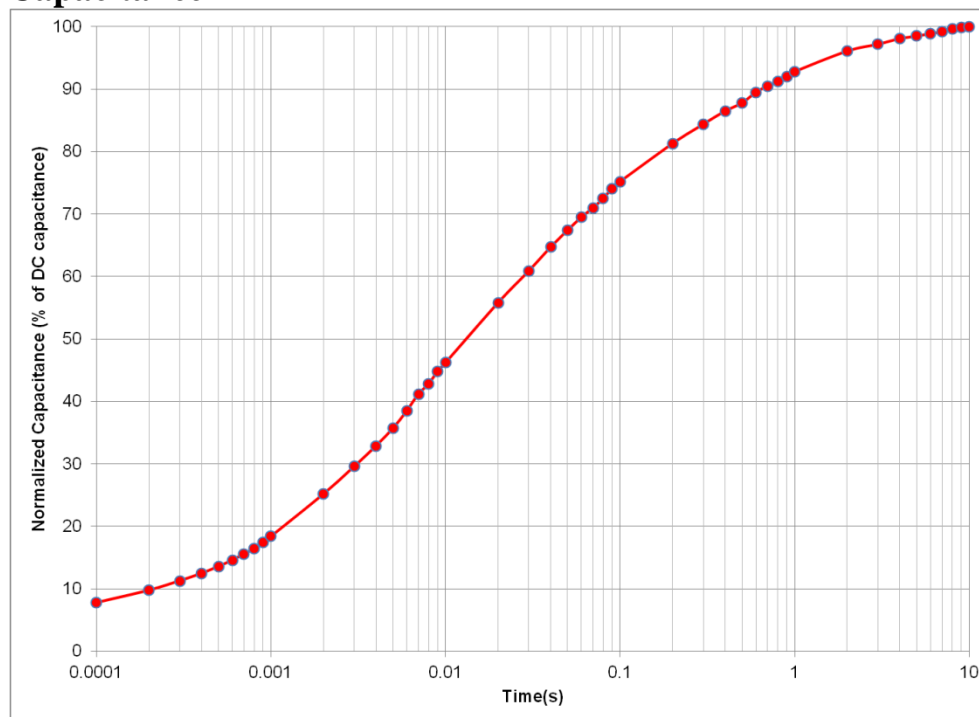
## Measurement of ESR



**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  $89\text{mV} / 1.03\text{A} = 86.4\text{m}\Omega$ .

## Effective Capacitance



**Figure 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 18% of DC capacitance or 28.8mF for a GA109 or 14.4mF for a GA209. At 10msecs you will measure 45% of the DC capacitance, and at 100msecs you will measure 75% of DC capacitance. Effective 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  $C_{eff}(10\text{msecs}) = 45\% \text{ of DC capacitance} = 36\text{mF}$  for a GA209, so  $V_{drop} = 1\text{A} \times \text{ESR} + 1\text{A} \times \text{duration} / C = 1\text{A} \times 130\text{m}\Omega + 1\text{A} \times 10\text{ms} / 36\text{mF} = 408\text{mV}$ . The next section on pulse response shows how the effective capacitance is sufficient for even short pulse widths.

## Pulse Response

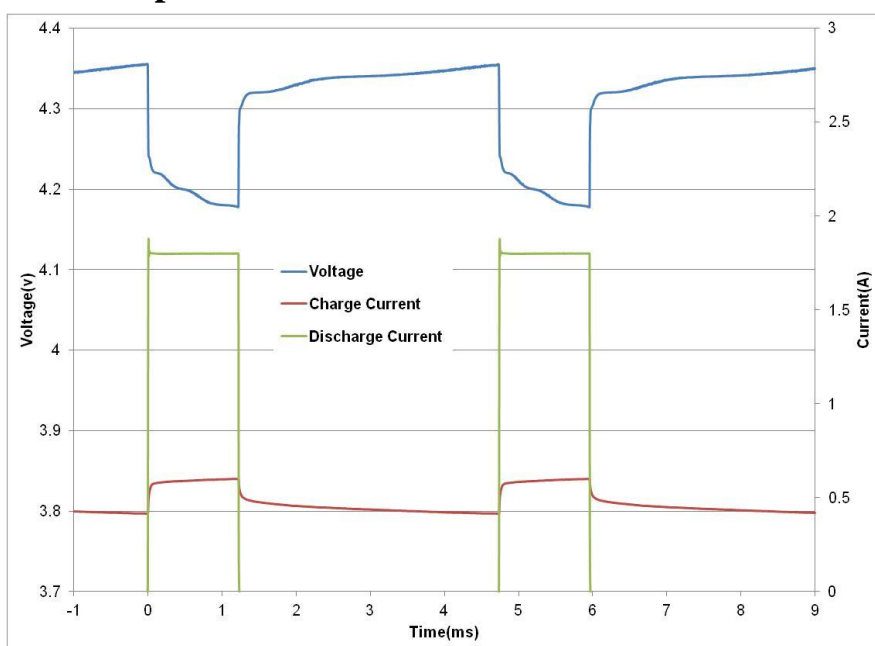
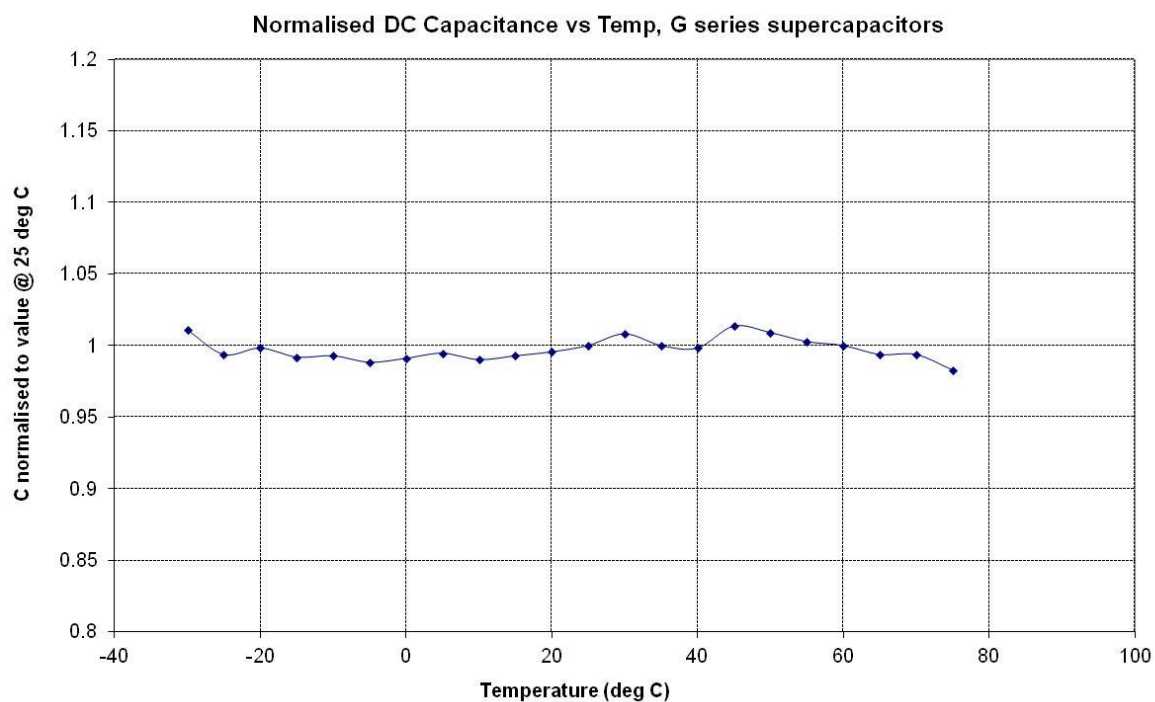


Fig 5 shows that the GA209 supercapacitor does an excellent job supporting a GPRS class 10 pulse train, drawing 1.8A for 1.1ms at 25% duty cycle. The source is current limited to 0.6A and the supercapacitor provides the 1.2A difference to achieve the peak current. At first glance the freq response of Fig 8 indicates the supercapacitor would not support a 1ms pulse, but the  $C_{eff}$  of 14.4mF coupled with the low ESR supports this pulse train with only ~180mV droop in the supply rail.

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

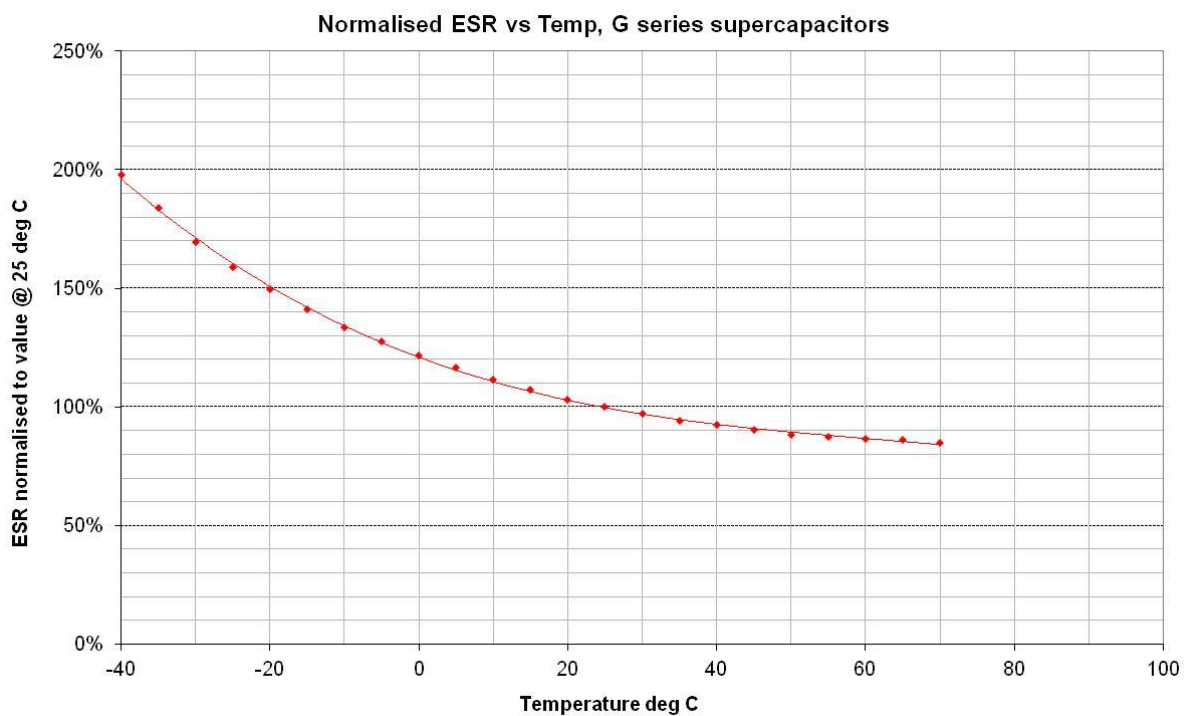
## DC Capacitance variation with temperature



**Figure 6: Capacitance change with temperature**

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

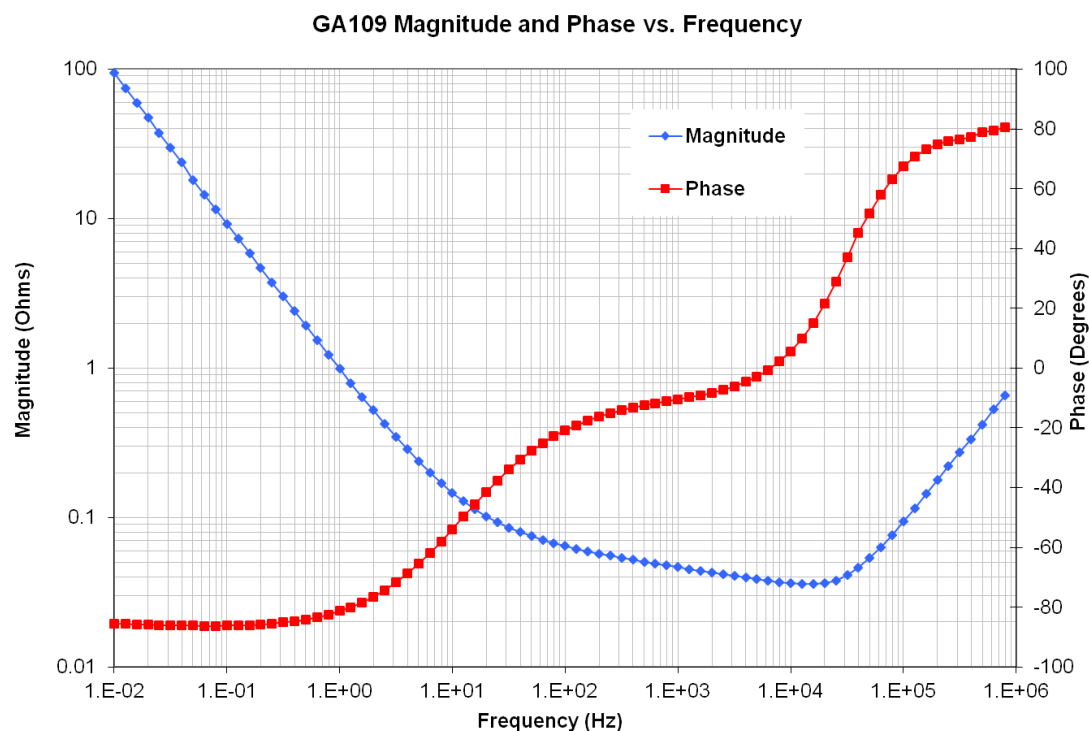
## ESR variation with temperature



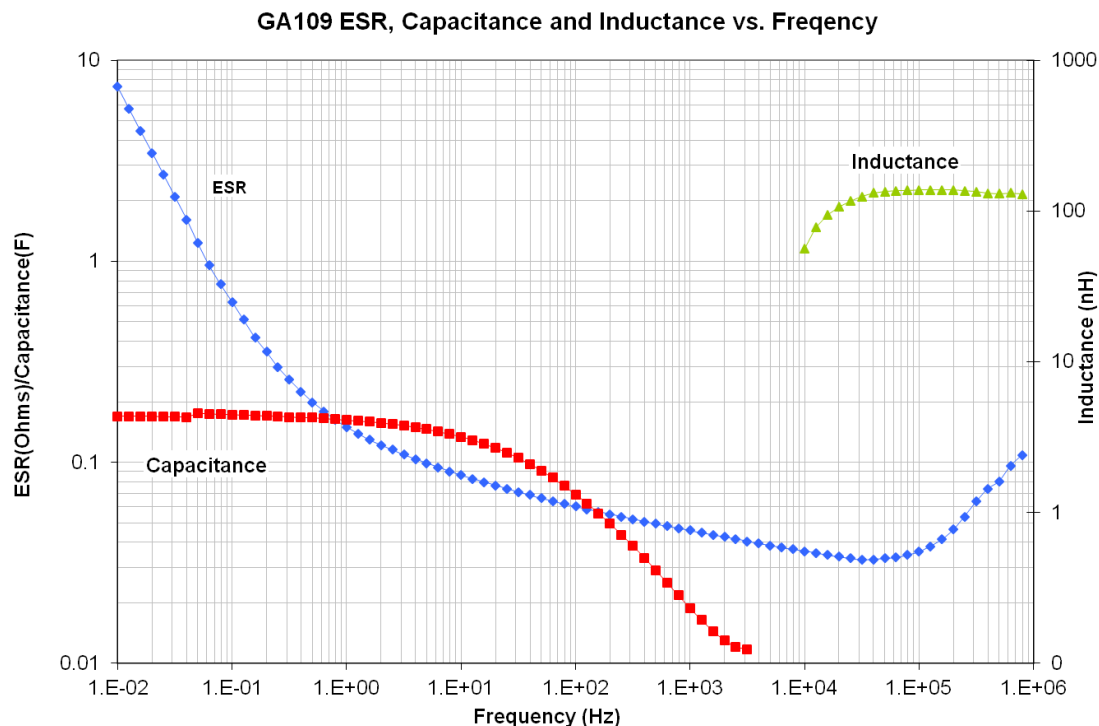
**Figure 7: ESR change with temperature**

Fig 7 shows that ESR at  $-40^{\circ}\text{C}$  is  $\sim 2 \times$  ESR at room temp, and that ESR at  $70^{\circ}\text{C}$  is  $\sim 0.85 \times$  ESR at room temperature.

## Frequency Response



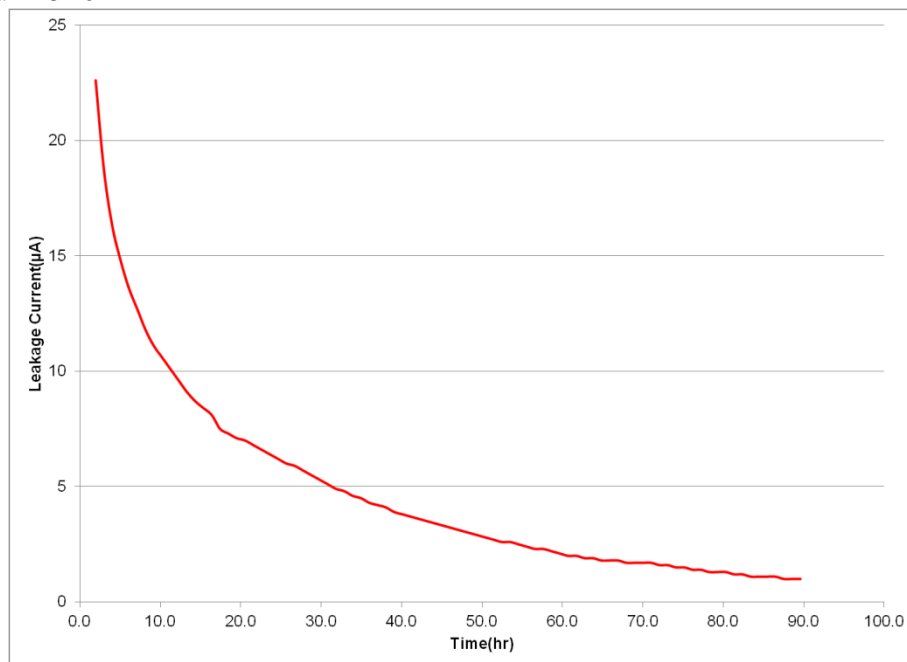
**Fig 8: Frequency Response of Impedance (biased at 2.3V with a 50mV test signal)**



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

Fig 8 shows the supercapacitor behaves as an ideal capacitor until approx 10 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.

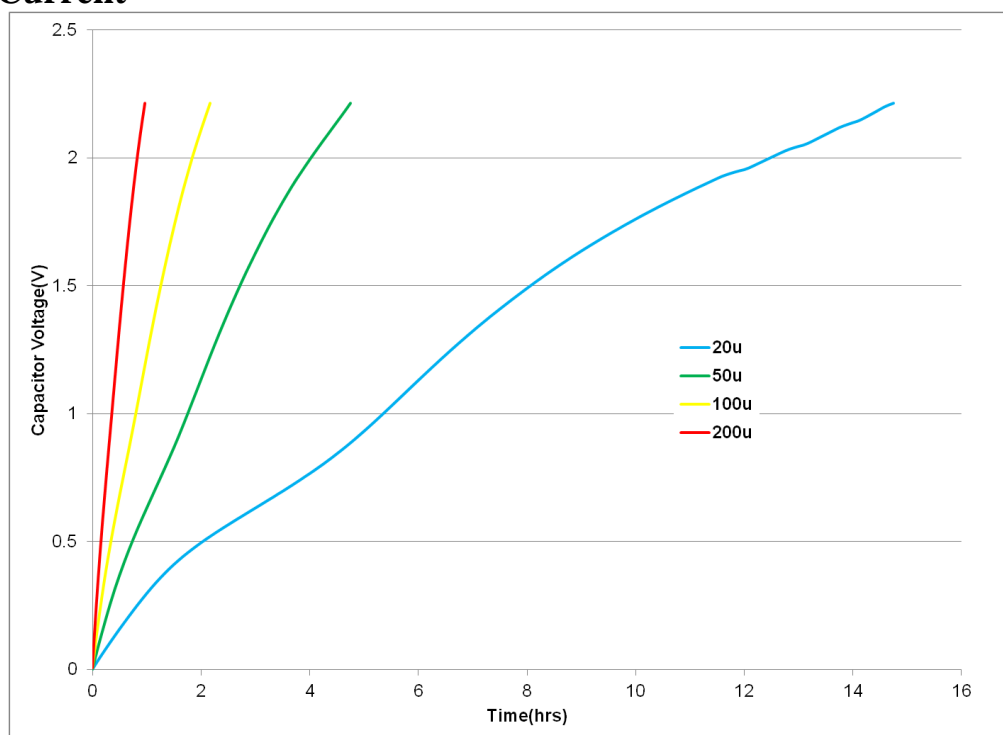
## Leakage Current



**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 1µA at room temperature. At 70°C leakage current will be ~5µA.

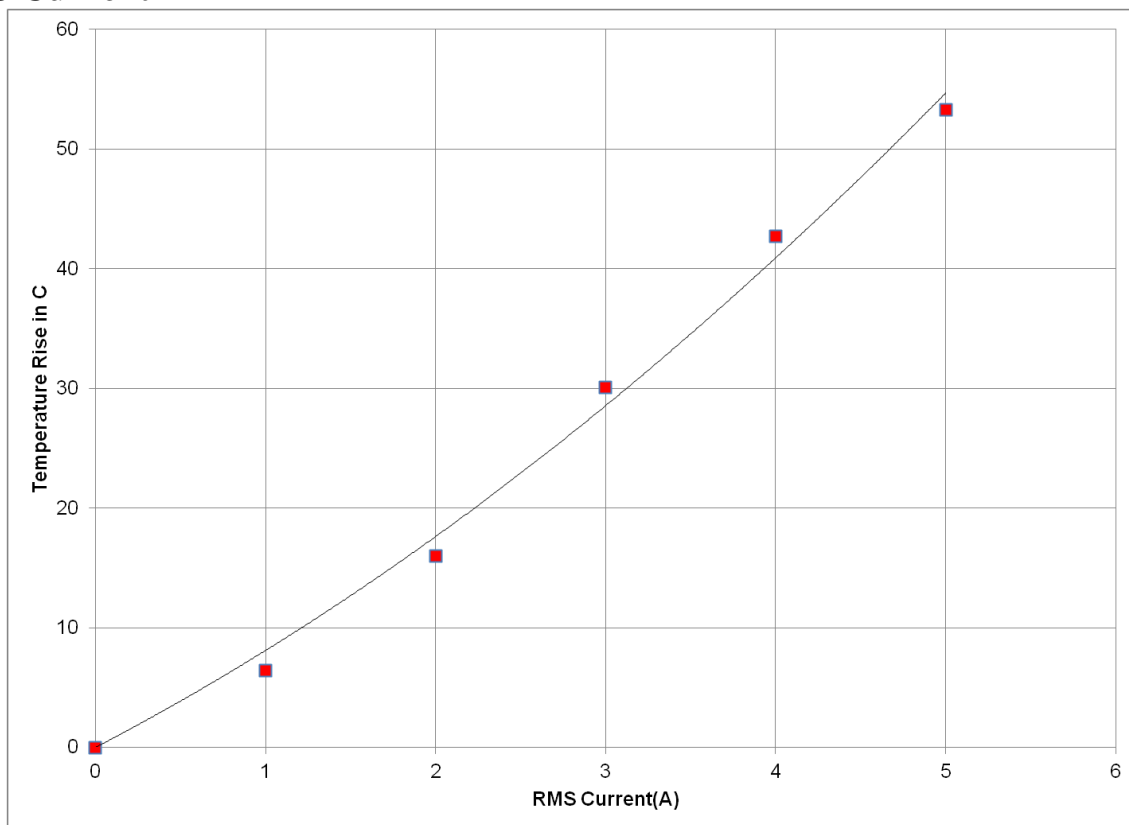
## Charge Current



**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  $160\text{mF} \times 2.3\text{V} / 0.00002\text{A} = 5.1\text{hrs}$  to charge a 160mF supercapacitor to 2.3V at 20µA, but Fig 11 shows it took 15hrs. At 200µA 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 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.

Refer to the CAP-XX Supercapacitors Product Guide for information on endurance and shelf life, transportation and storage, assembly and soldering, safety and RoHS/EREACH certification.