

HW209 SUPERCAPACITOR

Datasheet Revision 3.1

Features

- High capacitance (140mF @ DC)
- Low ESR (120mΩ @ step change in current);
- High peak current
- High pulsed power
- Thin form factor

Typical Applications

- High power LED Flash
- Improved audio performance
- Automatic Meter Reading
- PC Cards, Compact Flash Cards & USB
- Load leveling for PDAs & cell phones
- Power support during battery contact bounce

Electrical Specifications

Table 1: Nominal Characteristics

Device	Nominal Capacitance ¹	Nominal ESR ²	Tolerance about nominal value	Footprint	Height
HW209	140mF	120mΩ	±20%	28.5mm x 17.0mm	2.20mm

¹At 25°C DC. ²Measured using a 0.5A step in current @ 25°C.

Table 2: Absolute Maximum Ratings

Parameter	Name	Conditions	Min	Max	Units
Terminal Voltage	V _c			5.8	V
Temperature	T		-40	+85	°C

Table 3: Electrical Characteristics

Parameter	Name	Conditions	Min	Typical	Max	Units
Terminal Voltage	V _c				5.5	V
Leakage Current ¹	I _L	5.5V, 25°C 60hrs		1	4	μA
RMS Current	I _{RMS}	25°C			3.6	A
Peak Current ²	I _P	25°C			27	A

¹Refer to cap-XX for details. ²Single pulse, non repetitive current.

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 capacitor as in figure 1. In this figure the supercapacitor is pre-charged and then discharged with a current pulse (I). The ESR is found by dividing the instantaneous voltage step (ΔV) by I. 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 (C_e) is found by dividing the total charge removed from the capacitor (ΔQ_n) by the voltage lost by the capacitor (ΔV_n). 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.

In the example of Fig 1, using an HX209, $\Delta V = 5.40V - 5.29V = 0.11V$, $I = 0.97A$, so $ESR = 0.11V/0.97A = 113m\Omega$. Similarly for a $\Delta V_n = 5.29V - 4.90V = 0.39V$, $\Delta t_n = 0.02s$, and $I = 0.97A$. Therefore, $C = 0.97A \times 0.02s / 0.39V = 49.7mF$ which corresponds to 43% of the nominal capacitance (see figure 4 – Effective Capacitance).

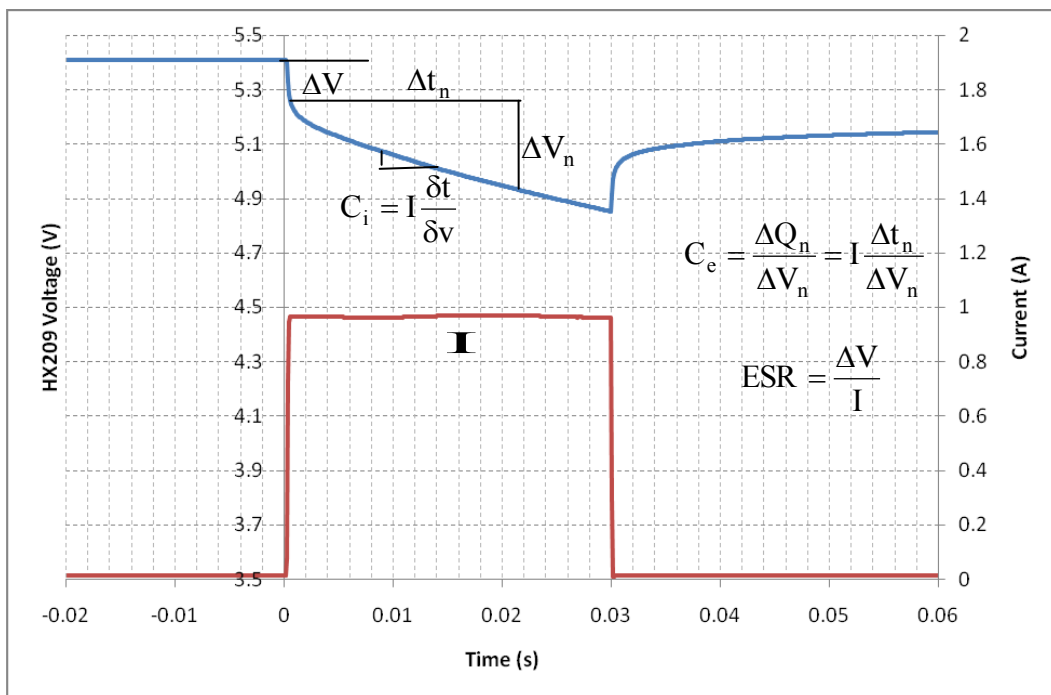


Figure 1: Definitions for Effective Capacitance, Instantaneous Capacitance and ESR

DC Capacitance

CAP-XX measures DC capacitance by charging the supercapacitor to 5.5V then disconnecting the supercapacitor from the source, and applying a constant current discharge of 100mA. We measure the time taken to drop from 3V to 1V, so $C = 100mA \times \text{time taken to drop from 3V to 1V} = 2V$.

In the example below for a $\Delta V_n = 3.0V - 1.0V = 2V$, the corresponding $\Delta t_n = 2.8s$. $C = I \times \Delta t_n / \Delta V_n$ where $I = 0.100A$, therefore $C = 0.100 \times 2.8s / 2V = 140mF$.

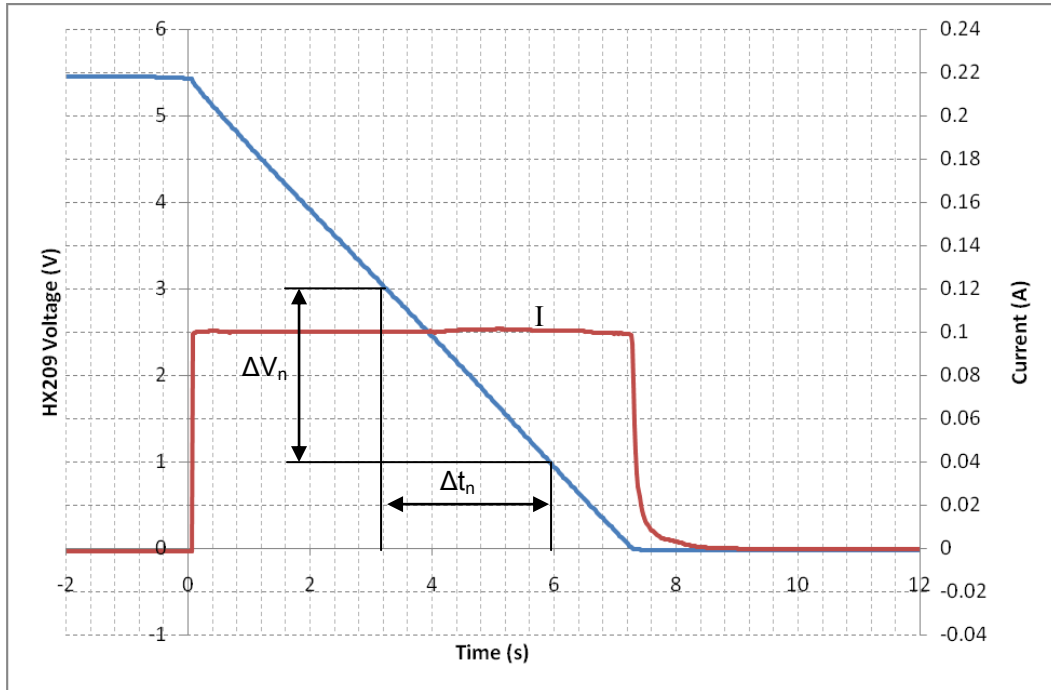


Figure 2: Measurement of DC capacitance

ESR Measurement

CAP-XX measures ESR by measuring the voltage drop across the supercapacitor when a current step is applied to a supercapacitor. The supercapacitor is first charged to 5.5V then disconnected from the source, and finally the current step applied and the voltage drop measured.

In the example of Fig 3, using an HX209, $\Delta V = 5.40V - 5.29V = 0.11V$, $I = 0.97A$, so $ESR = 0.11V/0.97A = 113m\Omega$.

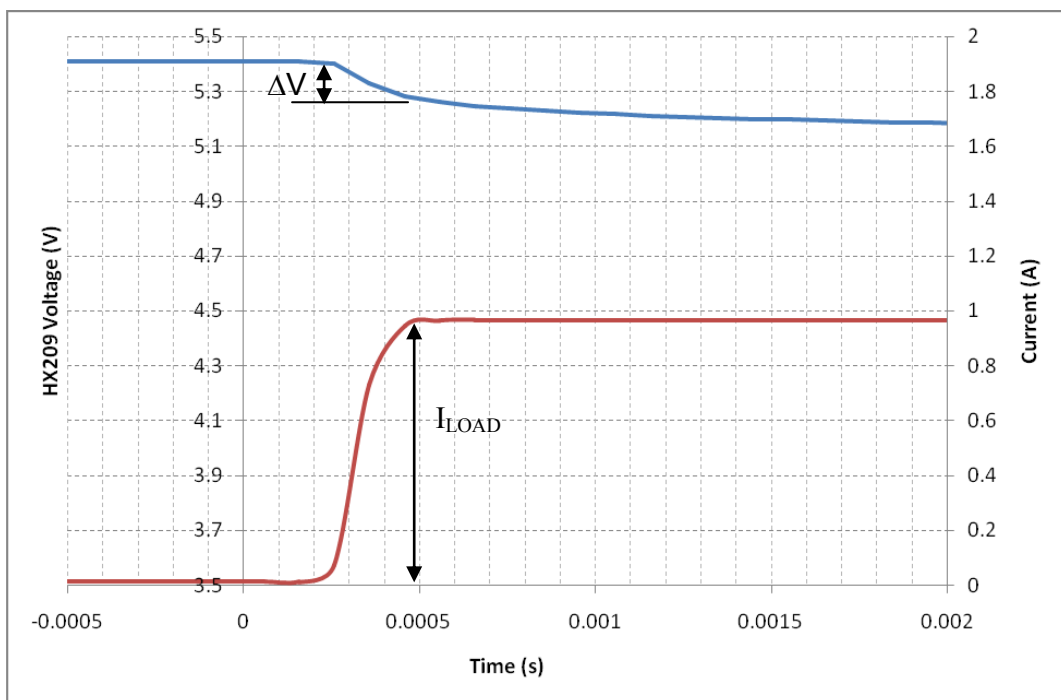


Figure 3: Measurement of ESR

Effective Capacitance

Figure 4 shows the Effective Capacitance for the HX209 @ 25°C. The supercapacitor was charged to and held at 5.5V until the current drawn by the supercapacitor dropped to less than 100µA. The supercapacitor was then disconnected from the source and a constant current discharge of 100mA was applied for 5 seconds.

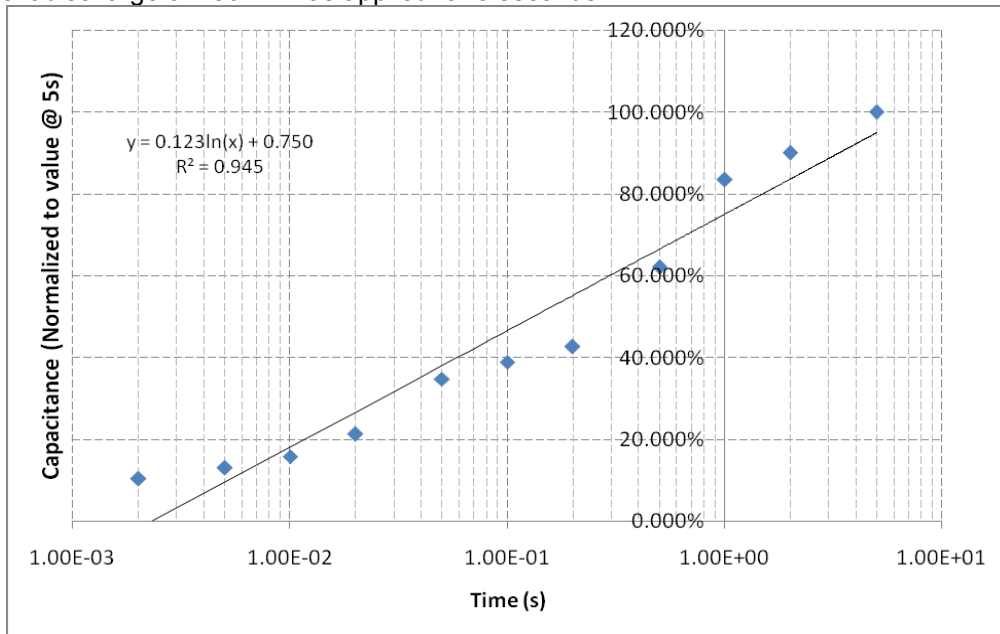


Figure 4: Effective Capacitance – charged to 5.5V and discharged with a 100mA pulse

Pulse Response

Figure 5 shows the voltage ripple for a class 10 GPRS pulse. A HX209 provides a 1.8A load pulse of 1.15ms duration @ 25% duty cycle and the source current is limited to 600mA, though there is some source current overshoot evident in the first 200µs. The low supercapacitor ESR and high effective capacitance result in the load seeing a voltage ripple of only 300mV. The supercapacitor is supplying the difference between the 1.8A load current and the 0.6A source current.

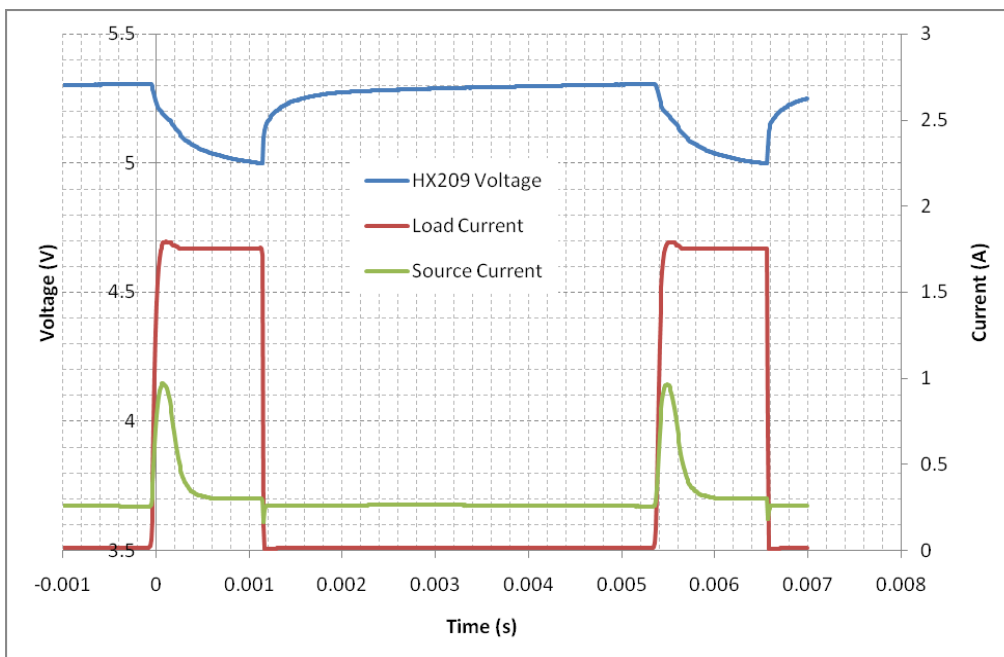


Figure 5: Supercapacitor voltage ripple for GPRS class 10 with 1.8A peak load current

Capacitance and ESR with temperature

Fig 6 below shows that DC capacitance does not vary over the operating temperature range.

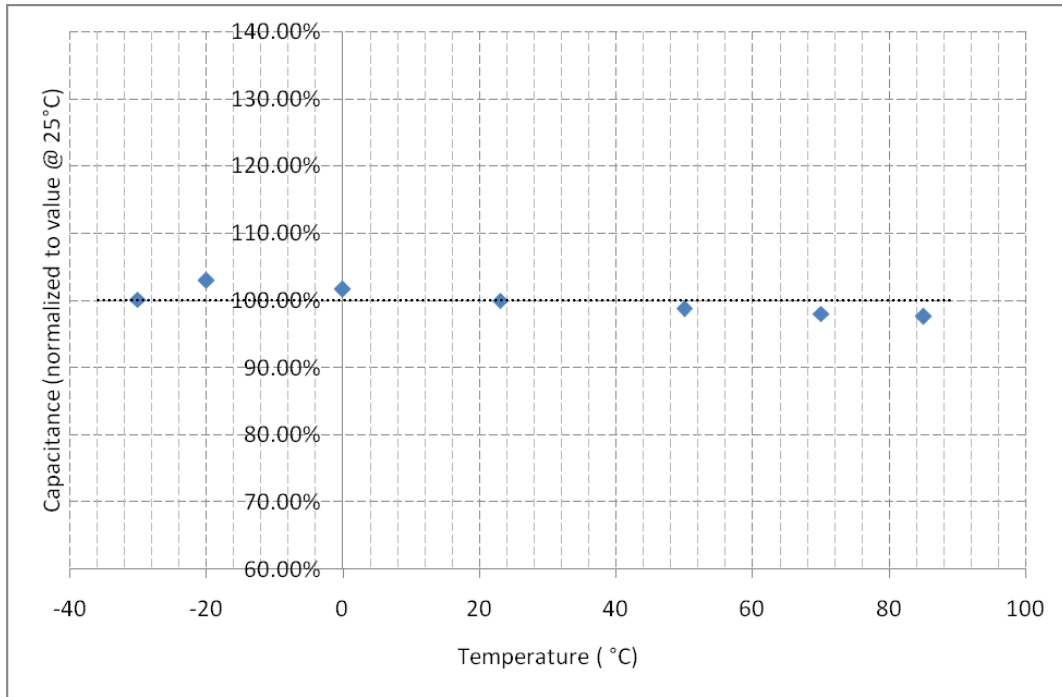


Figure 6: Capacitance change with temperature

Fig 7 shows the relationship between ESR and temperature. ESR at -40°C is ~ 300% of ESR at 25°C.

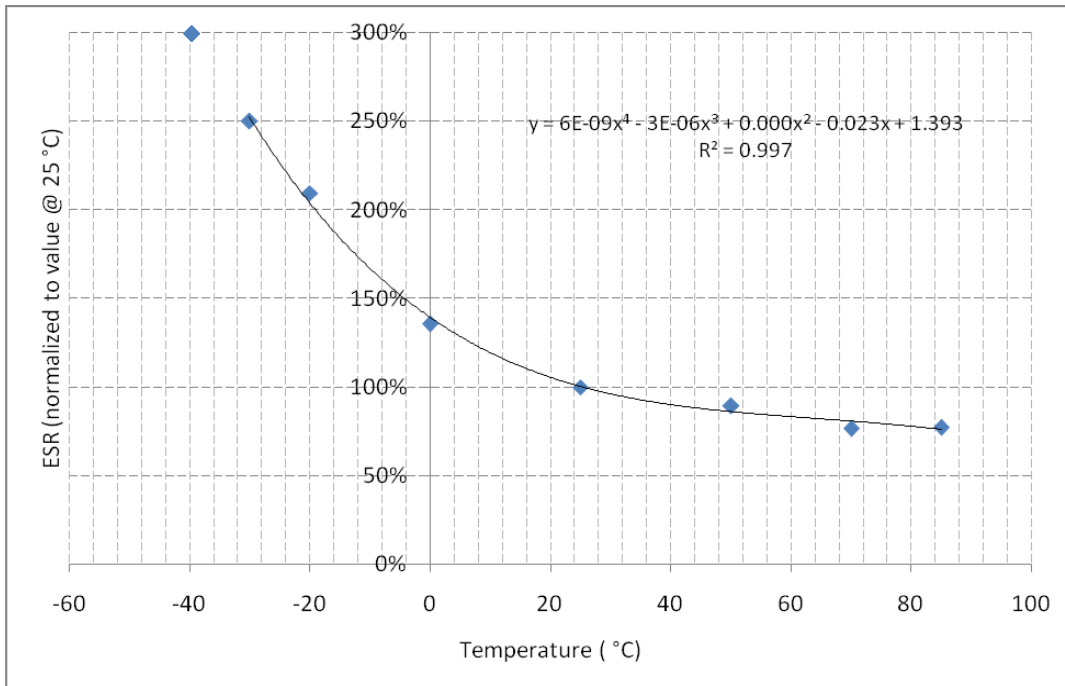


Figure 7: ESR change with temperature

Frequency Response

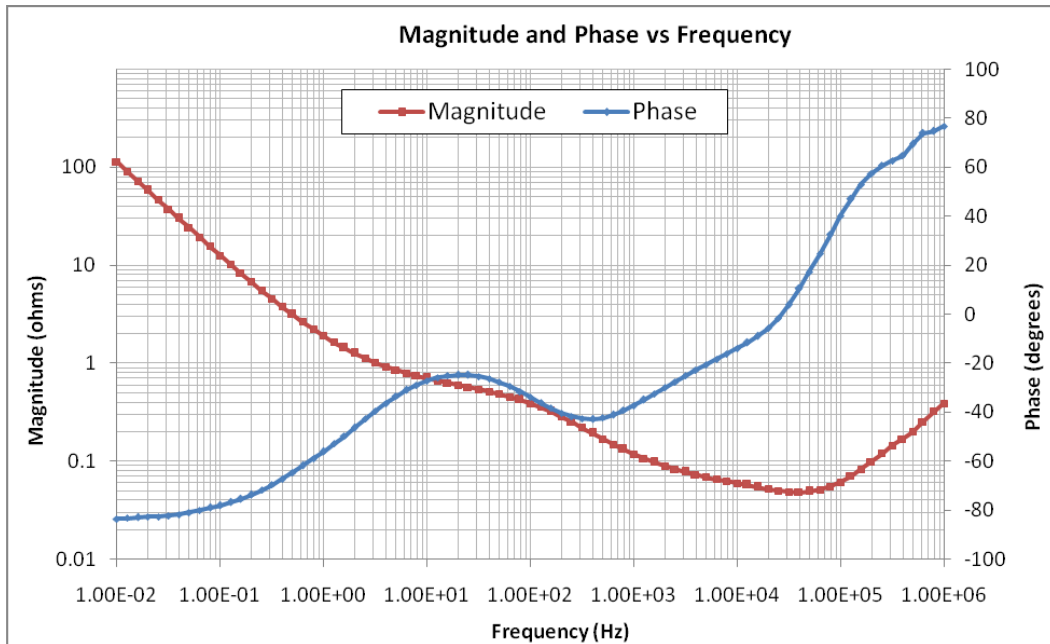


Figure 8: Frequency Response of Impedance (biased at 5.5V with a 50mV test signal)

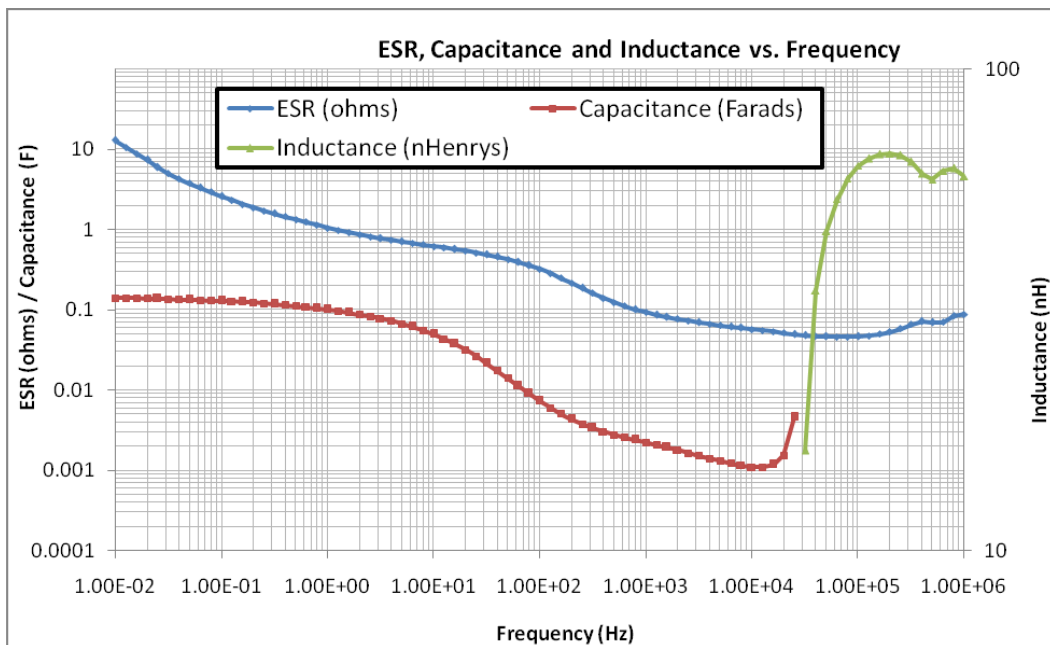


Figure 9: Frequency Response of ESR, Capacitance and Inductance

Fig 8 shows the supercapacitor behaves as an ideal capacitor until approx 10Hz 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 figure 4 which shows the effective capacitance as a function of pulse width. Inductance becomes significant above 10Khz and is approx 60nH. The HX209 is self resonant in the 3 KHz range.

Spice Model

Please refer to www.cap-xx.com for a SPICE model of our supercapacitors. Note that the spice model predicts freq and pulse response, not leakage current over the first 120hrs, prior to equilibrium being reached.

Leakage Current

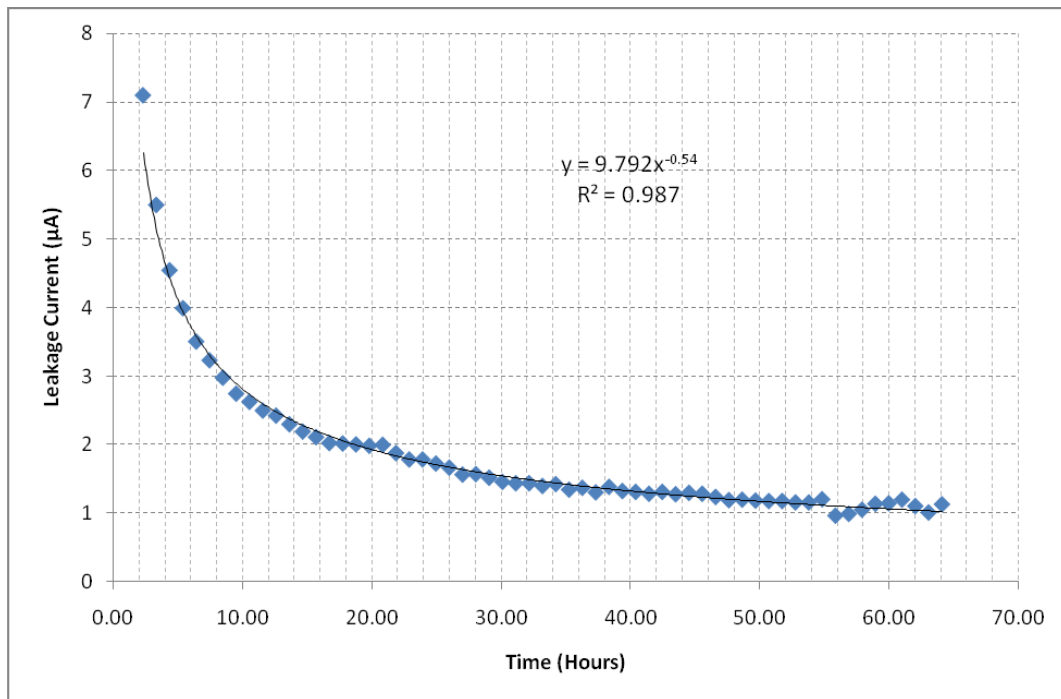


Figure 10: Average leakage current @ 25°C, 5.5V

Figure 10 shows how average leakage current decays with time. After 24hrs @ 25°C, leakage current has decayed to approx 2µA and after 60hrs it has decayed to approx 1µA. This is because the capacitance in a supercapacitor is distributed. This means that although the final terminal voltage has been reached, the device still draws some charge current which continues to decay until it reaches a final equilibrium value of leakage current. Devices would settle to leakage currents < 0.5µA in the long term. At 50°C, leakage current is approximately double the leakage current at 25°C.

Charge Current

Supercapacitors require a minimum charge current before they behave as expected, i.e. they follow $\Delta V = I \times \Delta t / C$, for constant current charging from 0V. For the HX209 this minimum charge current = 20 μ A. Figure 10 illustrates the voltage over time for a single cell of the HX209 using 200 μ A, 100 μ A, 50 μ A, 35 μ A and 20 μ A to achieve a final voltage of 2.75V. Note that the minimum charge current that allows $\Delta V = I \times \Delta t / C$ is 100 μ A.

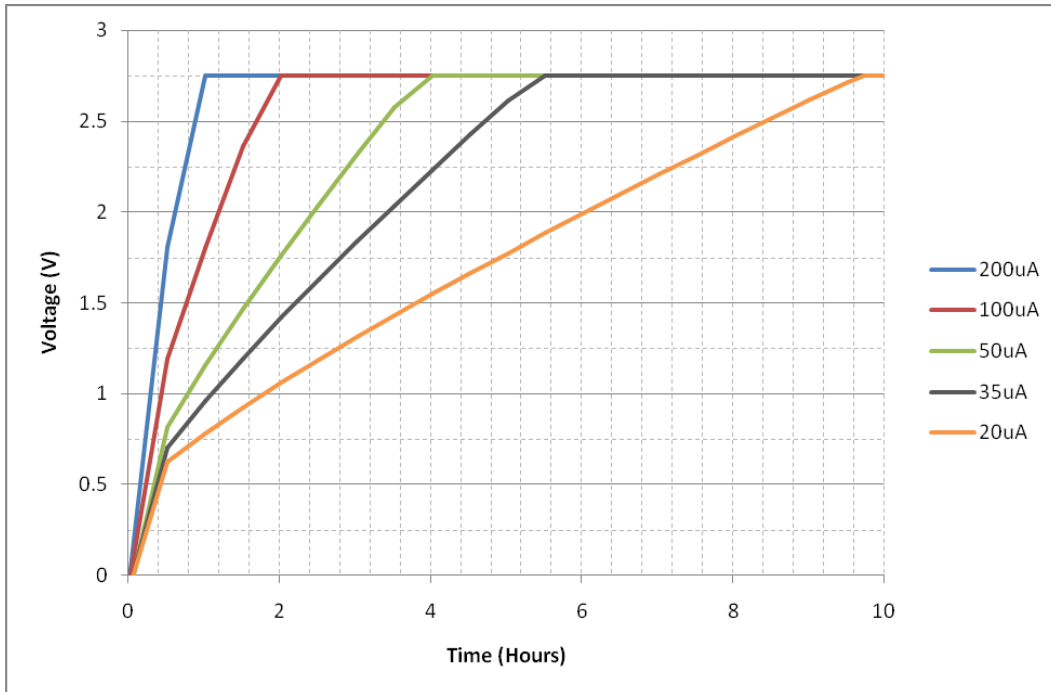


Figure 11: Voltage vs. Time for 200 μ A, 100 μ A, 50 μ A, 35 μ A and 20 μ A Charge Currents at 25 $^{\circ}$ C

Life

Supercapacitors age over time at voltage and temperature. This is evident as a loss of capacitance and increase in ESR. CAP-XX defines time to double ESR as an indicator of rate of ageing at different combinations of operating voltage and temperature.

Soldering

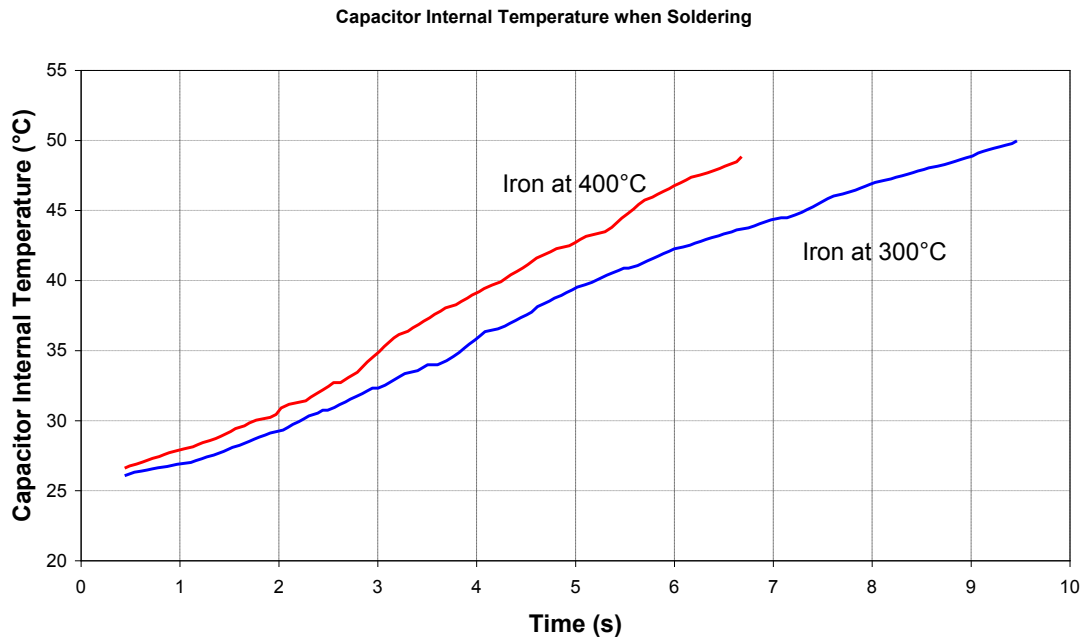


Figure 12: Capacitor temperature rise when soldering

The recommended maximum soldering time is 5 seconds when using an iron at 400°C in an ambient temperature of 25°C.

Vibration

Tested to IEC68-2-6

Type	Sinusoidal
Frequency	55Hz-500Hz
Amplitude	0.35mm±3dB (55Hz to 59.55Hz) 5g±3dB (59.55Hz to 500Hz)
Sweep Rate	1 Oct/min
No. of Cycles	10 (55Hz-500Hz-50Hz)
No. of Axis	3 orthogonal
Results	No electrical or mechanical degradation (adhesive not required)

Shock

Tested to IEC68-2-27

Pulse Shape	Half Sine
Amplitude	30g±20%
Duration	18ms±5%
No. of Shocks	3 in each direction (18 in total)
No. of Axis	3 orthogonal
Results	No electrical or mechanical degradation (adhesive not required)

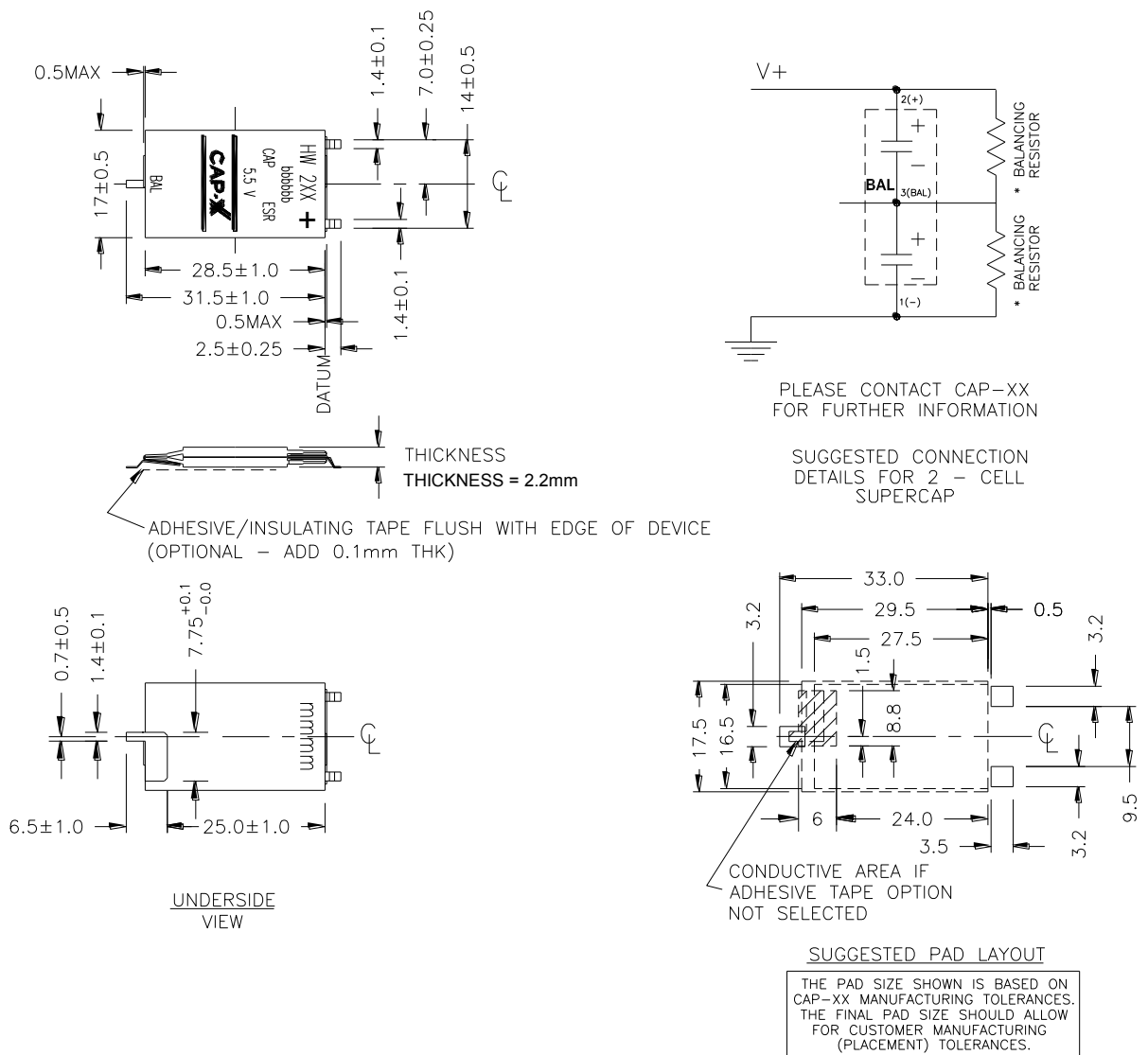


Figure 13: HW209 Product Drawing

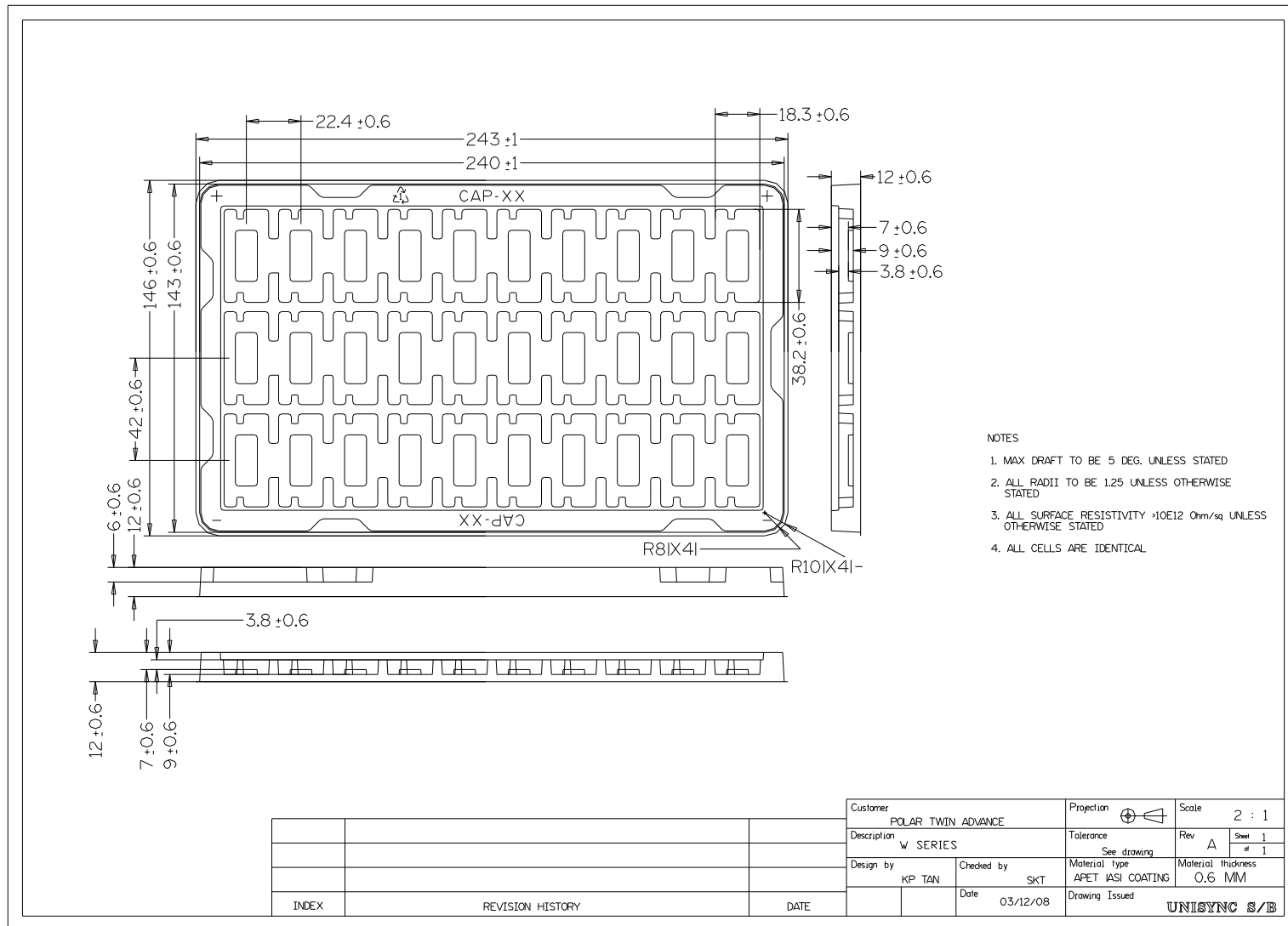


Figure 14: Packaging Tray