

# HA130 / HA230 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 HA130 is a single cell supercapacitor. The HA230 is a dual cell supercapacitor with two HA130 cells in series, so HA230 capacitance = Capacitance of HA130/2 and HA230 ESR = 2 x HA130 ESR.

**Table 1: Absolute Maximum Ratings**

| Parameter        | Name              |       | Conditions | Min | Typical | Max | Units |
|------------------|-------------------|-------|------------|-----|---------|-----|-------|
| Terminal Voltage | V <sub>peak</sub> | HA130 |            | 0   |         | 2.9 | V     |
|                  |                   | HA230 |            |     |         | 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>   | HA130 |                    | 0   |         | 2.75 | V     |
|                           |                  | HA230 |                    | 0   |         | 5.5  |       |
| Capacitance               | C                | HA130 | DC, 23°C           | 640 | 800     | 960  | mF    |
|                           |                  | HA230 |                    | 320 | 400     | 480  |       |
| ESR                       | ESR              | HA130 | DC, 23°C           |     | 65      | 72   | mΩ    |
|                           |                  | HA230 |                    |     | 130     | 156  |       |
| Leakage Current           | I <sub>L</sub>   |       | 2.75V, 23°C 120hrs |     | 1       | 2    | μA    |
| RMS Current               | I <sub>RMS</sub> |       | 23°C               |     |         | 3    | A     |
| Peak Current <sup>1</sup> | I <sub>P</sub>   |       | 23°C               |     |         | 30   | A     |

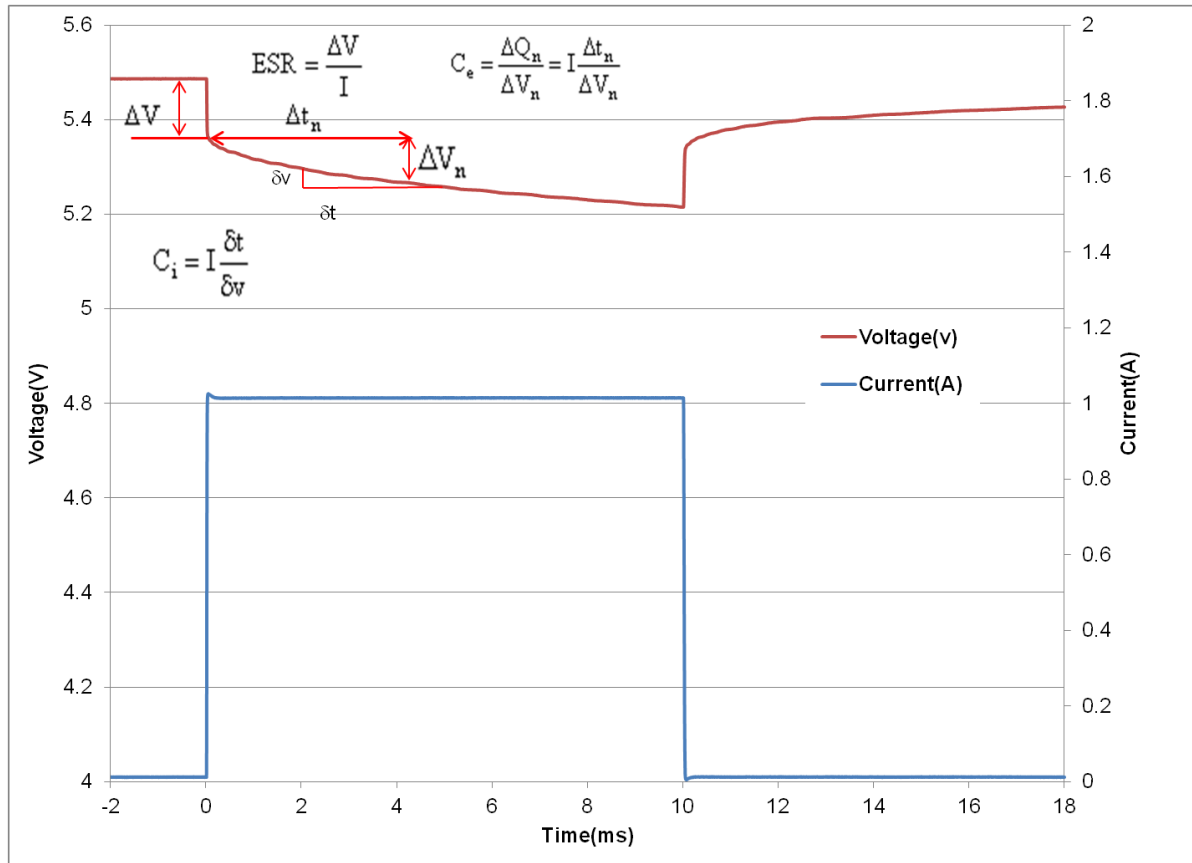
<sup>1</sup>Non-repetitive current, single pulse to discharge fully charged supercapacitor.

**Table 3: Thickness**

|        |       |   |        |       |  |
|--------|-------|---|--------|-------|--|
| HA130F | 1.7mm | No adhesive tape on underside of the supercapacitor | HA130G | 1.8mm | Adhesive tape on underside, release tape removed |
| HA230F | 3.5mm |   | HA230G | 3.6mm |  |

## 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  $0.01\text{ sec}$ .



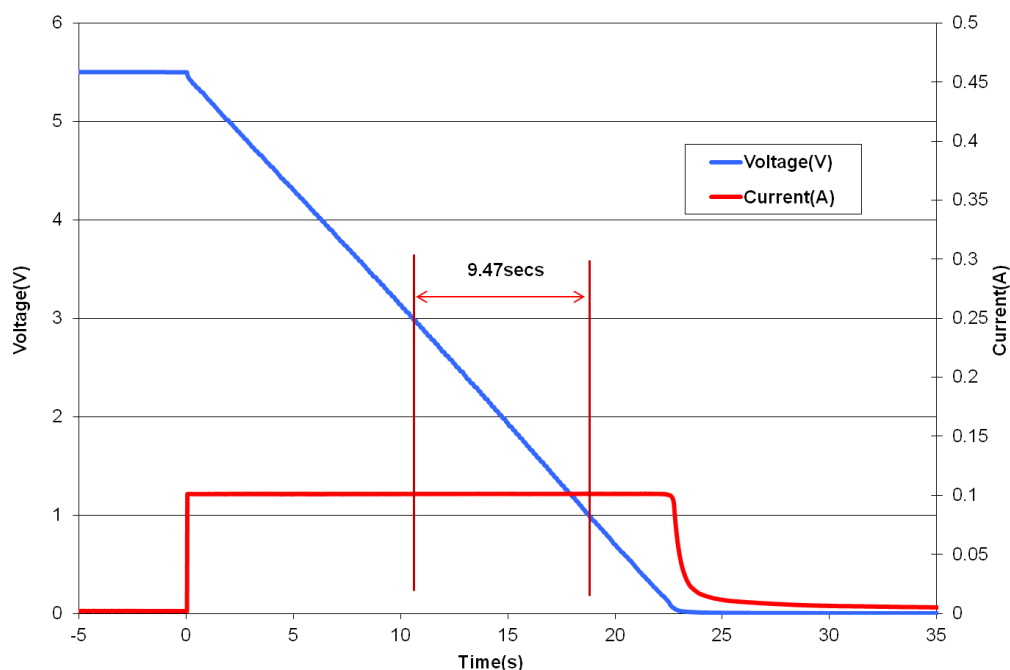
**Figure 1: Effective capacitance, instantaneous capacitance and ESR for an HA230**

The ESR is found by dividing the instantaneous voltage step ( $\Delta V$ ) by  $I$ . In this example  $= (5.487\text{V} - 5.37\text{V})/1\text{A} = 117\text{m}\Omega$ .

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  $V_{2\text{ms}} = (5.37\text{ V} - 5.296\text{V}) = 74\text{mV}$ . Therefore  $C_e(2\text{ms}) = 1\text{ A} \times 2\text{ms}/74\text{mV} = 27\text{mF}$ . After 10ms, the voltage drop  $= 5.37\text{ V} - 5.216\text{V} = 154\text{mV}$ . Therefore  $C_e(10\text{ms}) = 1\text{ A} \times 10\text{ms}/154\text{mV} = 65\text{mF}$ . The DC capacitance of an HA230 =  $0.4\text{ F}$ . 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.

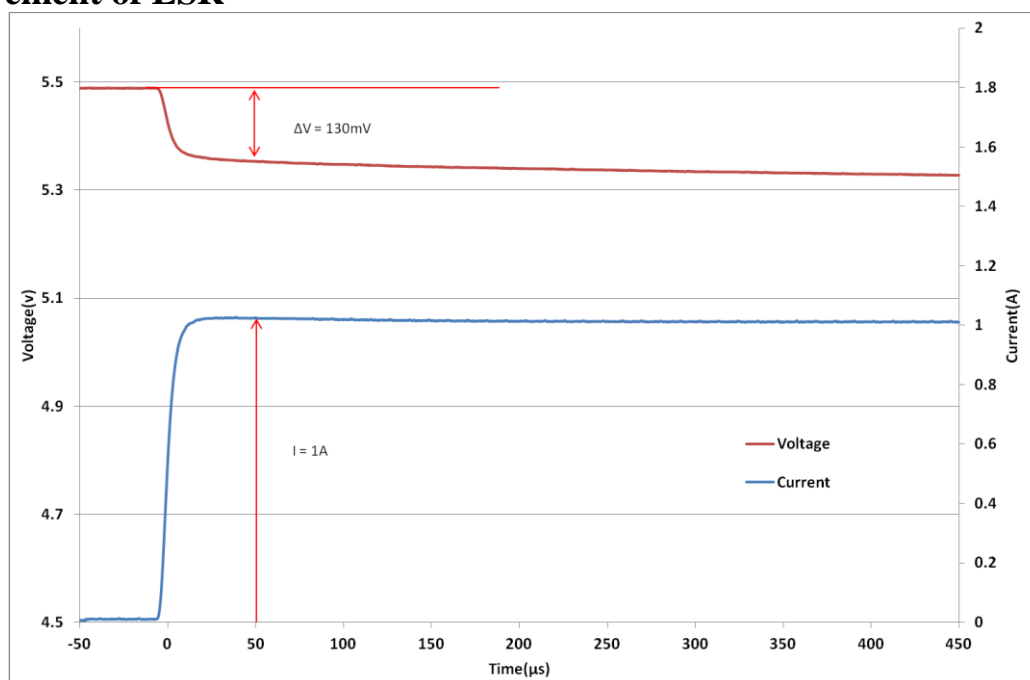
## Measurement of DC Capacitance



**Fig 2: Measurement of DC Capacitance for an HA230**

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,  $C = 0.1A \times 9.47s / 2V = 473.5F$ , which is well within the 0.4F +/- 20% tolerance for an HA230 cell.

## Measurement of ESR



**Fig 3: Measurement of ESR for an HA230**

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  $130mV/1.A = 130m\Omega$ .

## Effective Capacitance

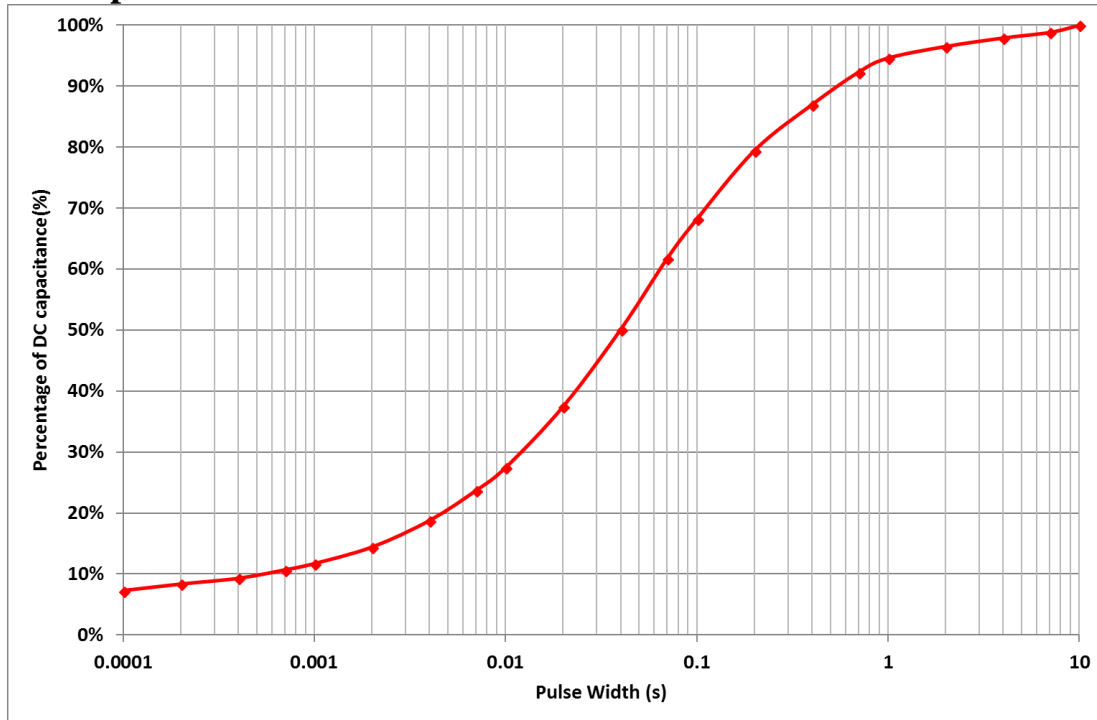


Figure 4: Effective Capacitance

Fig 4 shows the effective capacitance for the HA130, HA230 @ 23°C. This shows that for a 1ms PW, you will measure 12% of DC capacitance or 96mF for an HA130 or 48mF for an HA230. At 10ms you will measure 27% of the DC capacitance and at 100ms you will measure 68% 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 10ms, then you would use the  $C_{eff}(10ms) = 27\%$  of DC capacitance = 108mF for an HA230, so  $V_{drop} = 1A \times ESR + 1A \times duration/C = 1A \times 130m\Omega + 1A \times 10ms / 108mF = 277mV$ . The next section on pulse response shows how the effective capacitance is sufficient for even short pulse widths.

## Pulse Response

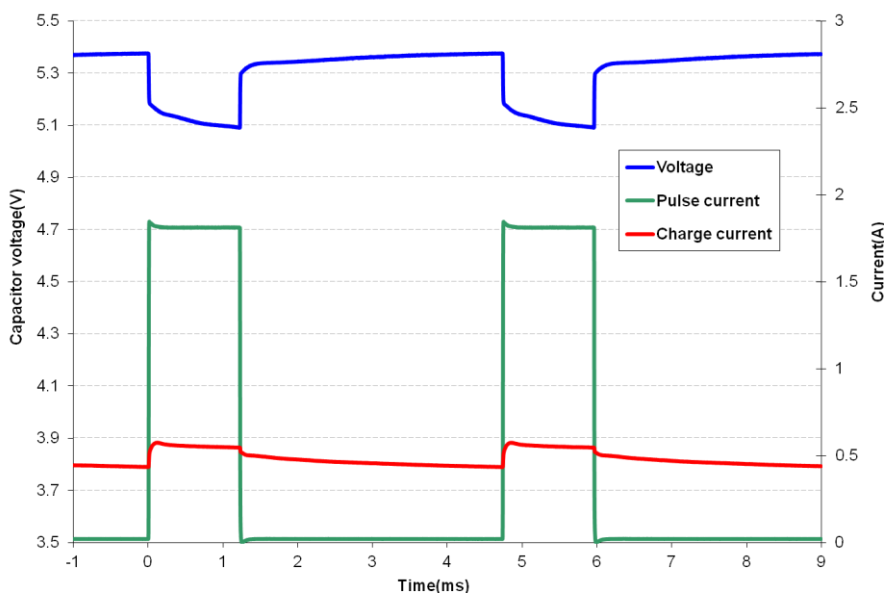


Fig 5 shows that the HA230 supercapacitor does an excellent job supporting a GPRS class 10 pulse train, drawing 1.8A for 1.1ms at 25% duty cycle. The source is current limited to 0.6A and the supercapacitor provides the 1.2A difference to achieve the peak current. At first glance the freq response of Fig 8 indicates the supercapacitor would not support a 1ms pulse, but the  $C_{eff}$  of 26mF coupled with the low ESR supports this pulse train with only ~280mV droop in the supply rail.

Fig 5: HA230 Pulse Response with GPRS Class 10 Pulse Train

## DC Capacitance variation with temperature

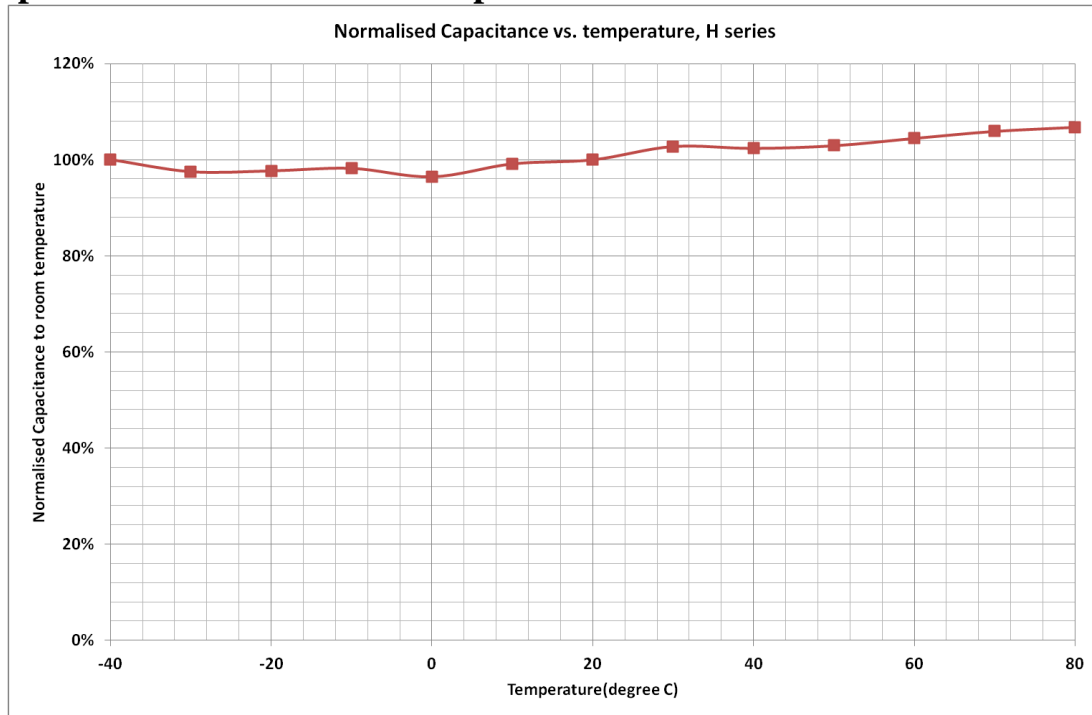


Figure 6: Capacitance change with temperature

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

## ESR variation with temperature

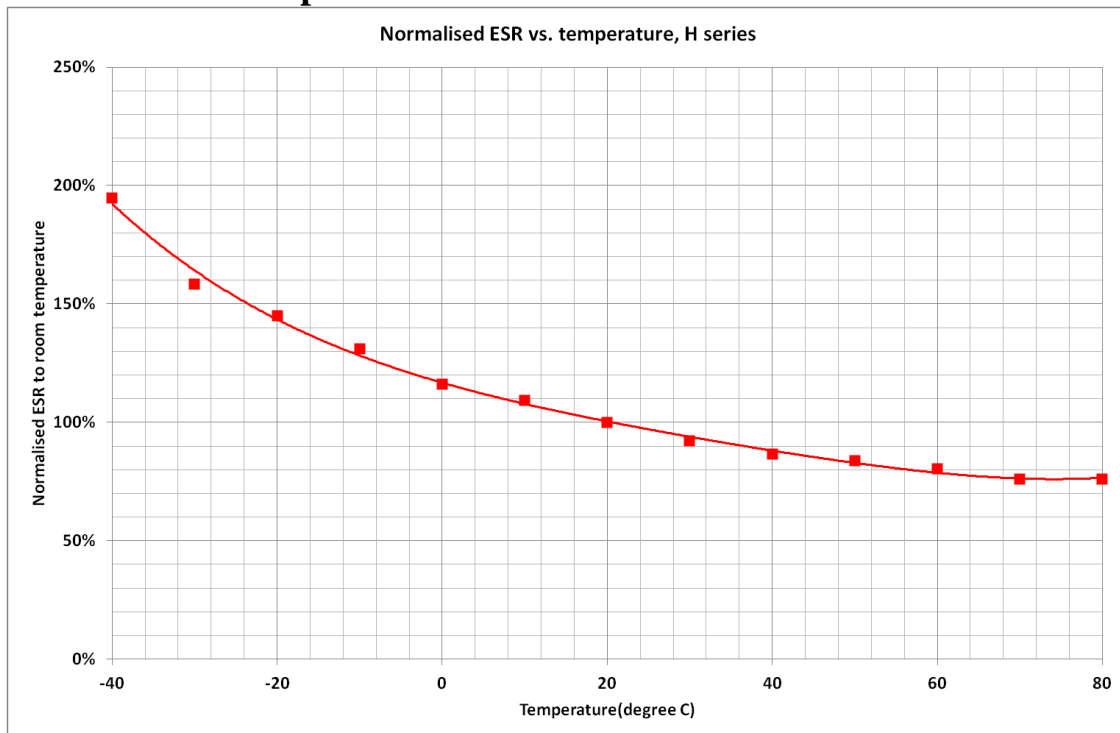


Figure 7: ESR change with temperature

Fig 7 shows that ESR at -40°C is ~1.9 x ESR at room temp, and that ESR at 70°C is ~0.8 x ESR at room temperature.

## Frequency Response

HA230 Magnitude and Phase vs. Frequency

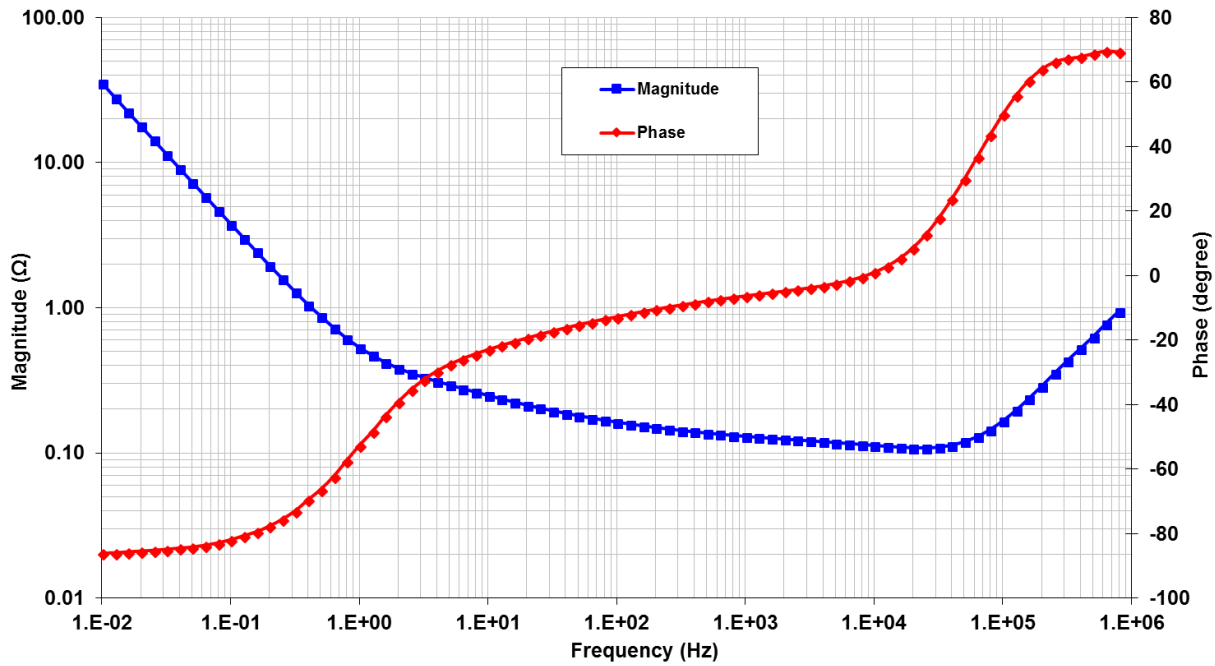


Fig 8: Frequency Response of Impedance (biased at 5.5V with a 50mV test signal)

HA230 ESR, Capacitance and Inductance vs. Frequency

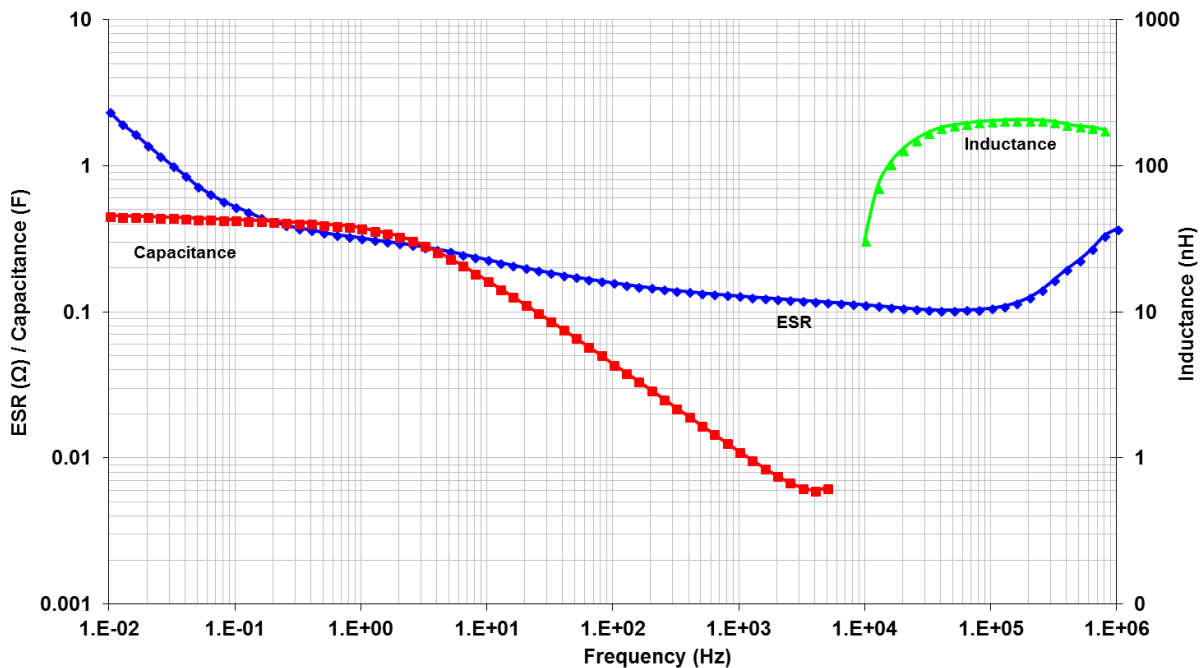
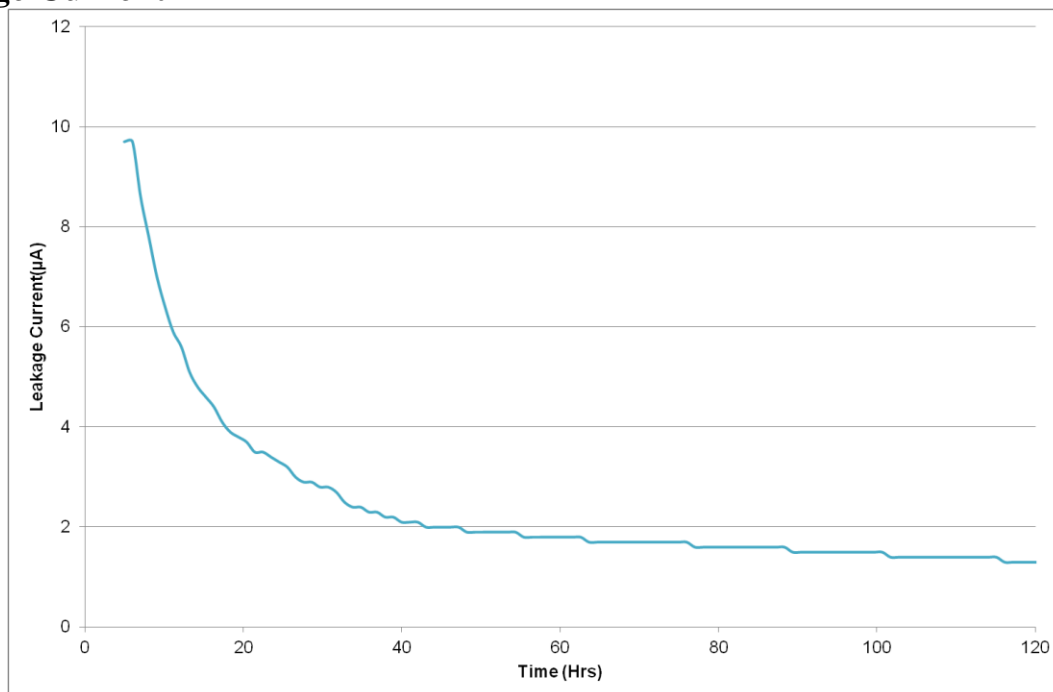


Fig 9: Frequency Response of ESR, Capacitance & Inductance

Fig 8 shows the supercapacitor behaves as an ideal capacitor until approx 1.5 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.

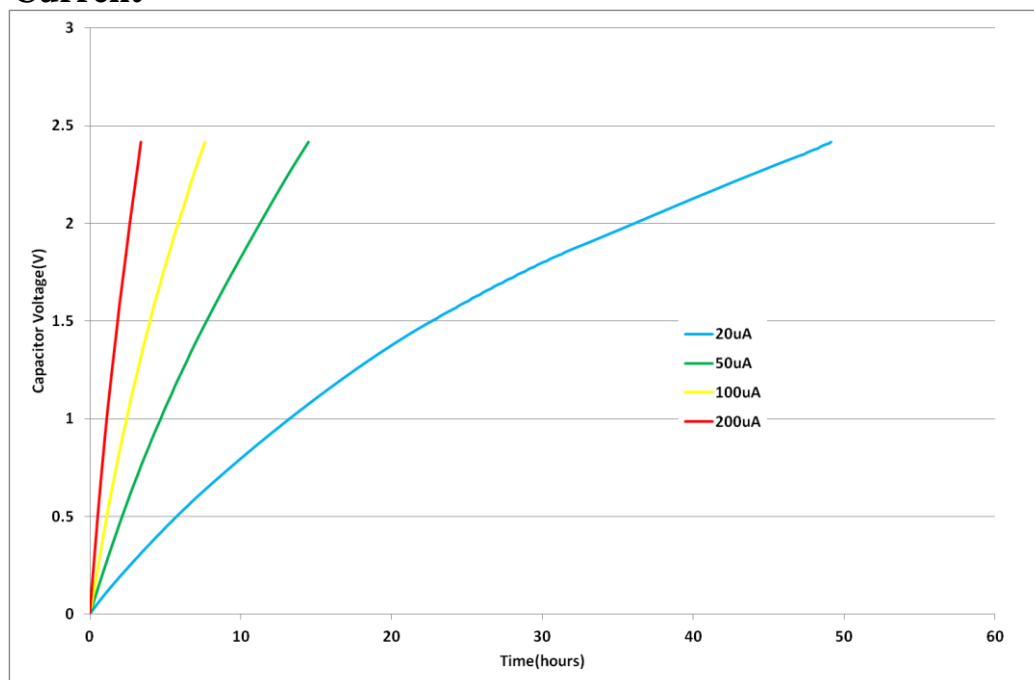
## Leakage Current



**Fig 10: Leakage Current**

Fig 10 shows the leakage current for HA130 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 1.5µA at room temperature. At 70°C leakage current will be ~5µA.

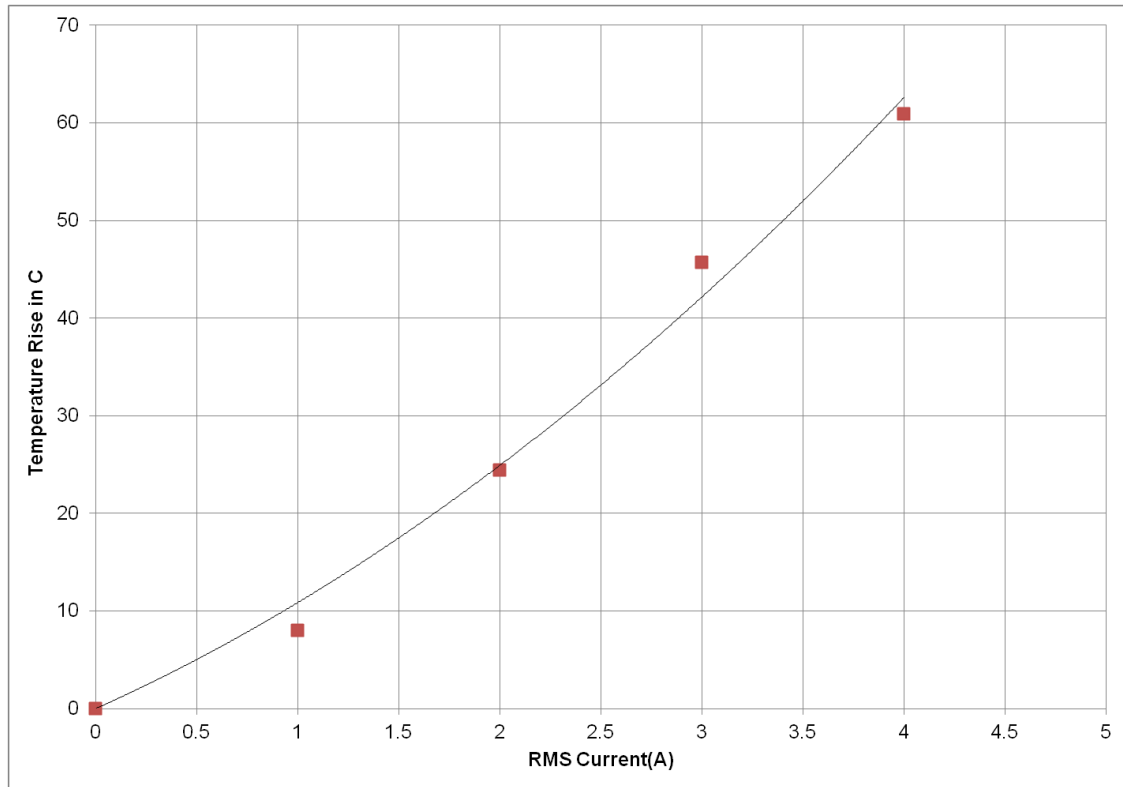
## Charge Current



**Fig 11: Charging an HA130 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  $0.8\text{F} \times 2.4\text{V} / 0.00002\text{A} = 26.7\text{hrs}$  to charge a 0.8 F supercapacitor to 2.4V at 20µA, but Fig 11 shows it took 50hrs. At 100µA charging occurs at a rate close to the theoretical rate.

## RMS Current



**Fig 12: Temperature rise in HA230 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 2.2A, 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.



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