

## DATASHEET

# HW102 / HW202 SUPERCAPACITOR

Revision 4.4, Dec 2019

## Electrical Specifications

The HW102 is a single cell supercapacitor. The HW202 is a dual cell supercapacitor with two HW102 cells in series, so HW202 capacitance = Capacitance of HW102/2 and HW202 ESR = 2 x HW102 ESR.

**Table 1: Absolute Maximum Ratings**

Parameter	Name		Conditions	Min	Typical	Max	Units
Terminal Voltage	V <sub>peak</sub>	HW102		0		2.9	V
		HW202				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>	HW102		0		2.75	V
		HW202		0		5.5	
Capacitance	C	HW102	DC, 23°C	320	400	480	mF
		HW202		160	200	240	
ESR	ESR	HW102	DC, 23°C		40	48	mΩ
		HW202			75	84	
Leakage Current	I <sub>L</sub>		2.75V, 23°C 120hrs		1	2	μA
RMS Current	I <sub>RMS</sub>		23°C			6	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.

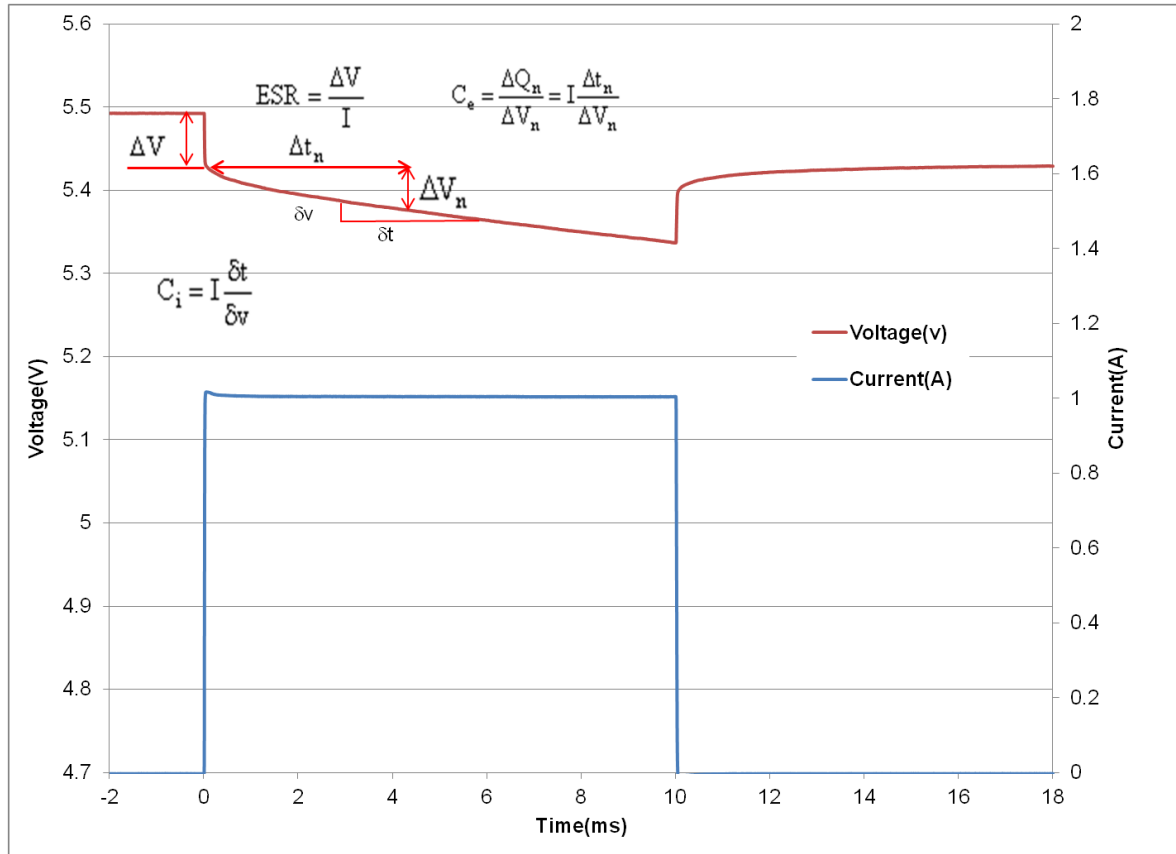
**Table 3: Thickness**

HW102F	1.3mm	No adhesive tape on underside of the supercapacitor	HW102G	1.4mm	Adhesive tape on underside, release tape removed
HW202F	2.7mm		HW202G	2.8mm	

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 sec.



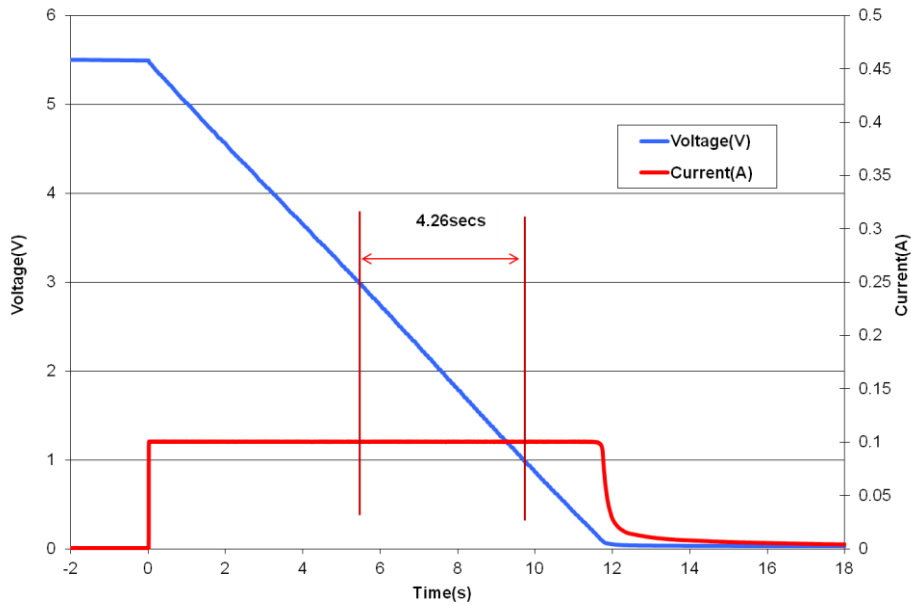
**Fig 1: Effective capacitance, instantaneous capacitance and ESR for an HW202**

The ESR is found by dividing the instantaneous voltage step ( $\Delta V$ ) by  $I$ . In this example =  $(5.492V - 5.438V)/1A = 54m\Omega$ .

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  $V_{2ms} = (5.43 V - 5.40V) = 30mV$ . Therefore  $C_e(2ms) = 1A \times 2ms / 30mV = 67mF$ . After 10ms, the voltage drop =  $5.43 V - 5.34V = 90mV$ . Therefore  $C_e(10ms) = 1 A \times 10ms / 90mV = 111mF$ . The DC capacitance of an HW202 = 0.2 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 behaviour in pulsed applications.

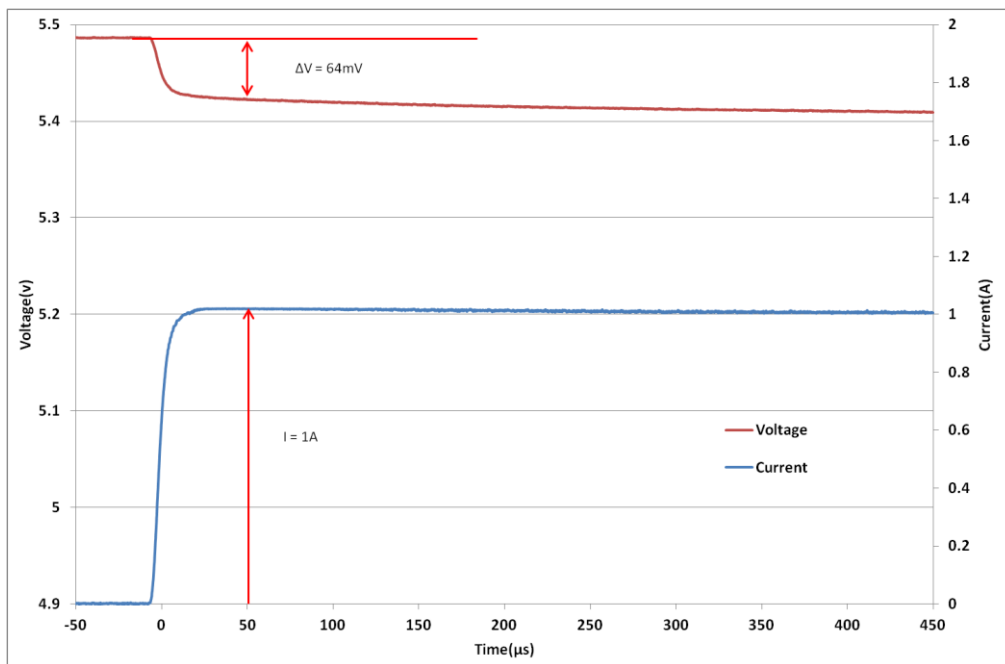
### Measurement of DC Capacitance



**Fig 2: Measurement of DC Capacitance for an HW202**

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,  $C = 0.1A \times 4.26s / 2V = 213mF$ , which is well within the 200mF +/- 20% tolerance for an HW202 cell.

### Measurement of ESR



**Fig 3: Measurement of ESR for an HW202**

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  $64mV/1A = 64m\Omega$ .

### Effective Capacitance

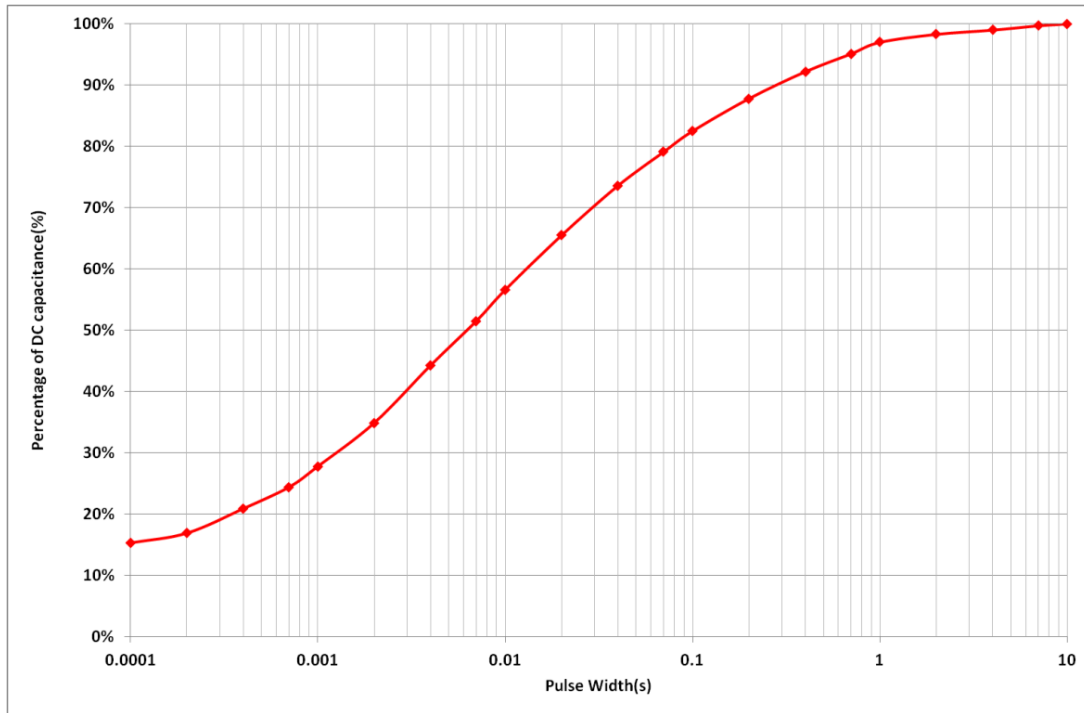


Fig 4: Effective Capacitance

Fig 4 shows the effective capacitance for the HW102, HW202 @ 23°C. This shows that for a 1msec PW, you will measure 28% of DC capacitance or 112mF for an HW102 or 56mF for an HW202. At 10msecs you will measure 57% of the DC capacitance, and at 100msecs you will measure 83% 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  $C_{eff}(10msecs) = 57\%$  of DC capacitance = 114mF for an HW202, so  $V_{drop} = 1A \times ESR + 1A \times duration/C = 1A \times 75m\Omega + 1A \times 10ms / 114mF = 163mV$ . The next section on pulse response shows how the effective capacitance is sufficient for even short pulse widths.

### Pulse Response

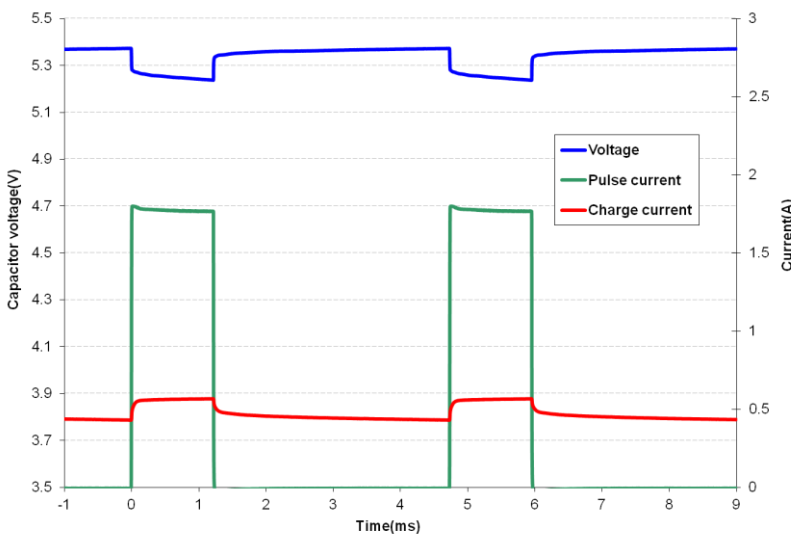
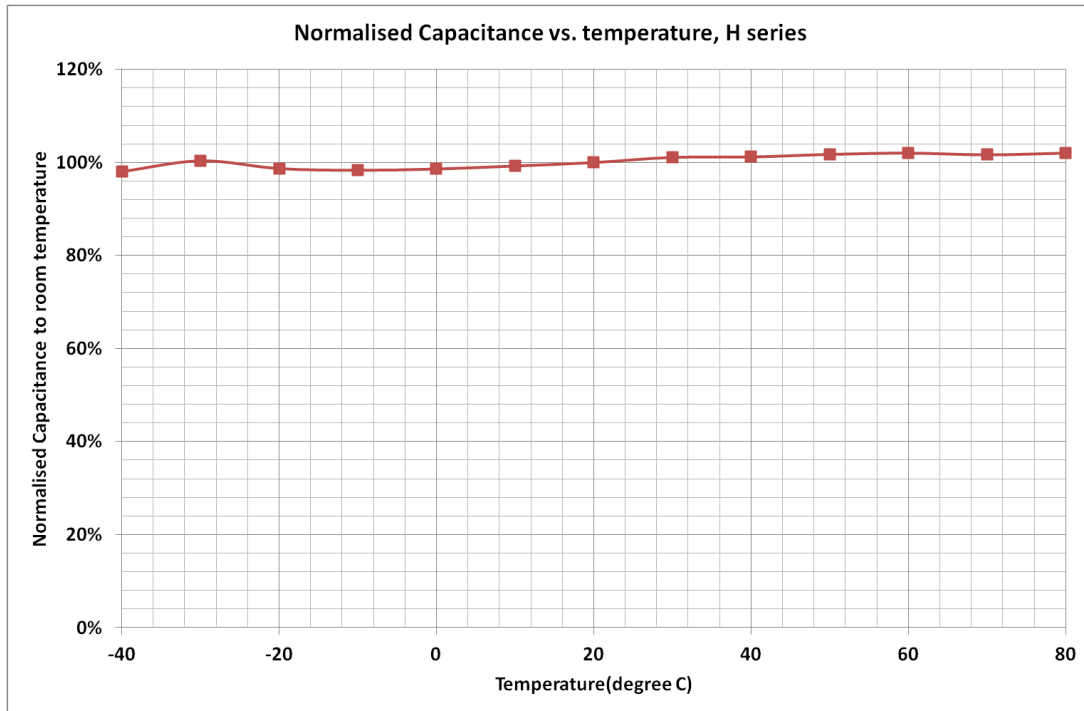


Fig 5 shows that the HW202 supercapacitor does an excellent job supporting a GPRS class 10 pulse train, drawing 1.8A for 1.1ms at 25% duty cycle. The source is current limited to 0.6A and the supercapacitor provides the 1.2A difference to achieve the peak current. At first glance the freq response of Fig 8 indicates the supercapacitor would not support a 1ms pulse, but the  $C_{eff}$  of 56mF coupled with the low ESR supports this pulse train with only ~110mV droop in the supply rail.

Fig 5: HW202 Pulse Response with GPRS Class 10 Pulse Train

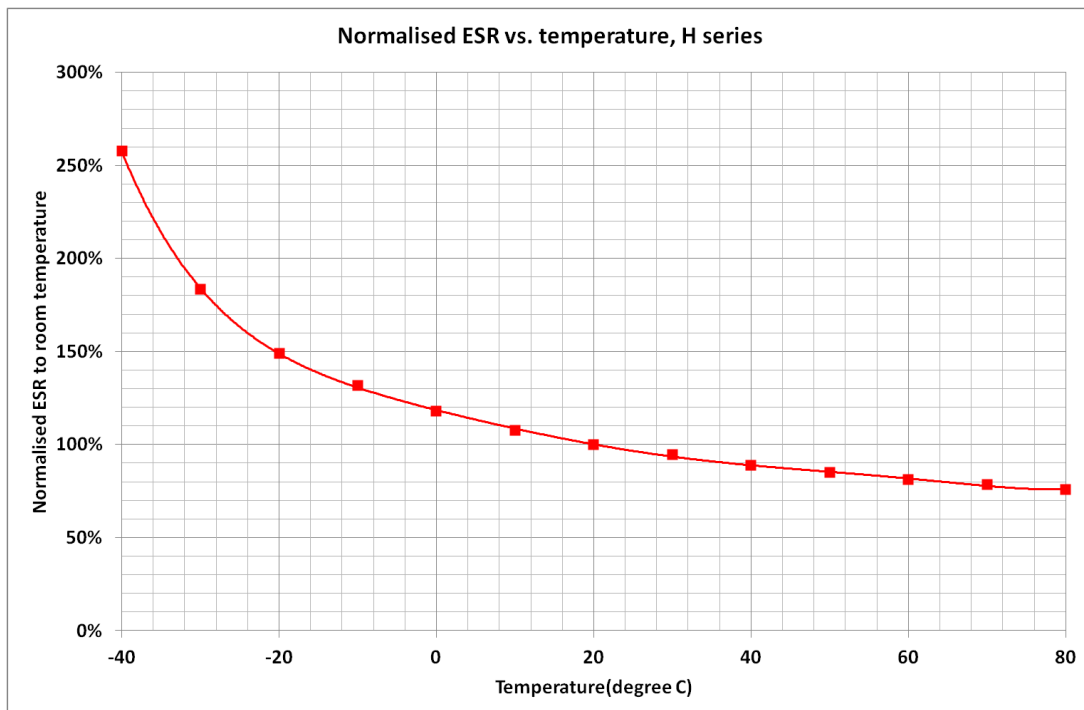
### DC Capacitance variation with temperature



**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 ~2.6 x ESR at room temp, and that ESR at 80°C is ~0.8 x ESR at room temperature.

### Frequency Response

HW102 Magnitude and Phase vs. Frequency

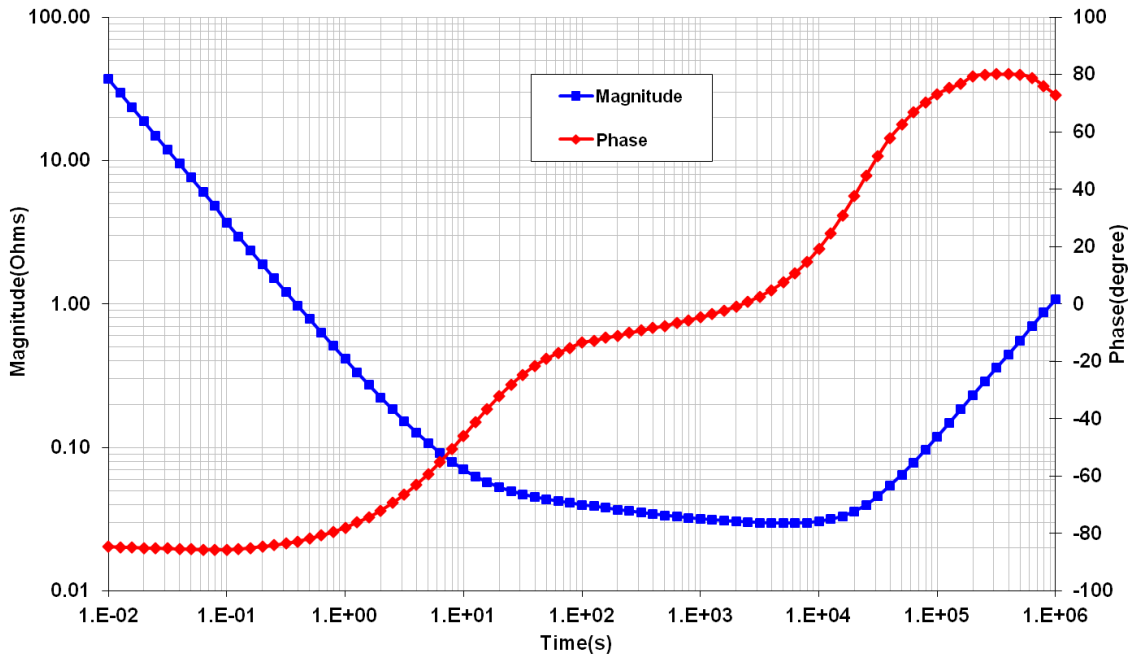


Fig 8: Frequency Response of Impedance (biased at 2.7V with a 50mV test signal)

HW102 ESR, Capacitance and Inductance vs. Frequency

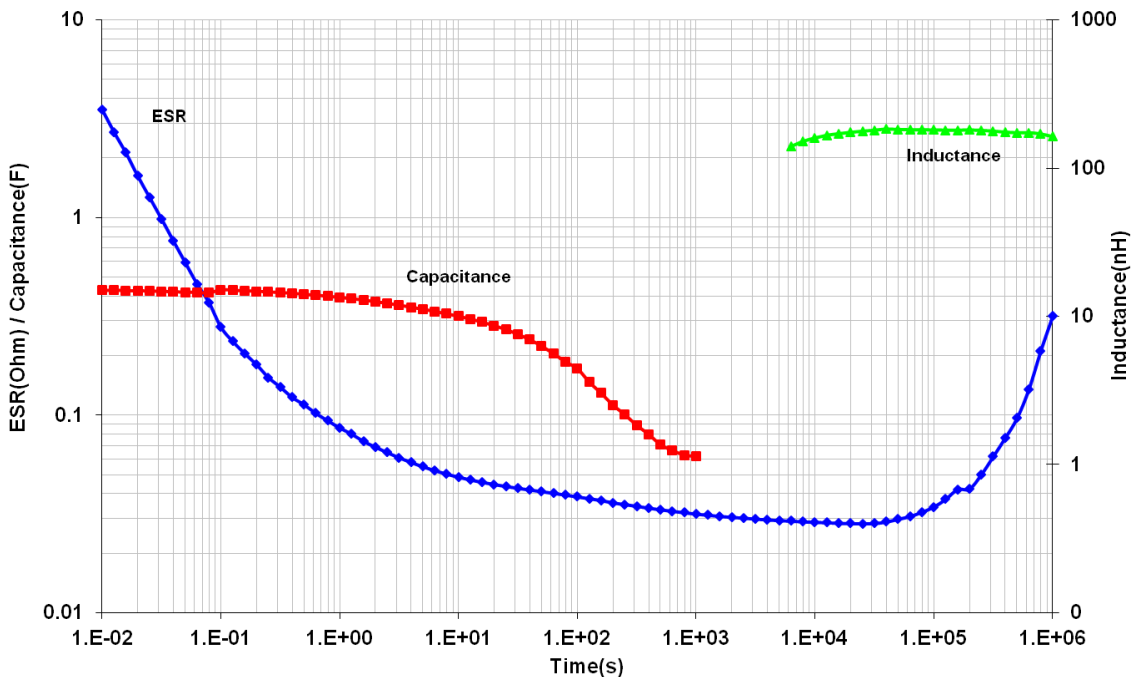
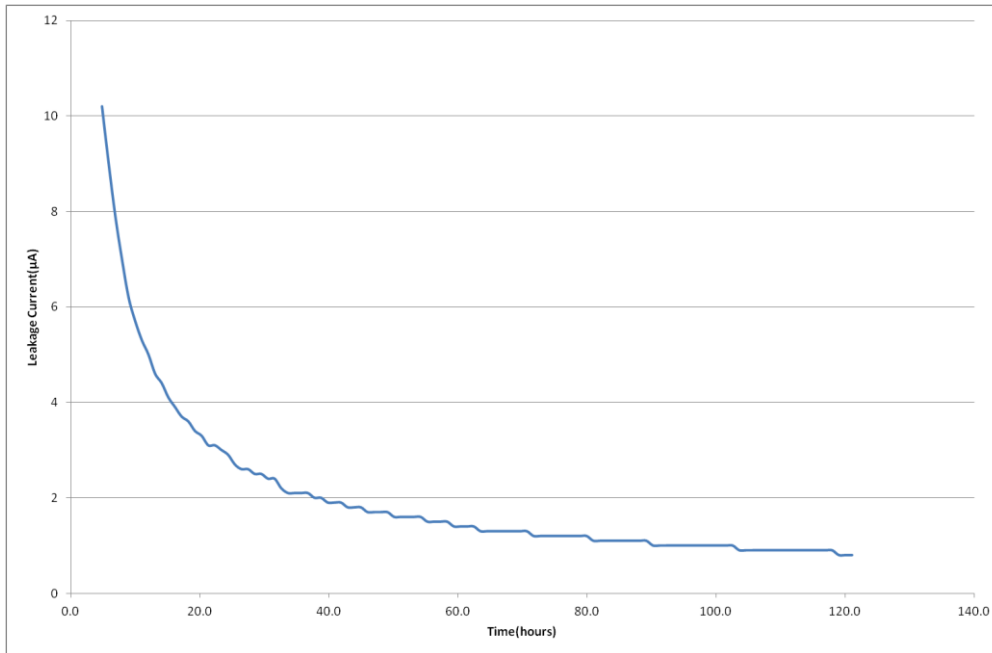


Fig 9: Frequency Response of ESR, Capacitance & Inductance

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

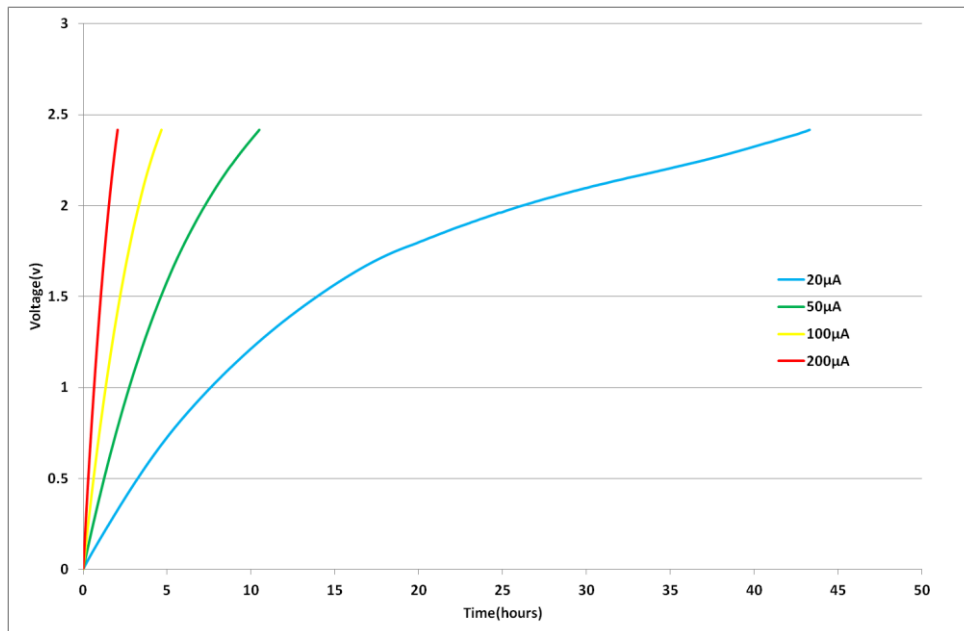
## Leakage Current



**Fig 10: Leakage Current**

Fig 10 shows the leakage current for HW102 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.

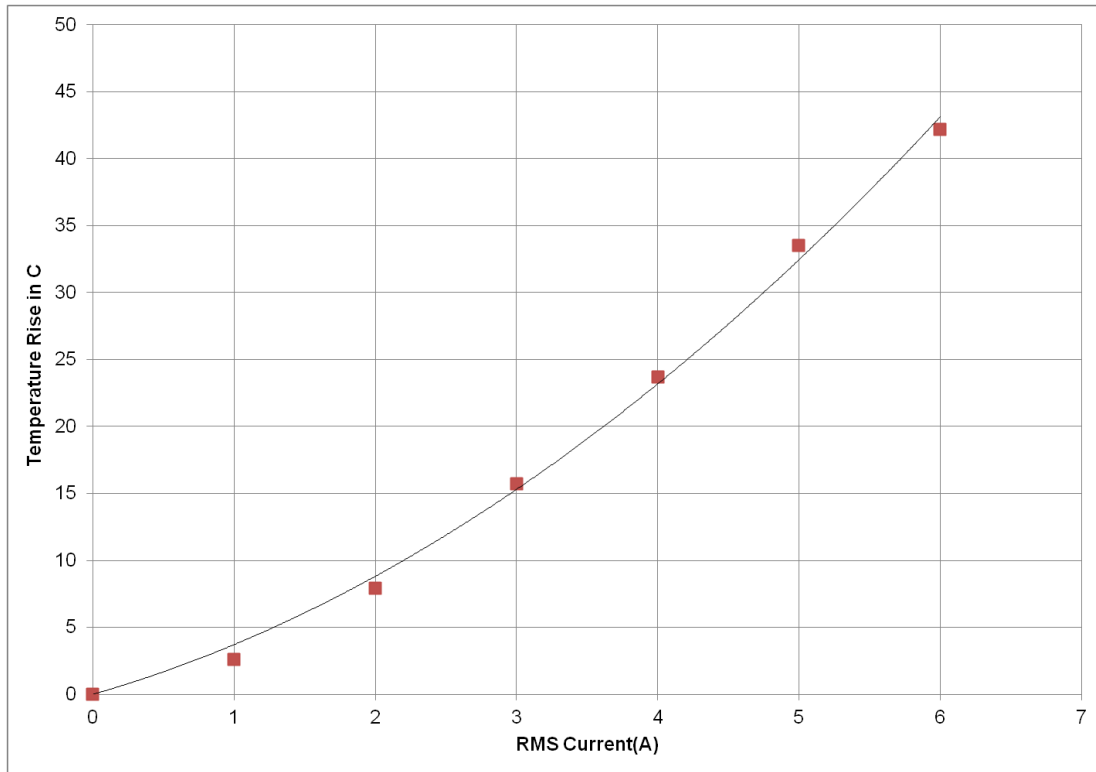
## Charge Current



**Fig 11: Charging an HW102 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  $0.4F \times 2.4V / 0.00002A = 13.3hrs$  to charge a 0.4 F supercapacitor to 2.4V at 20µA, but Fig 11 shows it took 45hrs. At 200µA charging occurs at a rate close to the theoretical rate.

## RMS Current



**Fig 12: Temperature rise in HW202 with RMS current**

Continuous current flow into/out of the supercapacitor 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 4.6A, 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, as well for information on endurance and shelf life, transportation and storage, assembly and soldering, safety and RoHS/REACH certification.