

GW109 / GW209 SUPERCAPACITOR

Datasheet Rev 4.3, July 2018

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 GW109 is a single cell supercapacitor. The GW209 is a dual cell supercapacitor with two GW109 cells in series, so GW209 capacitance = Capacitance of GW109/2 and GW209 ESR = 2 x GW109 ESR.

Table 1: Absolute Maximum Ratings

| Parameter | Name | | Conditions | Min | | Max | Units |
|------------------|-------------------|-------|------------|-----|--|------|-------|
| Terminal Voltage | V _{peak} | GW109 | | 0 | | 2.75 | V |
| | | GW209 | | | | 5.5 | |
| Temperature | T _{max} | | | -40 | | +70 | °C |

Table 2: Electrical Characteristics

| Parameter | Name | | Conditions | Min | Typical | Max | Units |
|---------------------------|------------------|-------|-------------------|-----|---------|-----|-------|
| Terminal Voltage | V _n | GW109 | | 0 | | 2.5 | V |
| | | GW209 | | 0 | | 5.0 | |
| Capacitance | C | GW109 | DC, 23°C | 256 | 320 | 384 | mF |
| | | GW209 | | 128 | 160 | 192 | |
| ESR | ESR | GW109 | DC, 23°C | | 30 | 36 | mΩ |
| | | GW209 | | | 55 | 66 | |
| Leakage Current | I _L | | 2.3V, 23°C 120hrs | | 0.5 | 1 | μA |
| RMS Current | I _{RMS} | | 23°C | | | 6 | A |
| Peak Current ¹ | I _P | | 23°C | | | 30 | A |

¹Non-repetitive current, single pulse to discharge fully charged supercapacitor.

Table 3: Thickness

| | | | | | |
|--------|-------|---|--------|-------|--|
| GW109F | 1.0mm | No adhesive tape on underside of the supercapacitor | GW109G | 1.1mm | Adhesive tape on underside, release tape removed |
| GW209F | 2.1mm | | GW209G | 2.2mm | |

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.

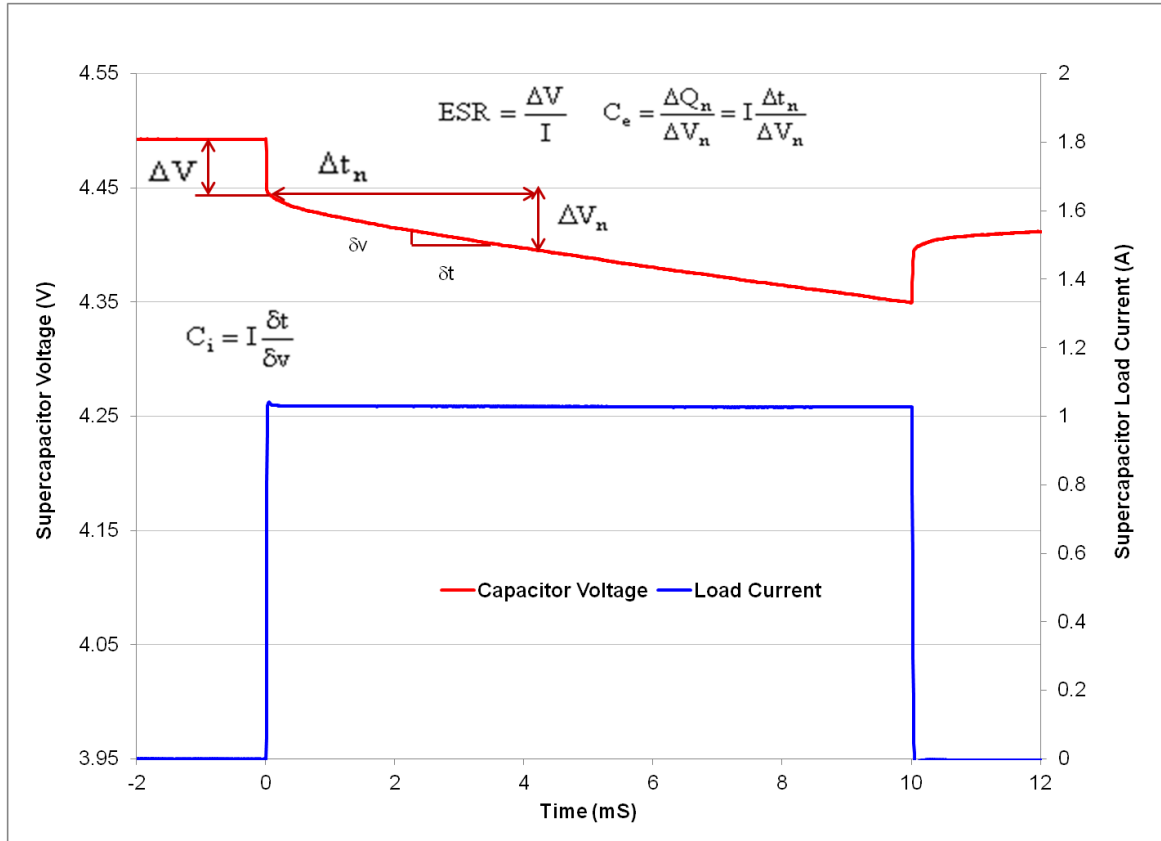


Figure 1: Effective capacitance, instantaneous capacitance and ESR for a GW209

The ESR is found by dividing the instantaneous voltage step (ΔV) by I . In this example $= (4.492V - 4.447V)/1.03A = 43.7m\Omega$.

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 Δt_n , $C_e(\Delta t_n)$ is found by dividing the total charge removed from the capacitor (ΔQ_n) by the voltage lost by the capacitor (ΔV_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 $V_{2ms} = (4.447V - 4.414V) = 33mV$. Therefore $C_e(2ms) = 1.03A \times 2ms / 33mV = 62.4mF$. After 10ms, the voltage drop $= 4.447V - 4.349V = 98mV$. Therefore $C_e(10ms) = 1.03A \times 10ms / 98mV = 105mF$. The DC capacitance of a GW209 = $160mF$. Note that ΔV , 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

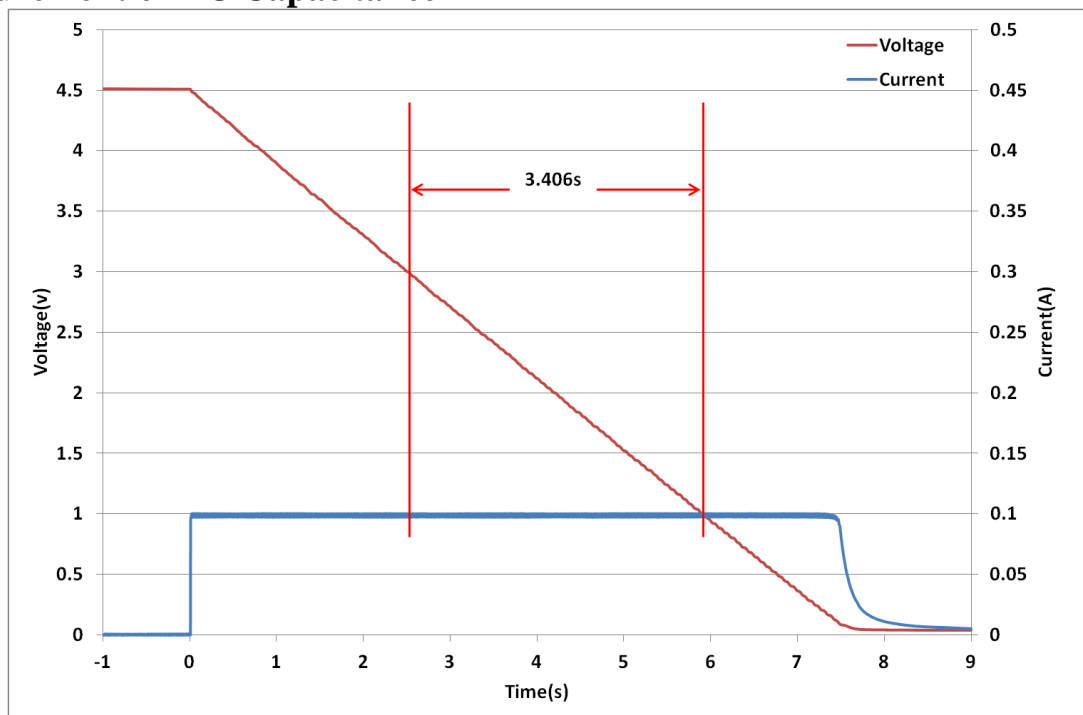


Fig 2: Measurement of DC Capacitance for a GW209

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, $C = 0.1A \times 3.406s / 2V = 170.3mF$, which is well within the 160mF +/- 20% tolerance for a GW209 cell.

Measurement of ESR

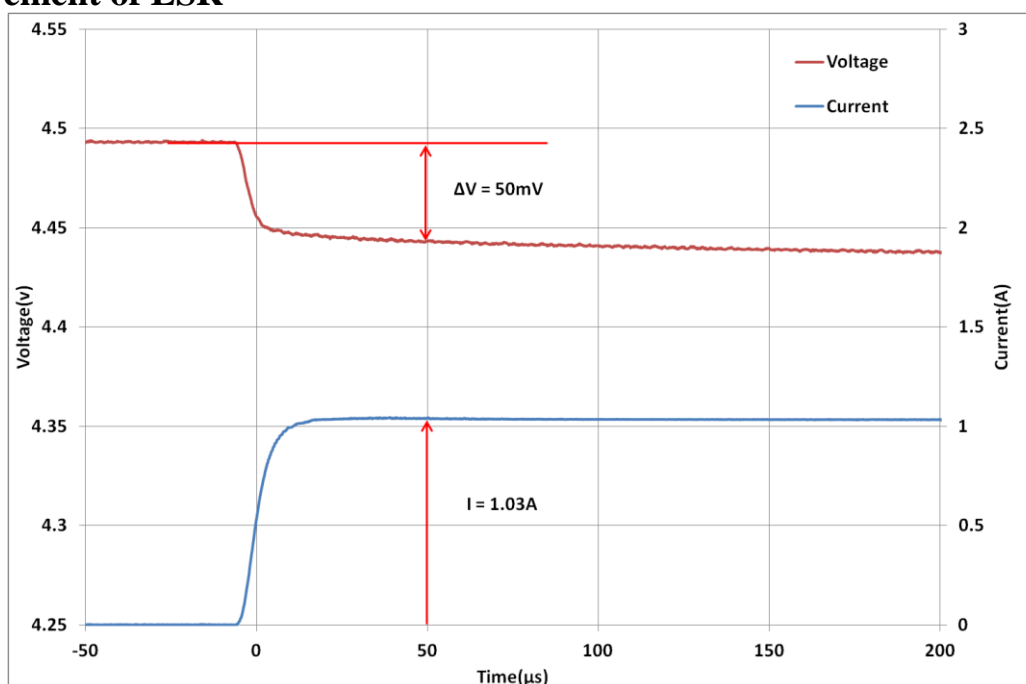


Fig 3: Measurement of ESR for a GW209

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 $50mV / 1.03A = 48.5m\Omega$.

Effective Capacitance

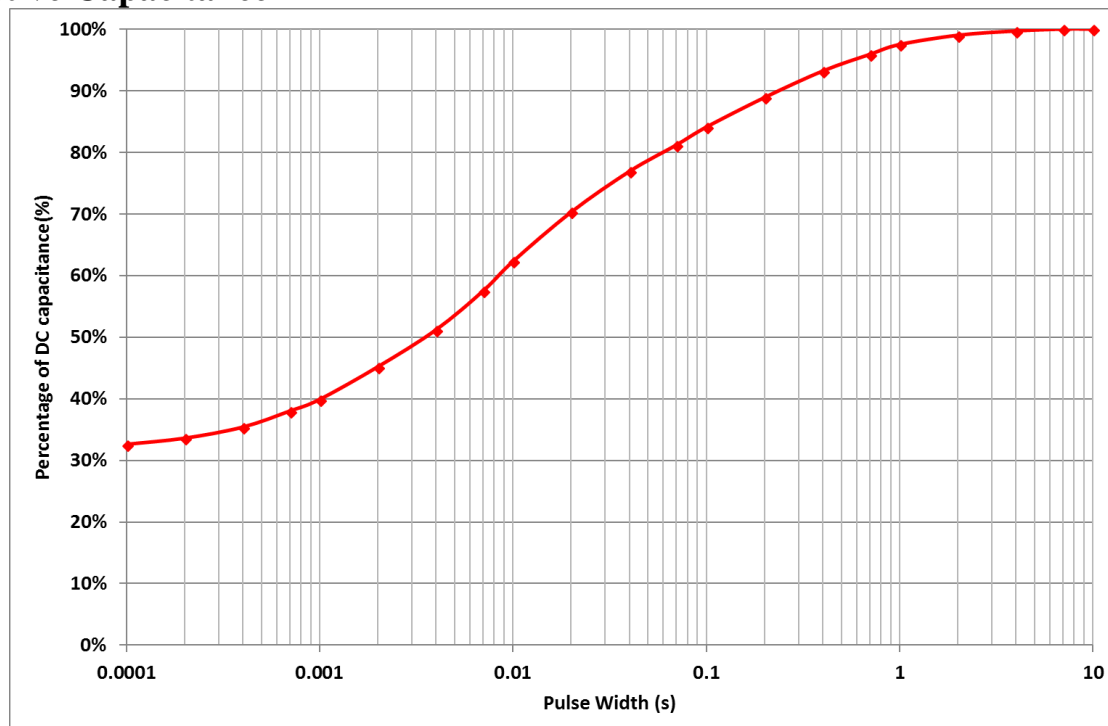


Figure 4: Effective Capacitance

Fig 4 shows the effective capacitance for the GW109, GW209 @ 23°C. This shows that for a 1ms PW, you will measure 40% of DC capacitance or 128mF for a GW109 or 64mF for a GW209. At 10ms you will measure 62% of the DC capacitance, and at 100msecs you will measure 84% 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 10ms, then you would use the $C_{eff}(10ms) = 62\% \text{ of DC capacitance} = 99mF$ for a GW209, so $V_{drop} = 1A \times ESR + 1A \times \text{duration}/C = 1A \times 55m\Omega + 1A \times 10ms / 99mF = 156mV$. The next section on pulse response shows how the effective capacitance is sufficient for even short pulse widths.

Pulse Response

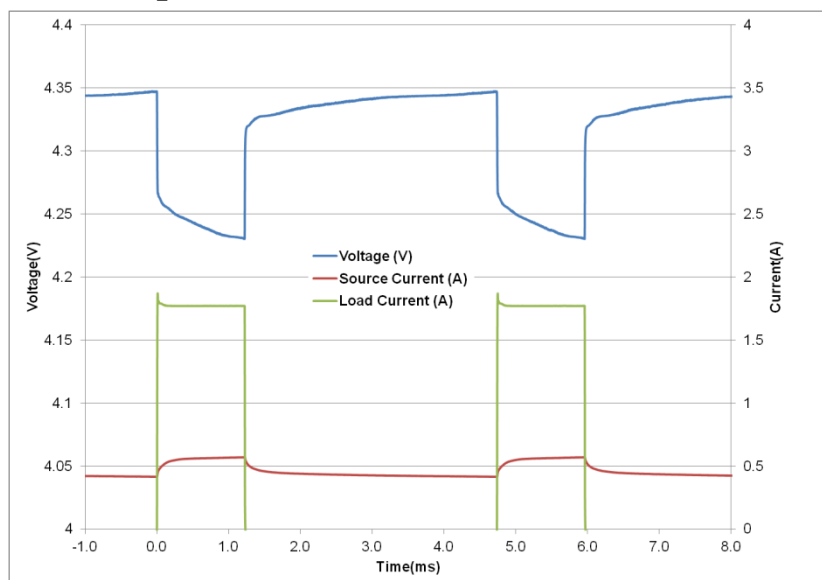


Fig 5 shows that the GW209 supercapacitor does an excellent job supporting a GPRS class 10 pulse train, drawing 1.8A for 1.1ms at 25% duty cycle. The source is current limited to 0.6A and the supercapacitor provides the 1.2A difference to achieve the peak current. At first glance the freq response of Fig 8 indicates the supercapacitor would not support a 1ms pulse, but the C_{eff} of 31.6mF coupled with the low ESR supports this pulse train with only ~117mV droop in the supply rail.

Fig 5: GW209 Pulse Response with GPRS Class 10 Pulse Train

DC Capacitance variation with temperature

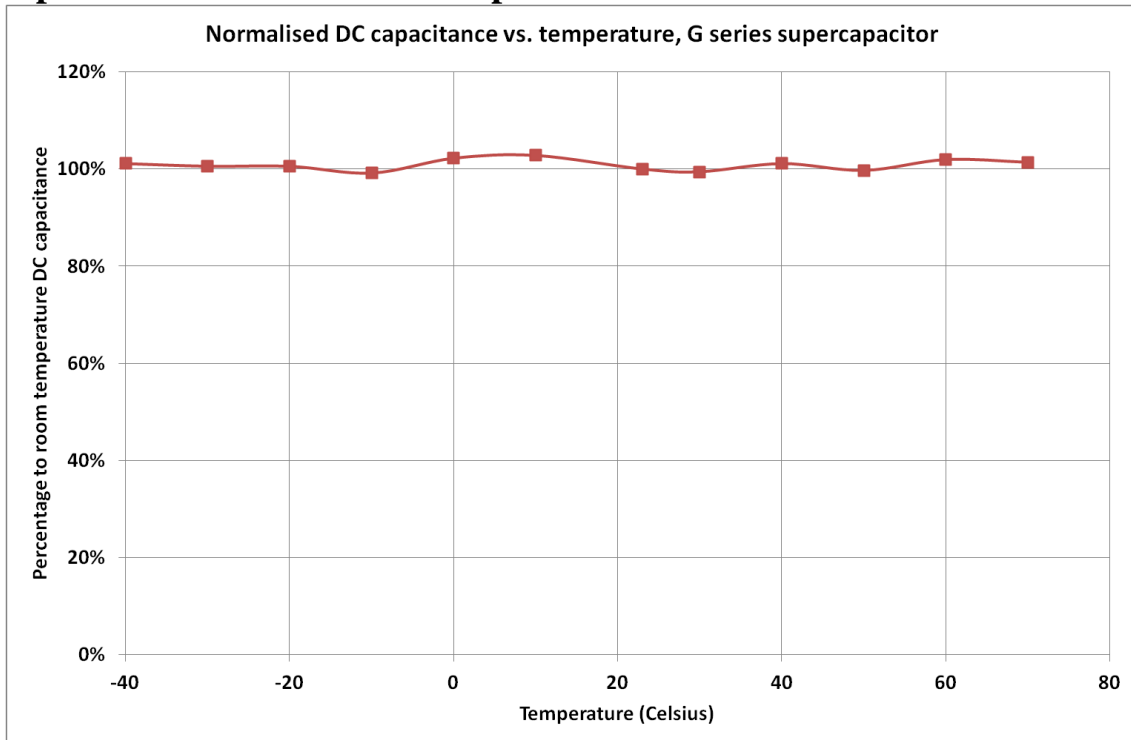


Figure 6: Capacitance change with temperature

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

ESR variation with temperature

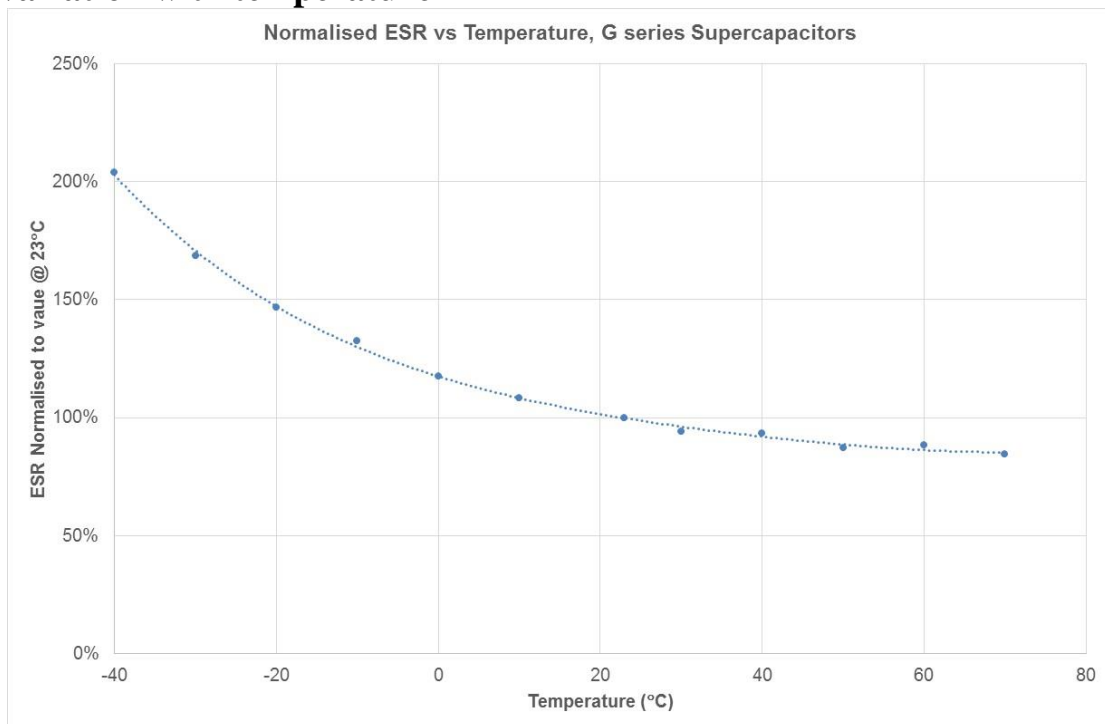


Figure 7: ESR change with temperature

Fig 7 shows that ESR at -40°C is ~2 x ESR at room temp, and that ESR at 70°C is ~0.8 x ESR at room temperature.

Frequency Response

GW209 Magnitude and Phase vs. Frequency

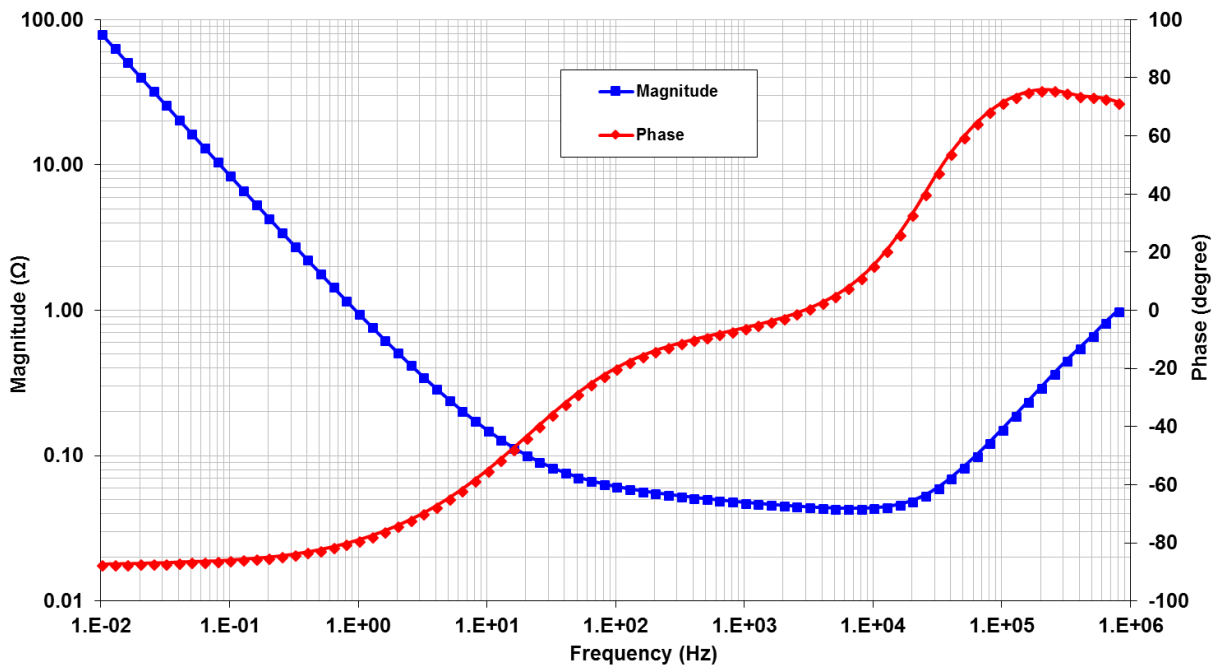


Fig 8: Frequency Response of Impedance (biased at 5V with a 50mV test signal)

GW209 ESR, Capacitance and Inductance vs. Frequency

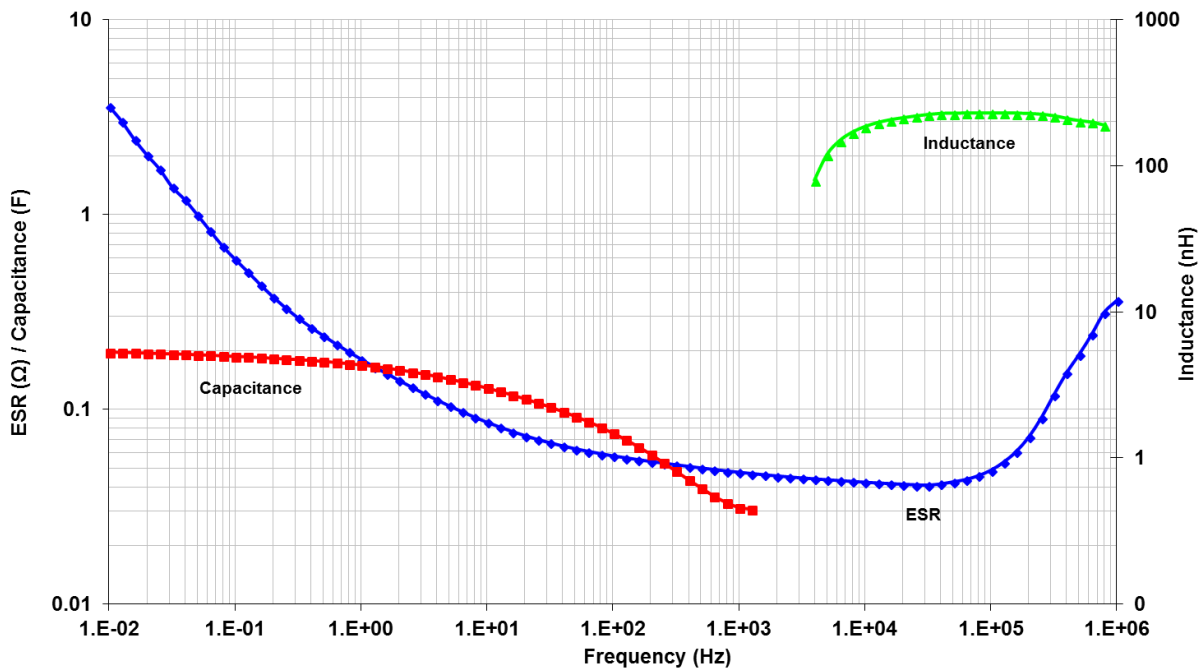


Fig 9: Frequency Response of ESR, Capacitance & Inductance

Fig 8 shows the supercapacitor behaves as an ideal capacitor until approx 20 Hz when the magnitude no longer rolls off proportionally to 1/freq and the phase crosses -45° . 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

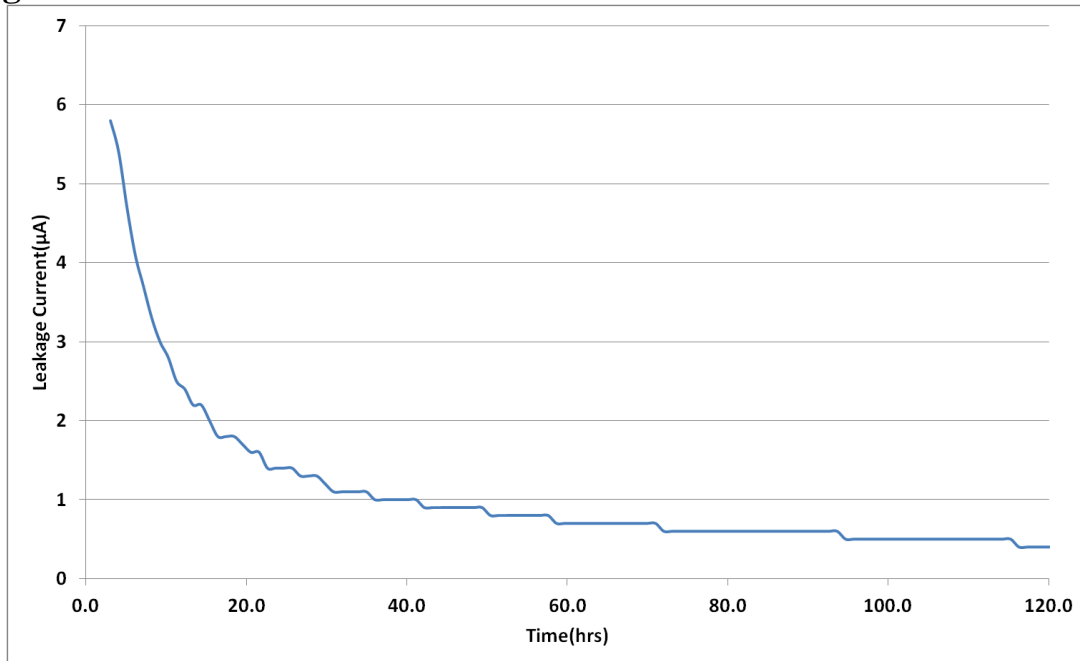


Fig 10: Leakage Current

Fig 10 shows the leakage current for GW109 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

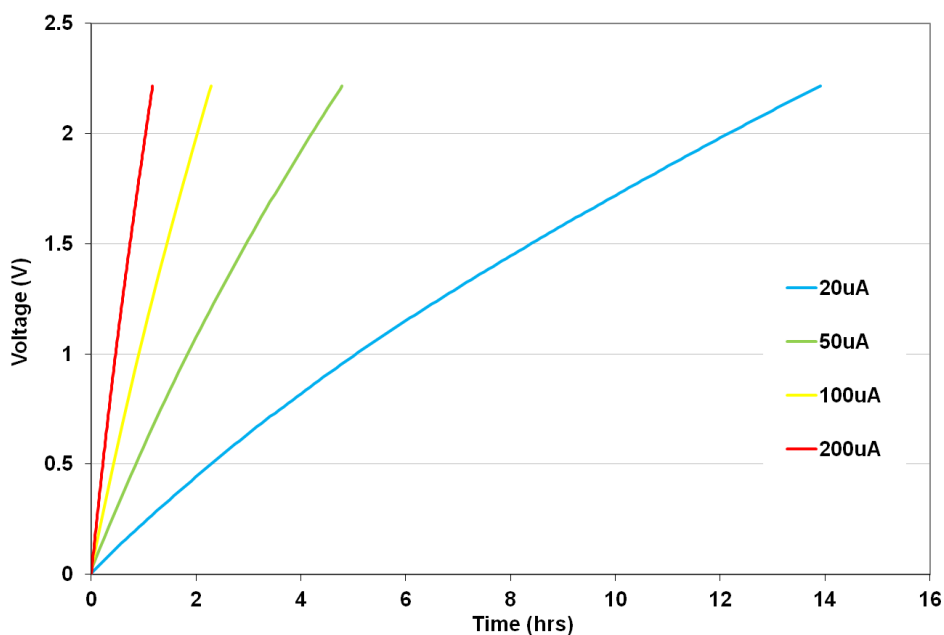


Fig 11: Charging an GW109 with low current

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 $0.32F \times 2.3V / 0.00002A = 10$ hrs to charge a 0.16F supercapacitor to 2.3V at 20µA, but Fig 11 shows it took 14hrs. At 100µA charging occurs at a rate close to the theoretical rate.

RMS Current

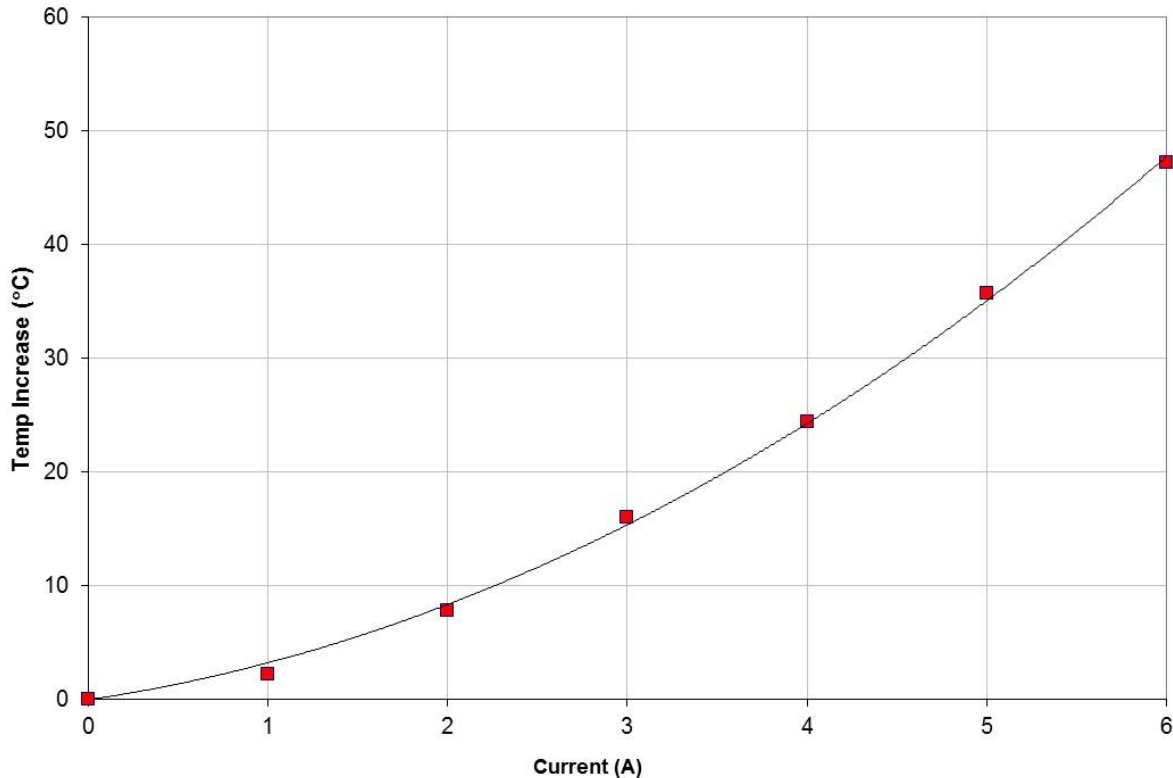


Fig 12: Temperature rise in GW209 with RMS current

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 4.5A, 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.