

# HW103 / HW203 SUPERCAPACITOR

## Datasheet Rev4.0, October 2015

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 HW103 is a single cell supercapacitor. The HW203 is a dual cell supercapacitor with two HW103 cells in series, so HW203 capacitance = Capacitance of HW103/2 and HW203 ESR = 2 x HW103 ESR.

**Table 1: Absolute Maximum Ratings**

| Parameter        | Name              |       | Conditions | Min | Typical | Max | Units |
|------------------|-------------------|-------|------------|-----|---------|-----|-------|
| Terminal Voltage | V <sub>peak</sub> | HW103 |            | 0   |         | 2.9 | V     |
|                  |                   | HW203 |            |     |         | 5.8 |       |
| Temperature      | T <sub>max</sub>  |       |            | -40 |         | +85 | °C    |

**Table 2: Electrical Characteristics**

| Parameter                 | Name             |       | Conditions         | Min | Typical | Max  | Units |
|---------------------------|------------------|-------|--------------------|-----|---------|------|-------|
| Terminal Voltage          | V <sub>n</sub>   | HW103 |                    | 0   |         | 2.75 | V     |
|                           |                  | HW203 |                    | 0   |         | 5.5  |       |
| Capacitance               | C                | HW103 | DC, 23°C           | 800 | 1000    | 1200 | mF    |
|                           |                  | HW203 |                    | 400 | 500     | 600  |       |
| ESR                       | ESR              | HW103 | DC, 23°C           | 27  | 34      | 41   | mΩ    |
|                           |                  | HW203 |                    | 56  | 70      | 84   |       |
| Leakage Current           | I <sub>L</sub>   |       | 2.75V, 23°C 120hrs |     | 1       | 2    | μA    |
| RMS Current               | I <sub>RMS</sub> |       | 23°C               |     |         | 5    | A     |
| Peak Current <sup>1</sup> | I <sub>P</sub>   |       | 23°C               |     |         | 30   | A     |

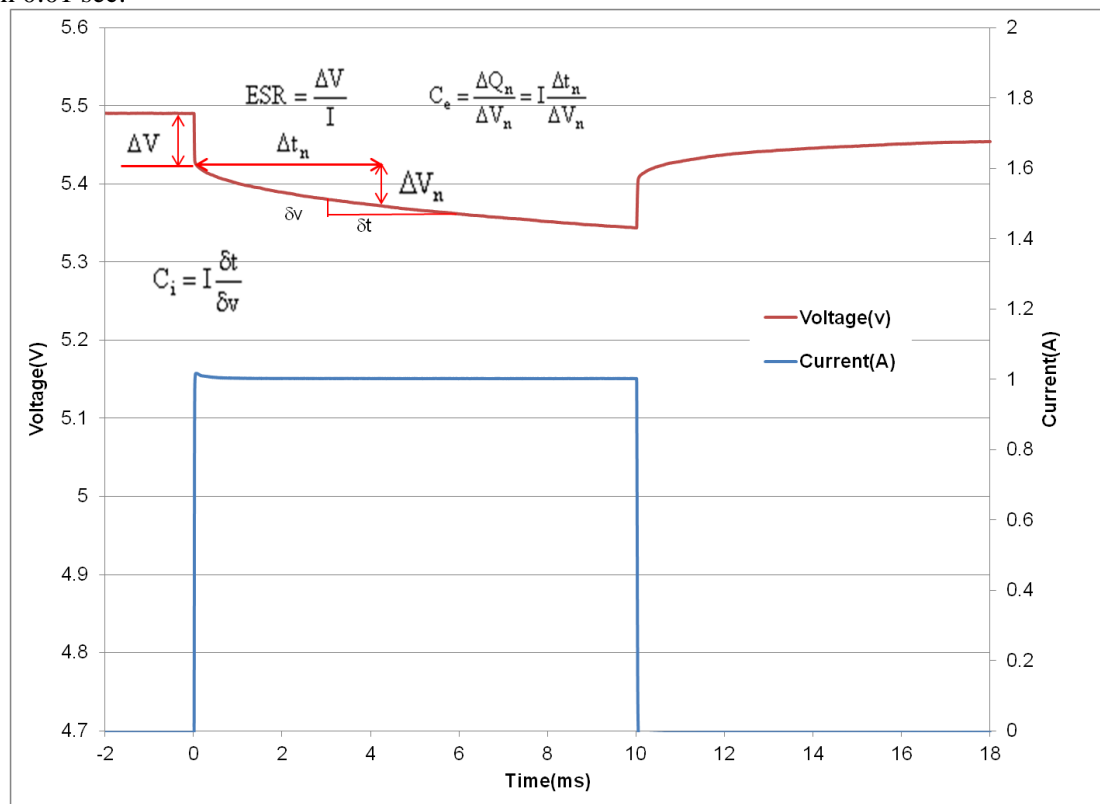
<sup>1</sup>Non-repetitive current, single pulse to discharge fully charged supercapacitor.

**Table 3: Thickness**

|        |        |   |        |        |  |
|--------|--------|---|--------|--------|--|
| HW103F | 1.5mm  | No adhesive tape on underside of the supercapacitor | HW103G | 1.6mm  | Adhesive tape on underside, release tape removed |
| HW203F | 3.00mm |   | HW203G | 3.10mm |  |

## 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 sec.



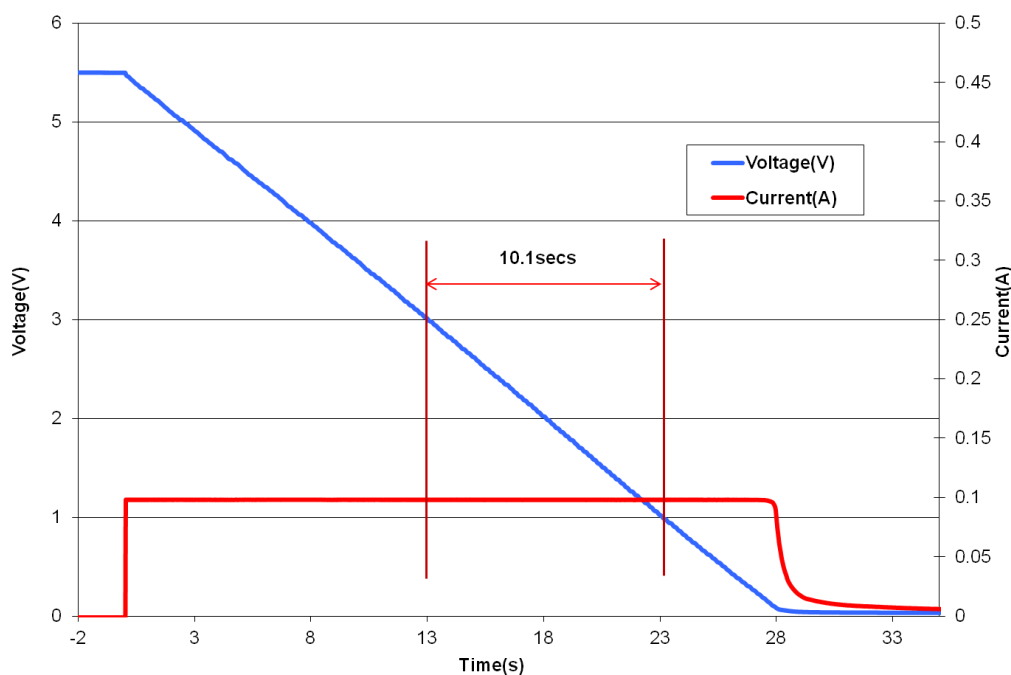
**Figure 1: Effective capacitance, instantaneous capacitance and ESR for an HW203**

The ESR is found by dividing the instantaneous voltage step ( $\Delta V$ ) by  $I$ . In this example  $= (5.490\text{V} - 5.435\text{V})/1\text{A} = 55\text{m}\Omega$ .

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 ( $\sim 10$  secs). After 2msecs, Fig 1 shows the voltage drop  $V_{2\text{ms}} = (5.435\text{V} - 5.389\text{V}) = 46\text{mV}$ . Therefore  $C_e(2\text{ms}) = 1\text{A} \times 2\text{ms}/46\text{mV} = 43.5\text{mF}$ . After 10ms, the voltage drop  $= 5.435\text{V} - 5.344\text{V} = 91\text{mV}$ . Therefore  $C_e(10\text{ms}) = 1\text{A} \times 10\text{ms}/91\text{mV} = 110\text{mF}$ . The DC capacitance of an HW203 = 0.5 F. 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.

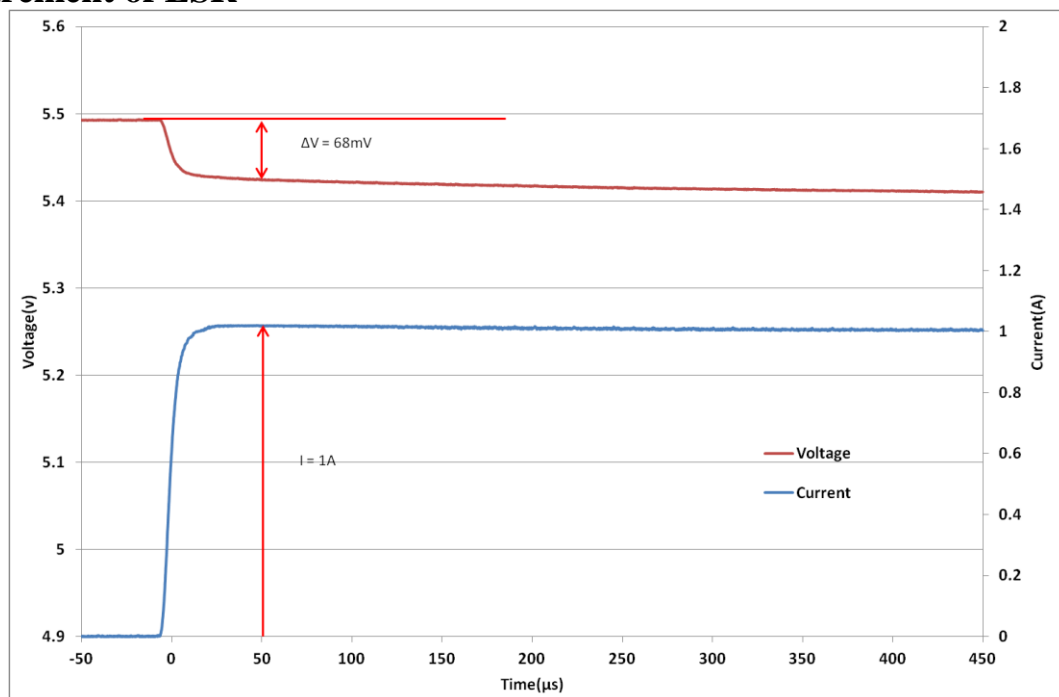
## Measurement of DC Capacitance



**Fig 2: Measurement of DC Capacitance for an HW203**

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,  $C = 0.1A \times 10.1s / 2V = 505mF$ , which is well within the 500mF +/- 20% tolerance for an HW203 cell.

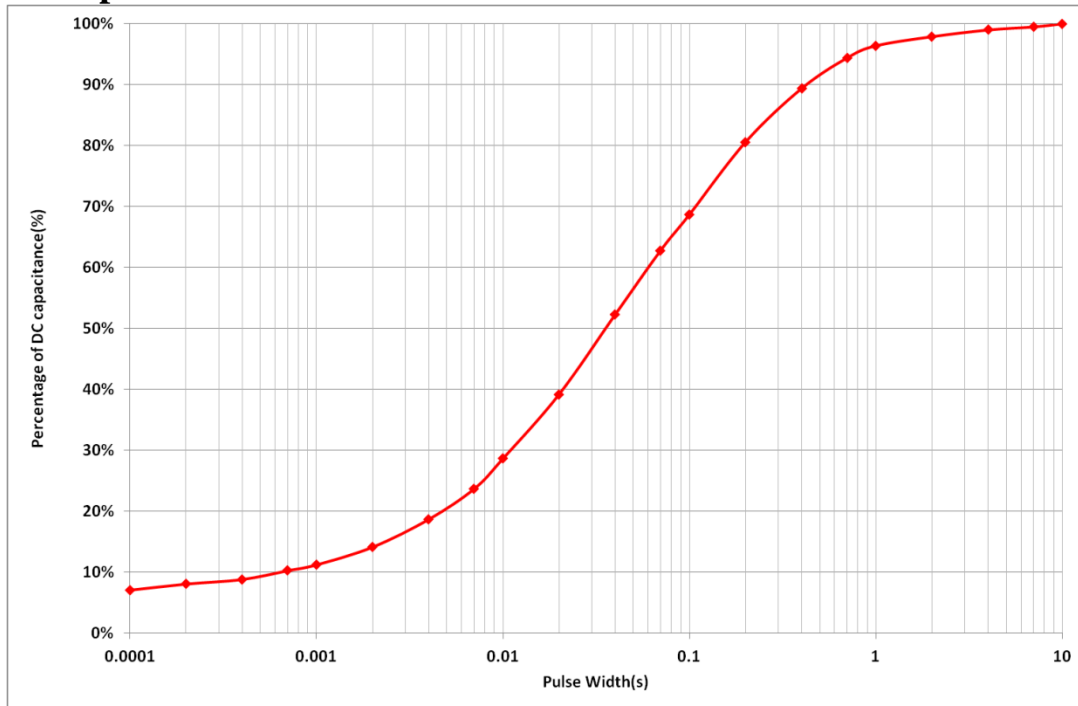
## Measurement of ESR



**Fig 3: Measurement of ESR for an HW203**

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  $68mV/1A = 68m\Omega$ .

## Effective Capacitance



**Figure 4: Effective Capacitance**

Fig 4 shows the effective capacitance for the HW103, HW203 @ 23°C. This shows that for a 1msec PW, you will measure 11% of DC capacitance or 110mF for an HW103 or 55mF for an HW203. At 10msecs you will measure 29% of the DC capacitance, and at 100msecs you will measure 69% 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  $C_{eff}(10msecs) = 29\%$  of DC capacitance = 145mF for an HW203, so  $V_{drop} = 1A \times ESR + 1A \times duration/C = 1A \times 70m\Omega + 1A \times 10ms / 145mF = 139mV$ . The next section on pulse response shows how the effective capacitance is sufficient for even short pulse widths.

## Pulse Response

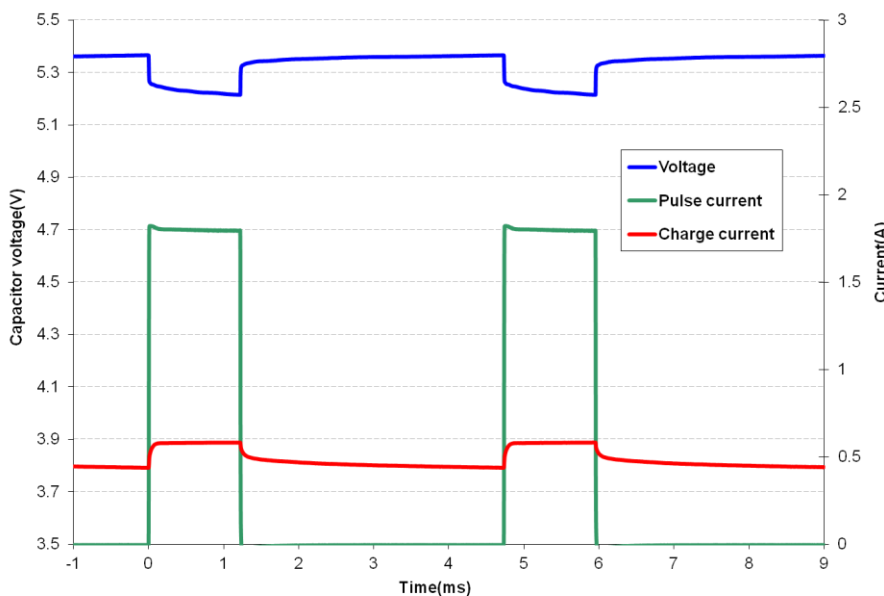


Fig 5 shows that the HW203 supercapacitor does an excellent job supporting a GPRS class 10 pulse train, drawing 1.8A for 1.1ms at 25% duty cycle. The source is current limited to 0.6A and the supercapacitor provides the 1.2A difference to achieve the peak current. At first glance the freq response of Fig 8 indicates the supercapacitor would not support a 1ms pulse, but the  $C_{eff}$  of 55mF coupled with the low ESR supports this pulse train with only ~150mV droop in the supply rail.

**Fig 5: HW203 Pulse Response with GPRS Class 10 Pulse Train**

## DC Capacitance variation with temperature

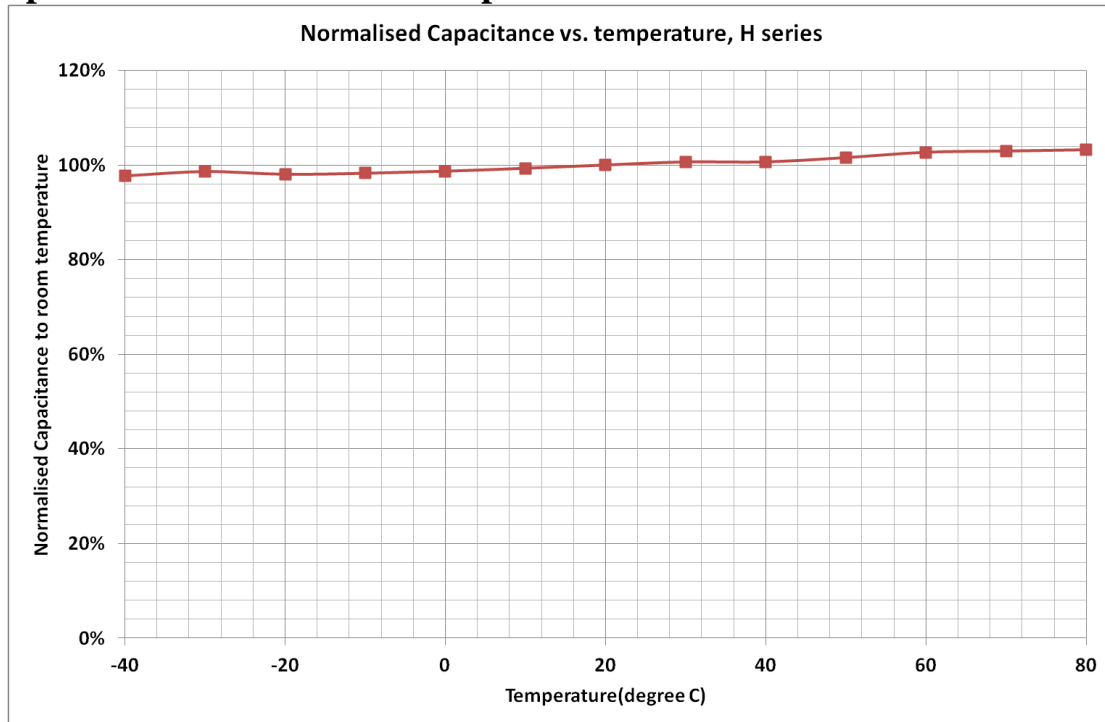


Figure 6: Capacitance change with temperature

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

## ESR variation with temperature

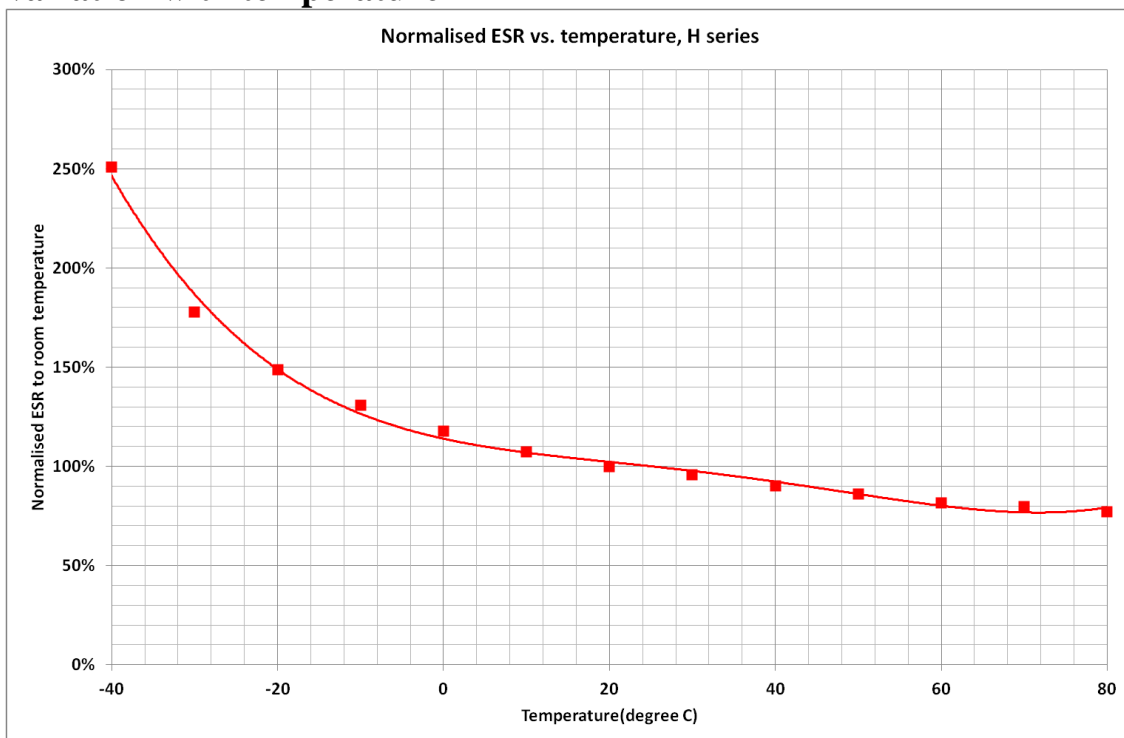
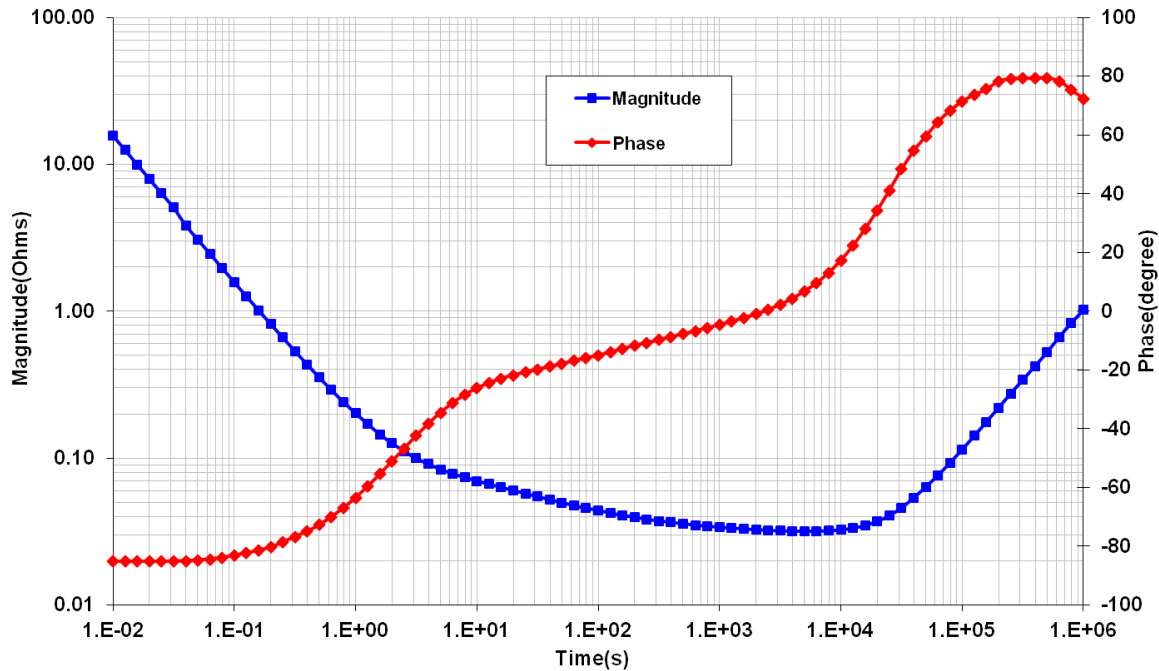


Figure 7: ESR change with temperature

Fig 7 shows that ESR at -40°C is ~2.5 x ESR at room temp, and that ESR at 80°C is ~0.8 x ESR at room temperature.

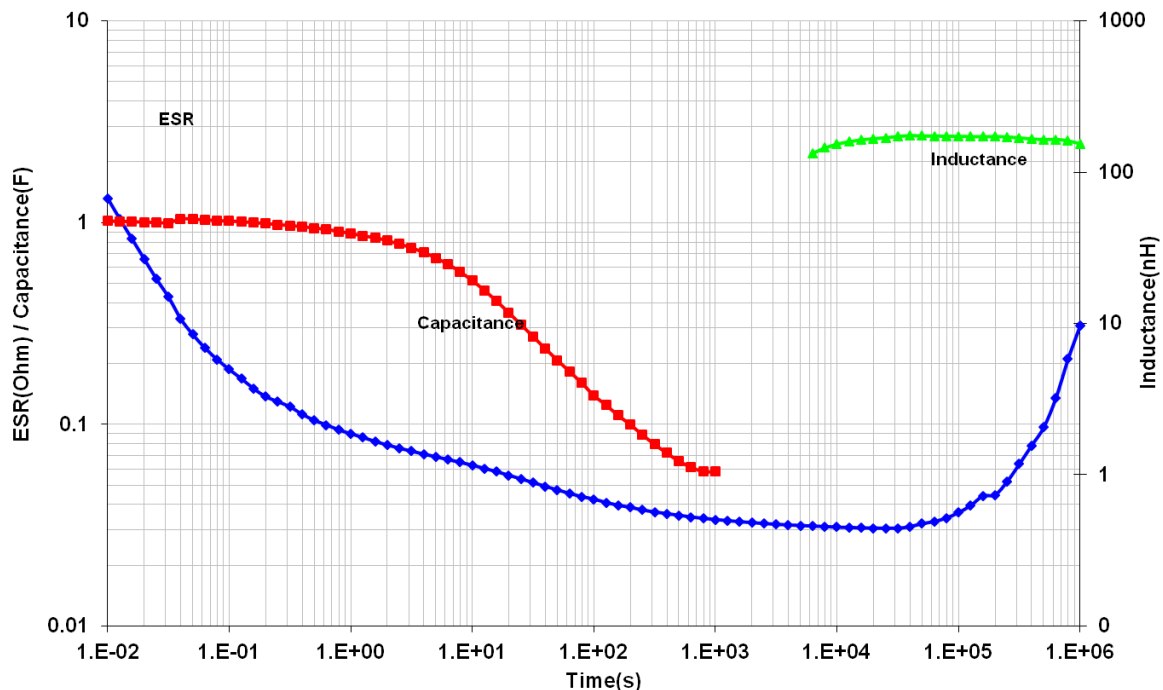
## Frequency Response

HW103 Magnitude and Phase vs. Frequency



**Fig 8: Frequency Response of Impedance (biased at 2.7V with a 50mV test signal)**

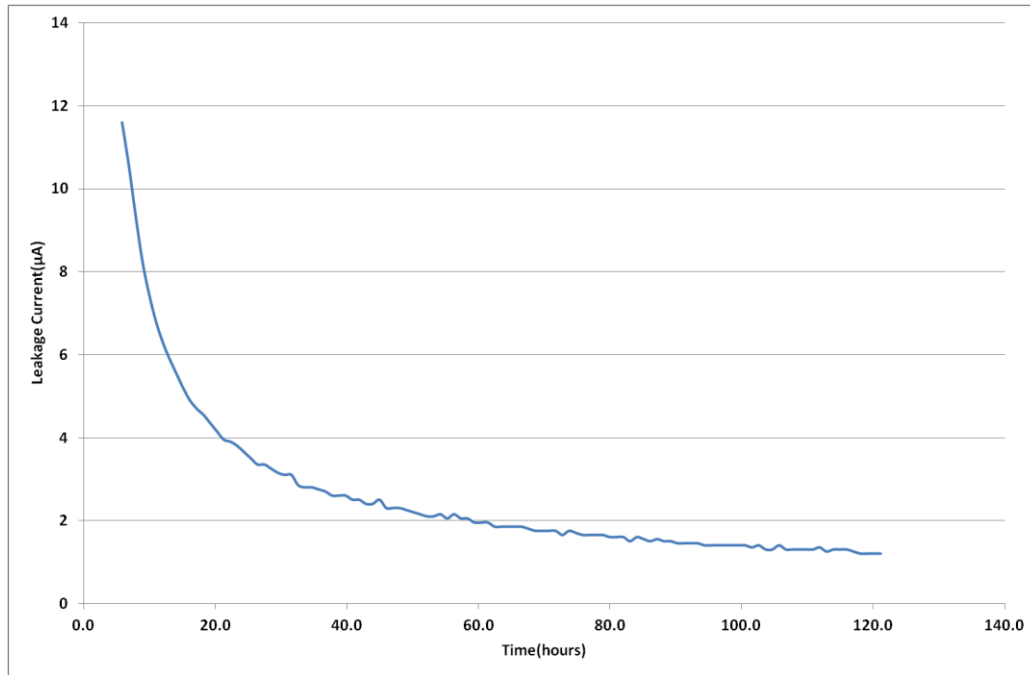
HW103 ESR, Capacitance and Inductance vs. Frequency



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

Fig 8 shows the supercapacitor behaves as an ideal capacitor until approx 3 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.

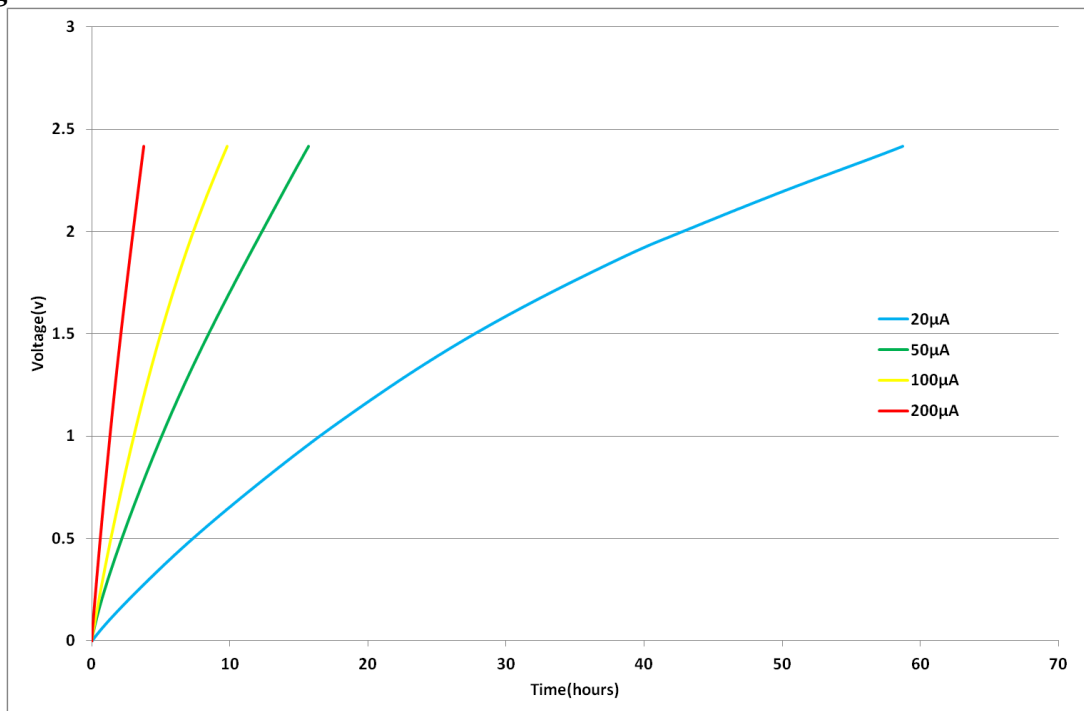
## Leakage Current



**Fig 10: Leakage Current**

Fig 10 shows the leakage current for HW103 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 ~10µA.

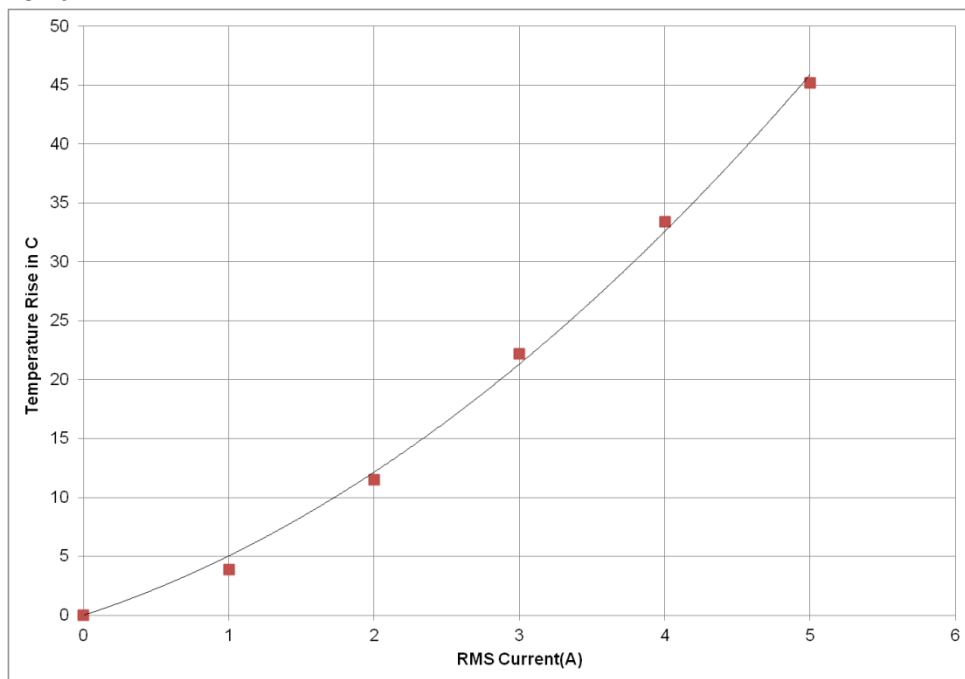
## Charge Current



**Fig 11: Charging an HW103 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  $1\text{ F} \times 2.4\text{V} / 0.00002\text{A} = 33.3\text{hrs}$  to charge a 1 F supercapacitor to 2.4V at 20µA, but Fig 11 shows it took 60hrs. At 200µA charging occurs at a rate close to the theoretical rate.

## RMS Current



**Fig 12: Temperature rise in HW203 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, 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 3.6A, 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.