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HA102 / HA202 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 HA102 is a single cell supercapacitor. The HA202 is a dual cell supercapacitor with two HA102 cells in series, so HA202 capacitance = Capacitance of HA102/2 and HA202 ESR = 2 x HA102 ESR.

Table 1: Absolute Maximum Ratings

Parameter	Name		Conditions	Min	Typical	Max	Units
Terminal Voltage	Vpeak	HA102		0		2.9	V
		HA202				5.8	
Temperature	Tmax			-40		+85	°C

Table 2: Electrical Characteristics

Parameter	Name		Conditions	Min	Typical	Max	Units
Terminal Voltage	Vn	HA102		0		2.75	V
		HA202		0		5.5	
Capacitance	C	HA102	DC, 23°C	192	240	288	mF
		HA202		96	120	144	
ESR	ESR	HA102	DC, 23°C		60	72	mΩ
		HA202			120	144	
Leakage Current	I_L		2.75V, 23°C 120hrs		1	2	µA
RMS Current	I_{RMS}		23°C			4	A
Peak Current[1]	I_P		23°C			30	A

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

Table 3: Thickness

HA102F	**1.2mm**	No adhesive tape on underside of the supercapacitor	**HA102G**	**1.3mm**	Adhesive tape on underside, release tape removed
HA202F	**2.5mm**		**HA202G**	**2.6mm**	

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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.

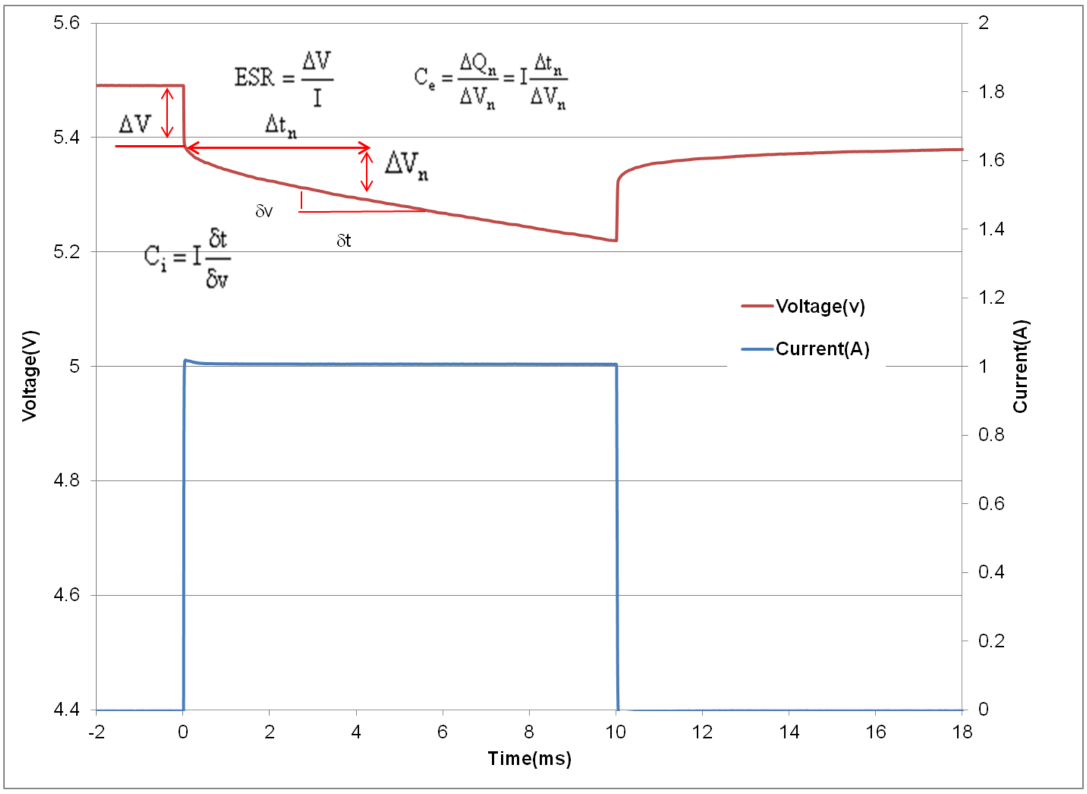

Figure 1: Effective capacitance, instantaneous capacitance and ESR for an HA202

The ESR is found by dividing the instantaneous voltage step (ΔV) by I. In this example = (5.491V-5.391V)/1A = 117mΩ.

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, $Ce(\Delta t_n)$ 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 $Ce(\Delta t_n)$ = I x $\Delta t_n/\Delta V_n$. Ce 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} = (5.391 V – 5.323V) = 68mV. Therefore Ce(2ms) = 1A x 2ms/68mV = 29.4mF. After 10ms, the voltage drop = 5.391 V – 5.219V = 172mV. Therefore Ce(10ms) = 1 A x 10ms/172mV = 58.1mF. The DC capacitance of an HA202 = 0.12 F. Note that ΔV, or IR drop, is not included because very little charge is removed from the capacitor during this time. Ce shows the time response of the capacitor and it is useful for predicting circuit behavior in pulsed applications.

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Measurement of DC Capacitance

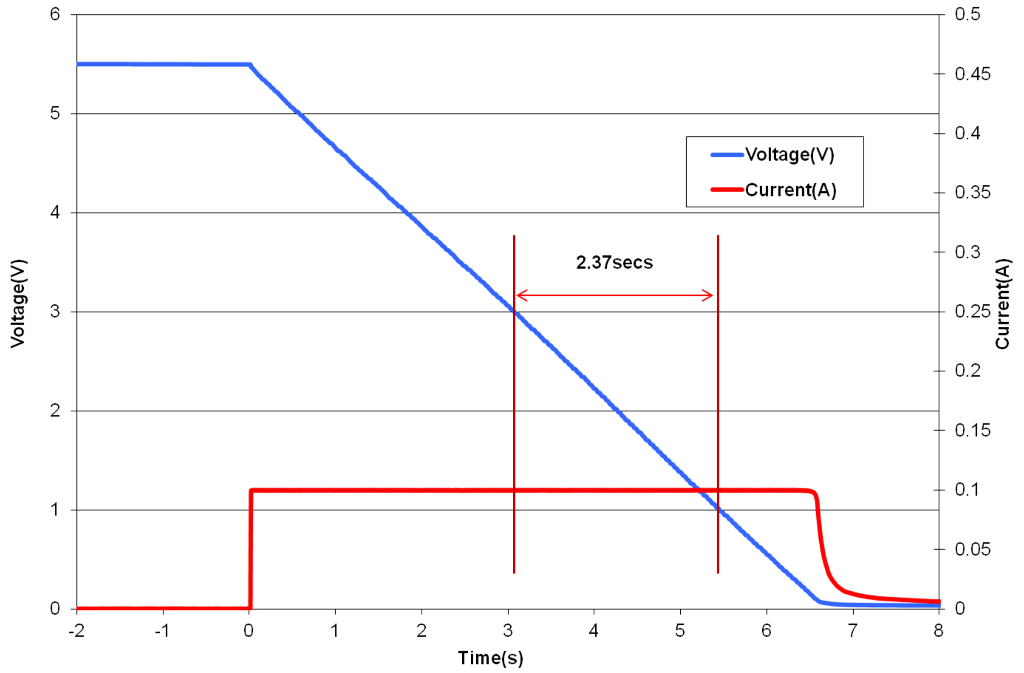

Fig 2: Measurement of DC Capacitance for an HA202

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 x 2.37s /2V = 118.5mF, which is well within the 120mF +/- 20% tolerance for an HA202 cell.

Measurement of ESR

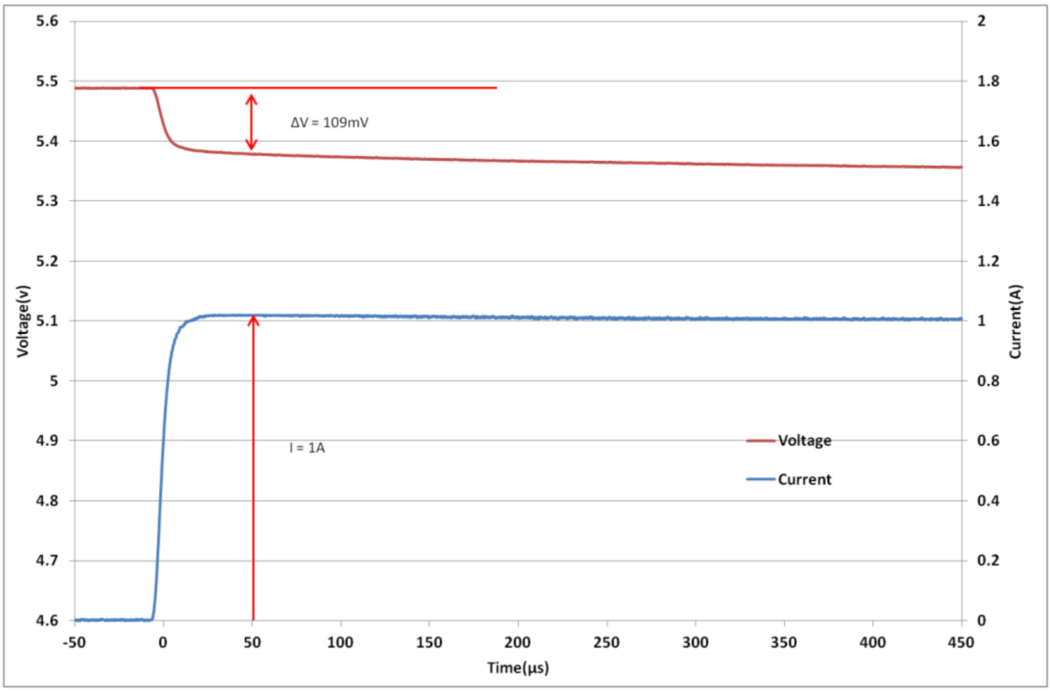

Fig 3: Measurement of ESR for an HA202

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 109mV/1.A = 109mΩ.

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Effective Capacitance

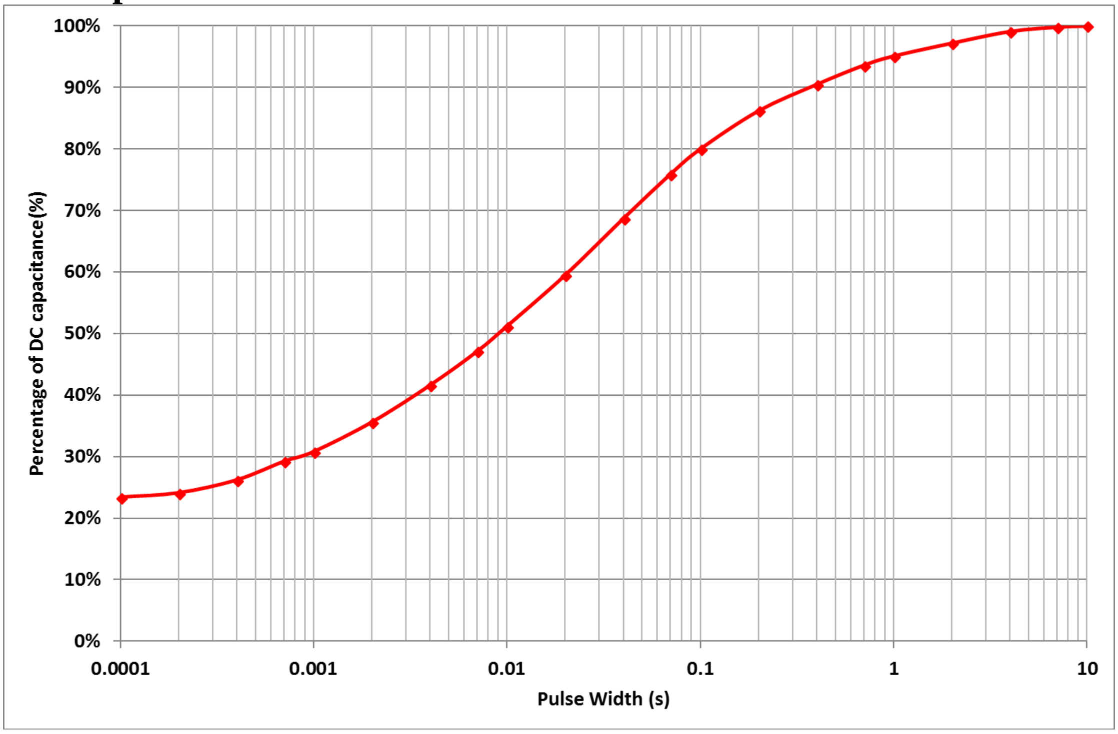

Figure 4: Effective Capacitance

Fig 4 shows the effective capacitance for the HA102, HA202 @ 23°C. This shows that for a 1ms PW, you will measure 30% of DC capacitance or 72mF for an HA102 or 36mF for an HA202. At 10ms you will measure 50% of the DC capacitance, and at 100ms you will measure 80% 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 Ceff(10ms) = 50% of DC capacitance = 60mF for an HA202, so Vdrop = 1A x ESR + 1A x duration/C = 1A x 120mΩ + 1A x 10ms / 60mF = 287mV. The next section on pulse response shows how the effective capacitance is sufficient for even short pulse widths.

Pulse Response

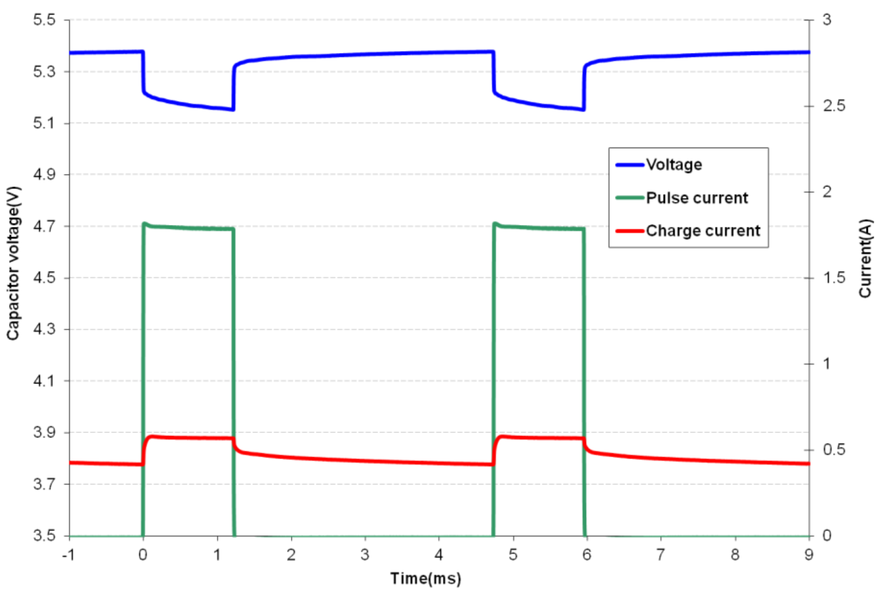

Fig 5 shows that the HA202 supercapacitor does an excellent job supporting a GPRS class 10 pulse train, drawing 1.8A for 1.1ms at 25% duty cycle. The source is current limited to 0.6A and the supercapacitor provides the 1.2A difference to achieve the peak current. At first glance the freq response of Fig 8 indicates the supercapacacitor would not support a 1ms pulse, but the Ceff of 22.8mF coupled with the low ESR supports this pulse train with only ~220mV droop in the supply rail.

Fig 5: HA202 Pulse Response with GPRS Class 10 Pulse Train

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DC Capacitance variation with temperature

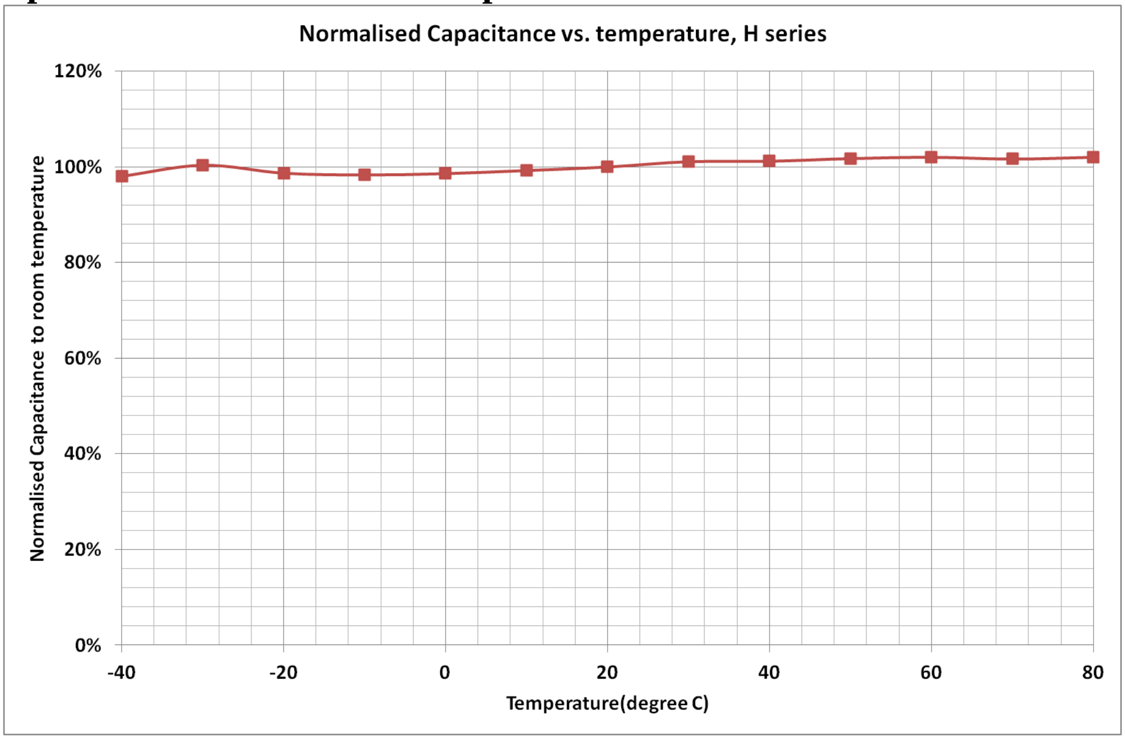

Figure 6: Capacitance change with temperature

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

ESR variation with temperature

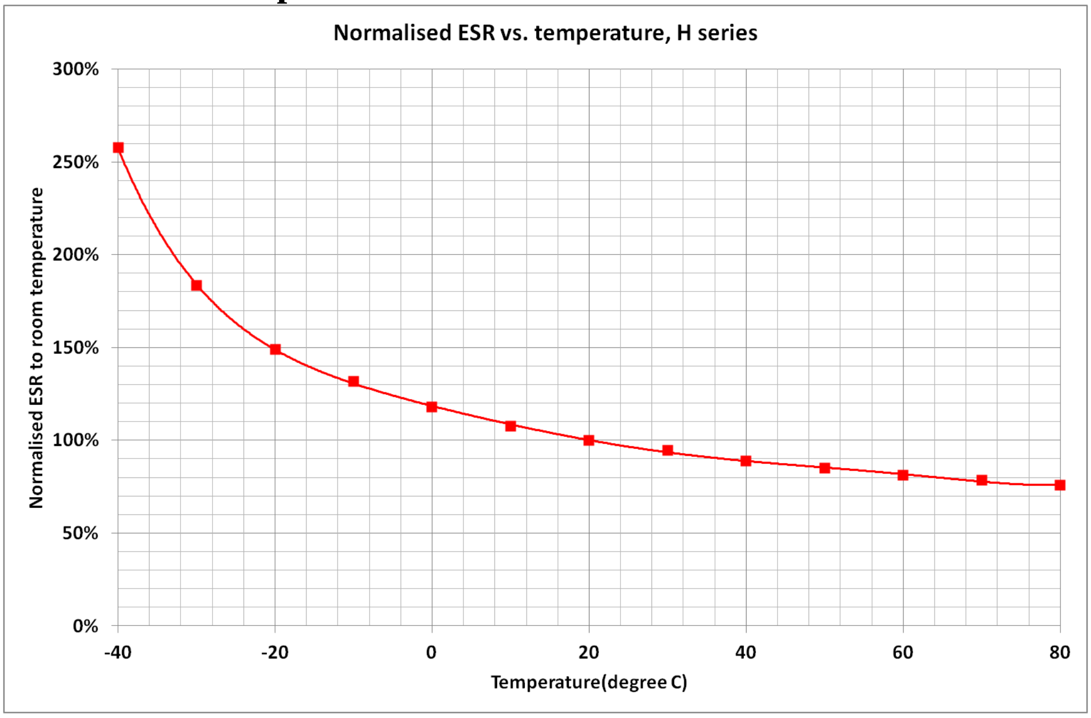

Figure 7: ESR change with temperature

Fig 7 shows that ESR at -40°C is ~2.6 x ESR at room temp, and that ESR at 80ºC is ~0.75 x ESR at room temperature.

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Frequency Response

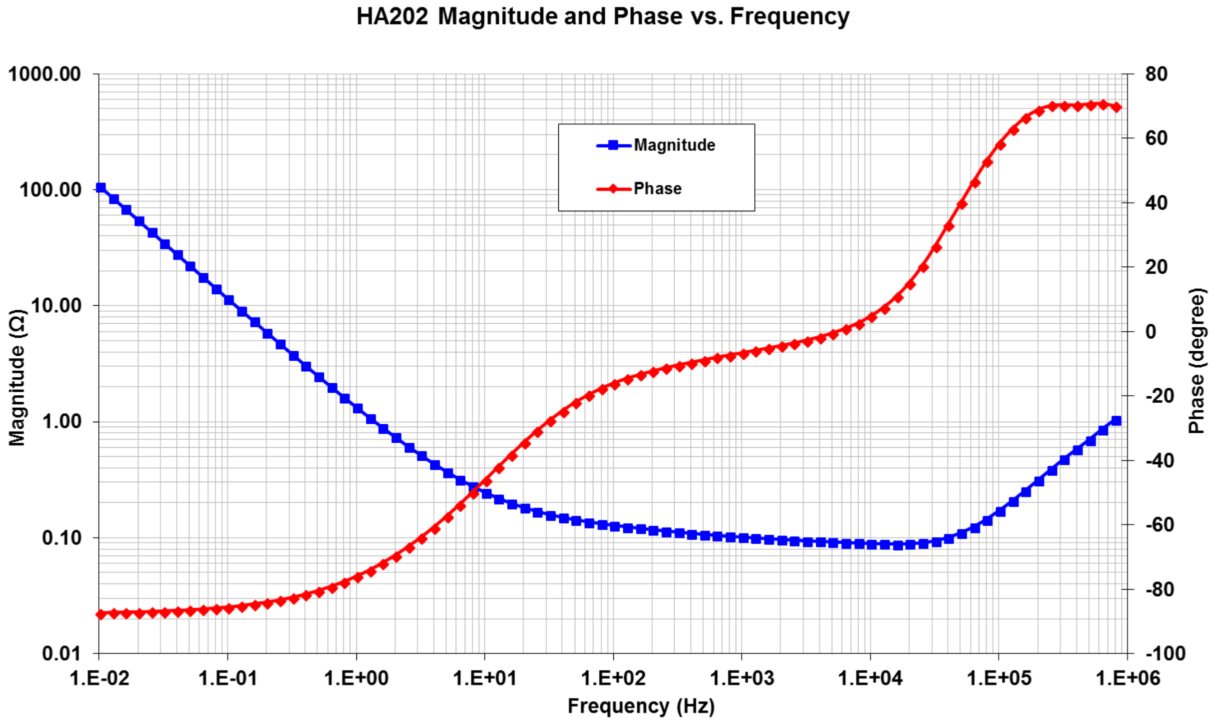

Fig 8: Frequency Response of Impedance (biased at 5.5V with a 50mV test signal)

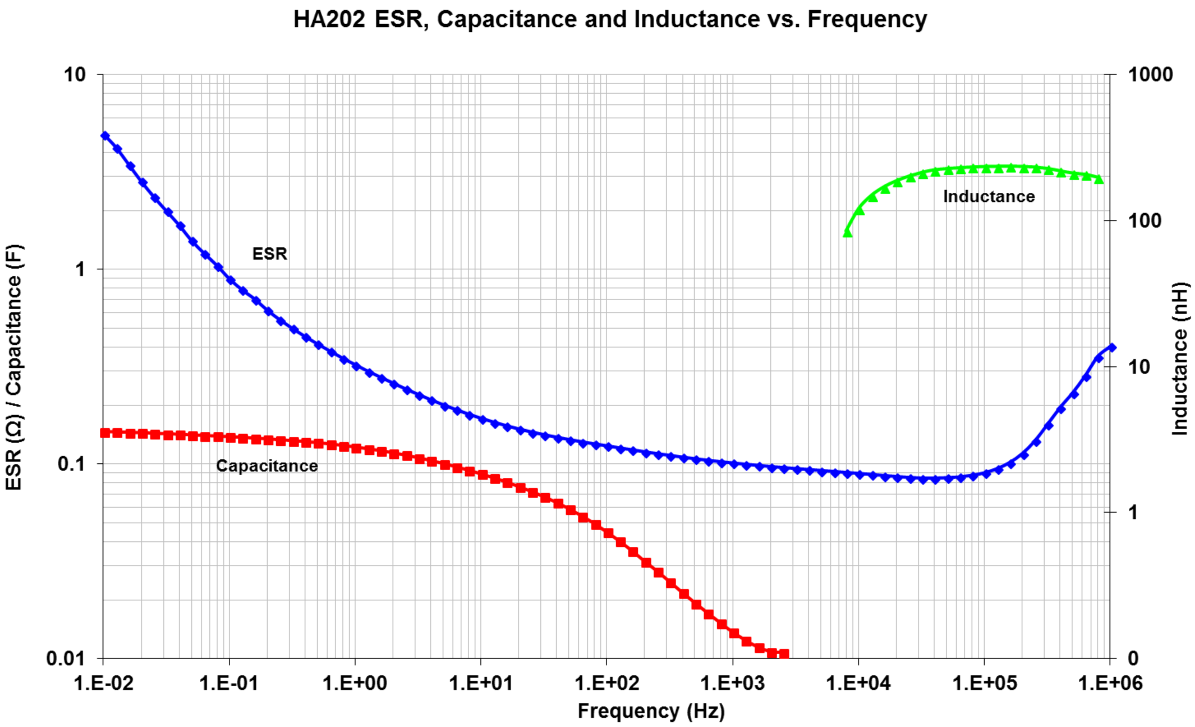

Fig 9: Frequency Response of ESR, Capacitance & Inductance

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.

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Leakage Current

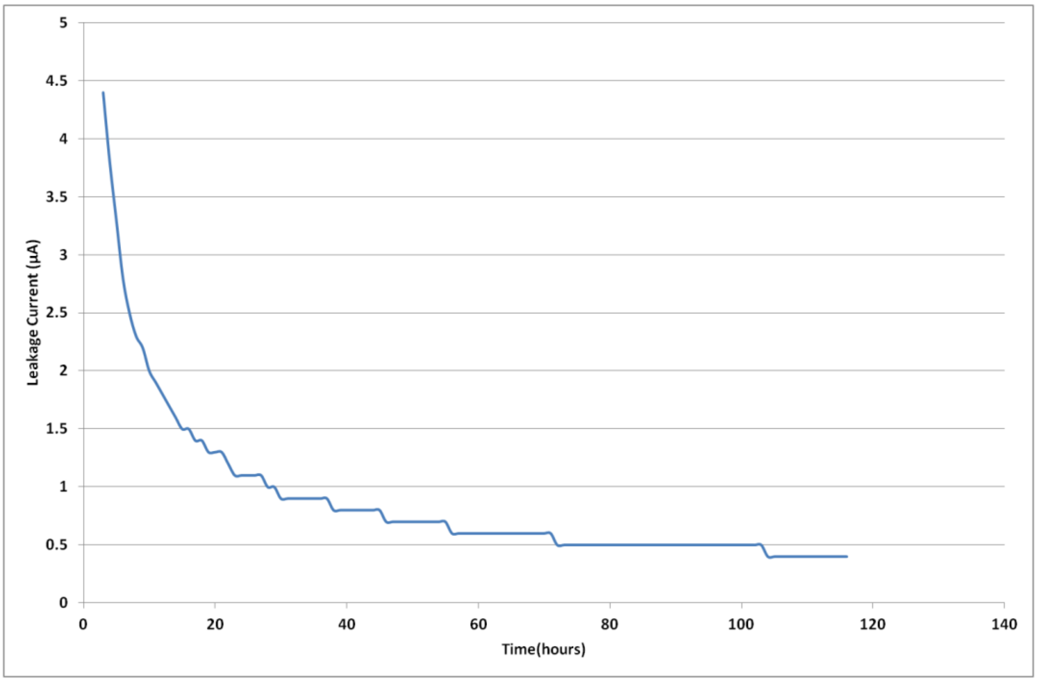

Fig 10: Leakage Current

Fig 10 shows the leakage current for HA102 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

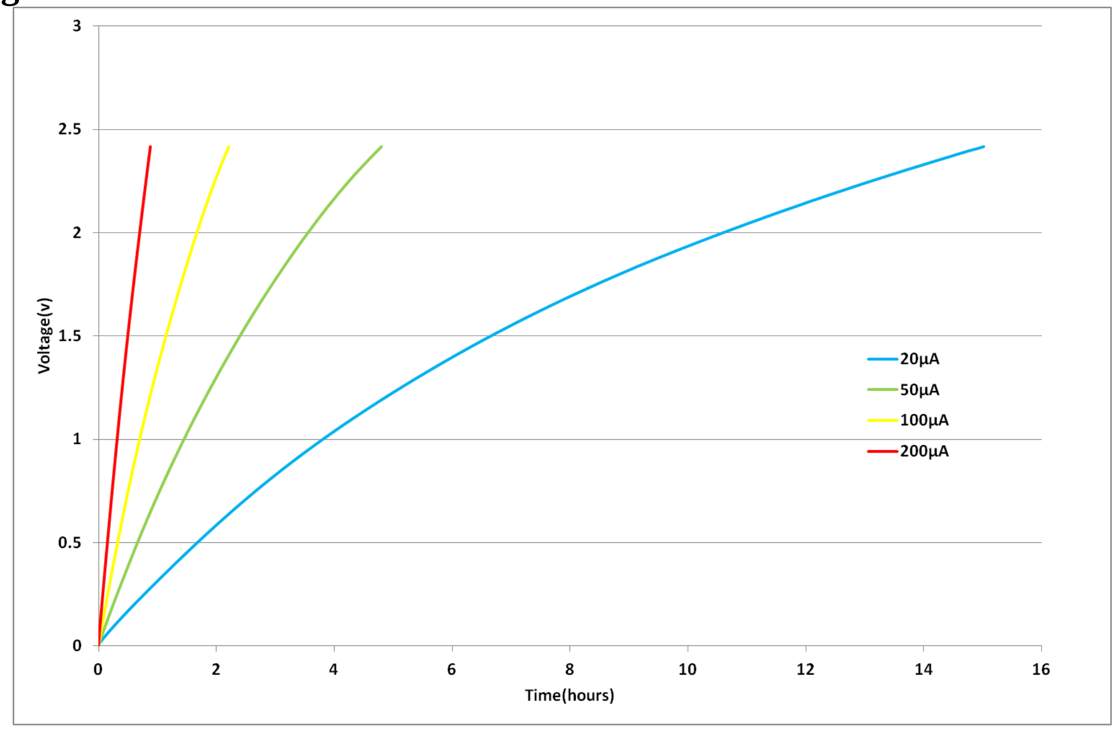

Fig 11: Charging an HA102 with low current

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 0.24F x 2.4V / 0.00002A = 7.3hrs to charge a 0.24 F supercapacitor to 2.4V at 20µA, but Fig 11 shows it took 15hrs. At 100µA charging occurs at a rate close to the theoretical rate.

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RMS Current

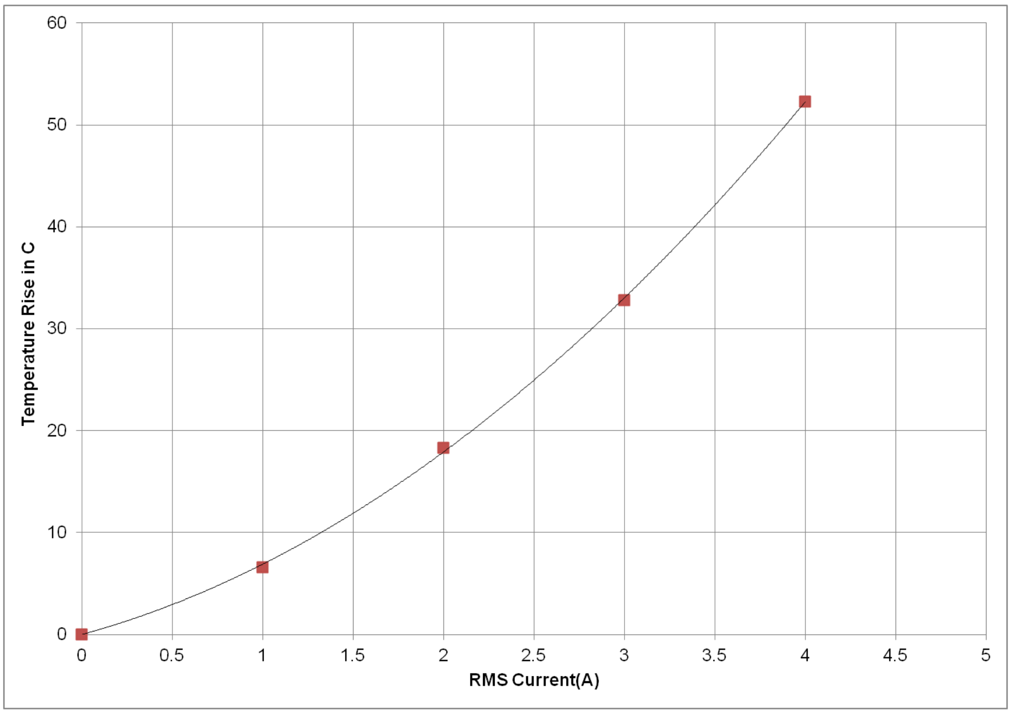

Fig 12: Temperature rise in HA202 with RMS current

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 2.8A, 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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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	Vpeak	HA130		0		2.9	V
		HA230				5.8	
Temperature	Tmax			-40		+85	°C

Table 2: Electrical Characteristics

Parameter	Name		Conditions	Min	Typical	Max	Units
Terminal Voltage	Vn	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_L		2.75V, 23°C 120hrs		1	2	µA
RMS Current	I_{RMS}		23°C			3	A
Peak Current[1]	I_P		23°C			30	A

[1]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**	

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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.

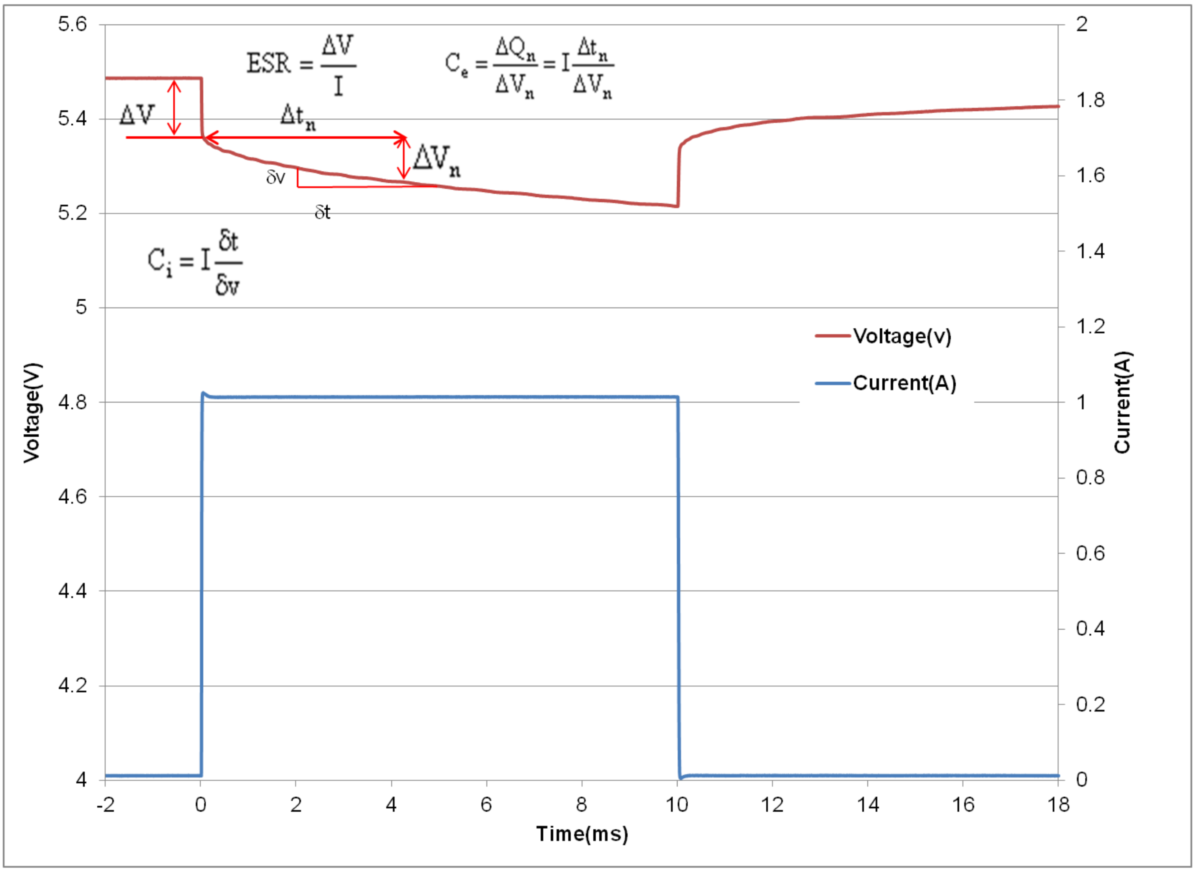

Figure 1: Effective capacitance, instantaneous capacitance and ESR for an HA230

The ESR is found by dividing the instantaneous voltage step (ΔV) by I. In this example = (5.487V-5.37V)/1A = 117mΩ.

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, $Ce(\Delta t_n)$ 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 $Ce(\Delta t_n)$ = I x $\Delta t_n/\Delta V_n$. Ce 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} = (5.37 V – 5.296V) = 74mV. Therefore Ce(2ms) = 1A x 2ms/74mV = 27mF. After 10ms, the voltage drop = 5.37 V – 5.216V = 154mV. Therefore Ce(10ms) = 1 A x 10ms/154mV = 65mF. The DC capacitance of an HA230 = 0.4 F. Note that ΔV, or IR drop, is not included because very little charge is removed from the capacitor during this time. Ce shows the time response of the capacitor and it is useful for predicting circuit behavior in pulsed applications.

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Measurement of DC Capacitance

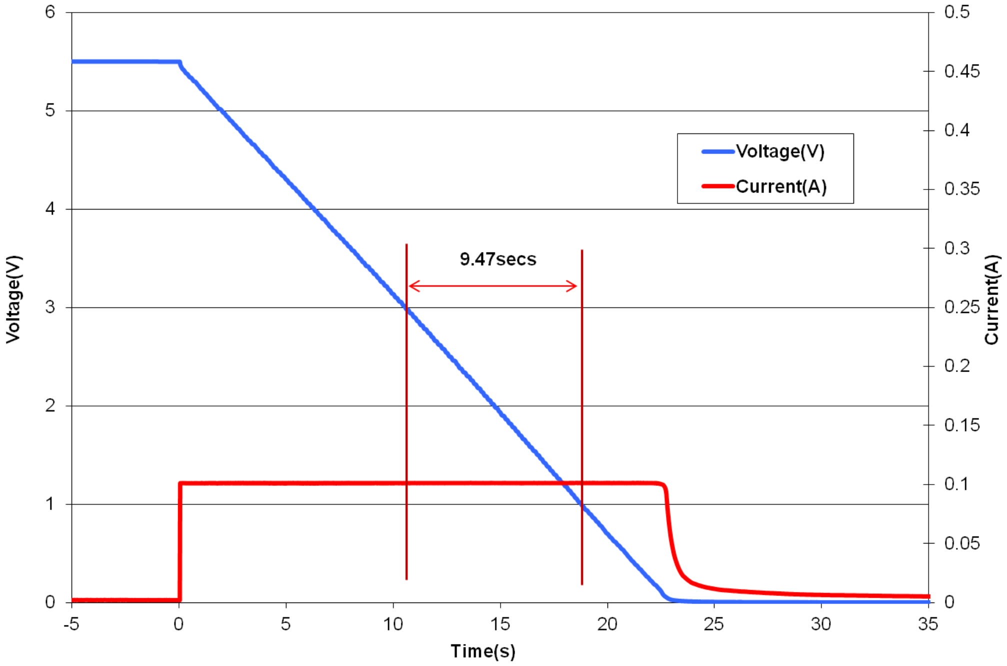

Fig 2: Measurement of DC Capacitance for an HA230

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 x 9.47s /2V = 473.5F, which is well within the 0.4F +/- 20% tolerance for an HA230 cell.

Measurement of ESR

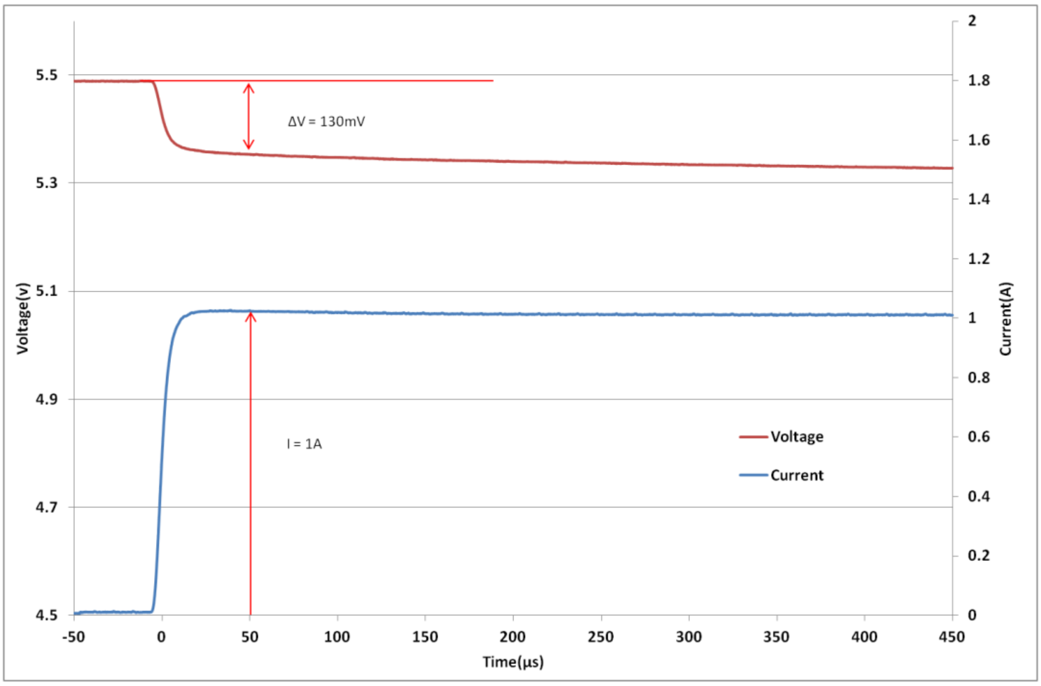

Fig 3: Measurement of ESR for an HA230

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 = 130mΩ.

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Effective Capacitance

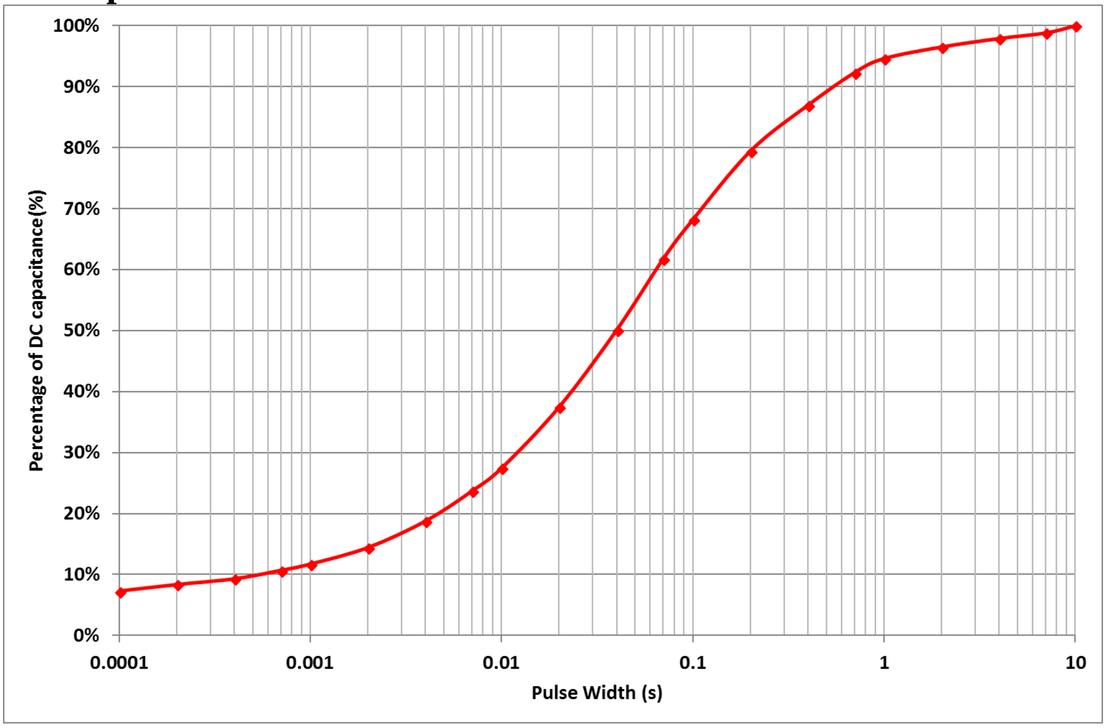

Figure 4: Effective Capacitance

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. 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 Ceff(10ms) = 27% of DC capacitance = 108mF for an HA230, so Vdrop = 1A x ESR + 1A x duration/C = 1A x 130mΩ + 1A x 10ms / 108mF = 277mV. The next section on pulse response shows how the effective capacitance is sufficient for even short pulse widths.

Pulse Response

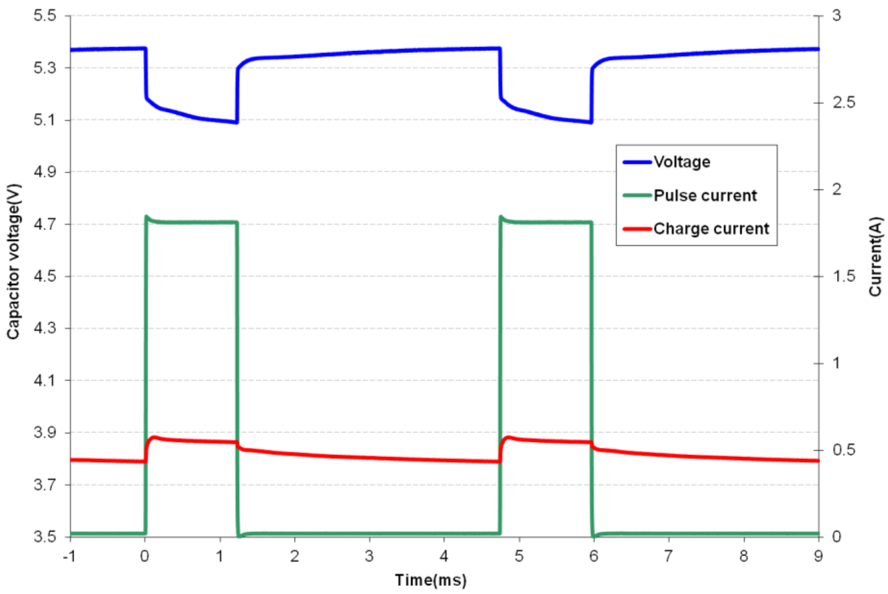

Fig 5 shows that the HA230 supercapacitor does an excellent job supporting a GPRS class 10 pulse train, drawing 1.8A for 1.1ms at 25% duty cycle. The source is current limited to 0.6A and the supercapacitor provides the 1.2A difference to achieve the peak current. At first glance the freq response of Fig 8 indicates the supercapacacitor would not support a 1ms pulse, but the Ceff 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

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DC Capacitance variation with temperature

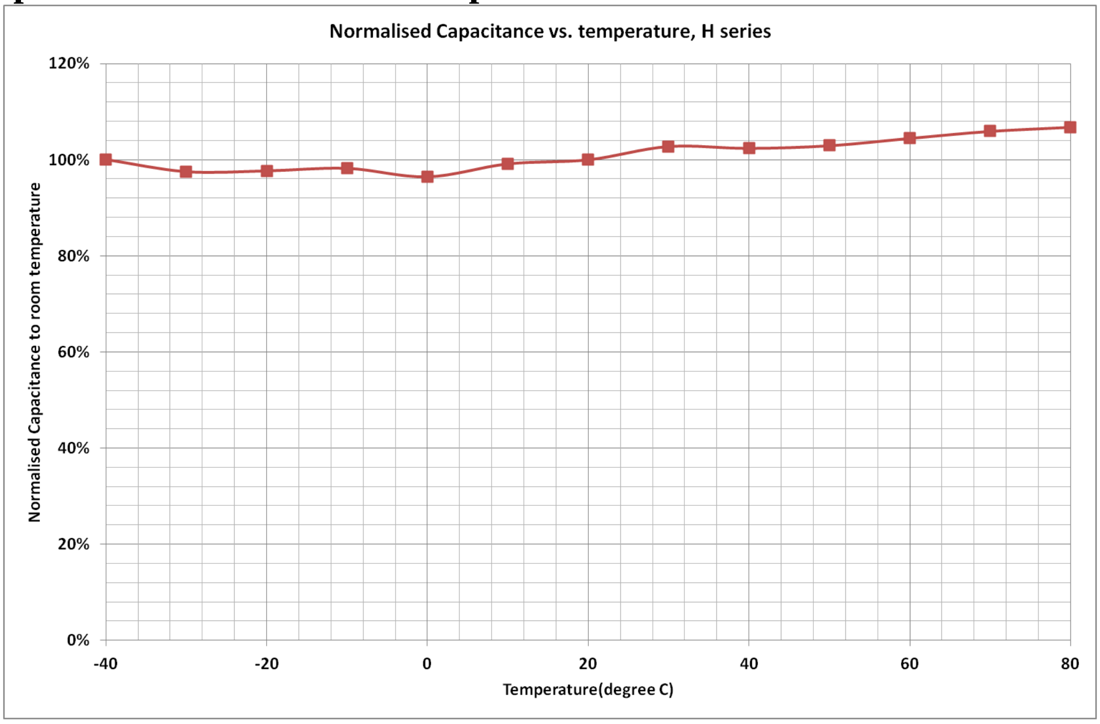

Figure 6: Capacitance change with temperature

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

ESR variation with temperature

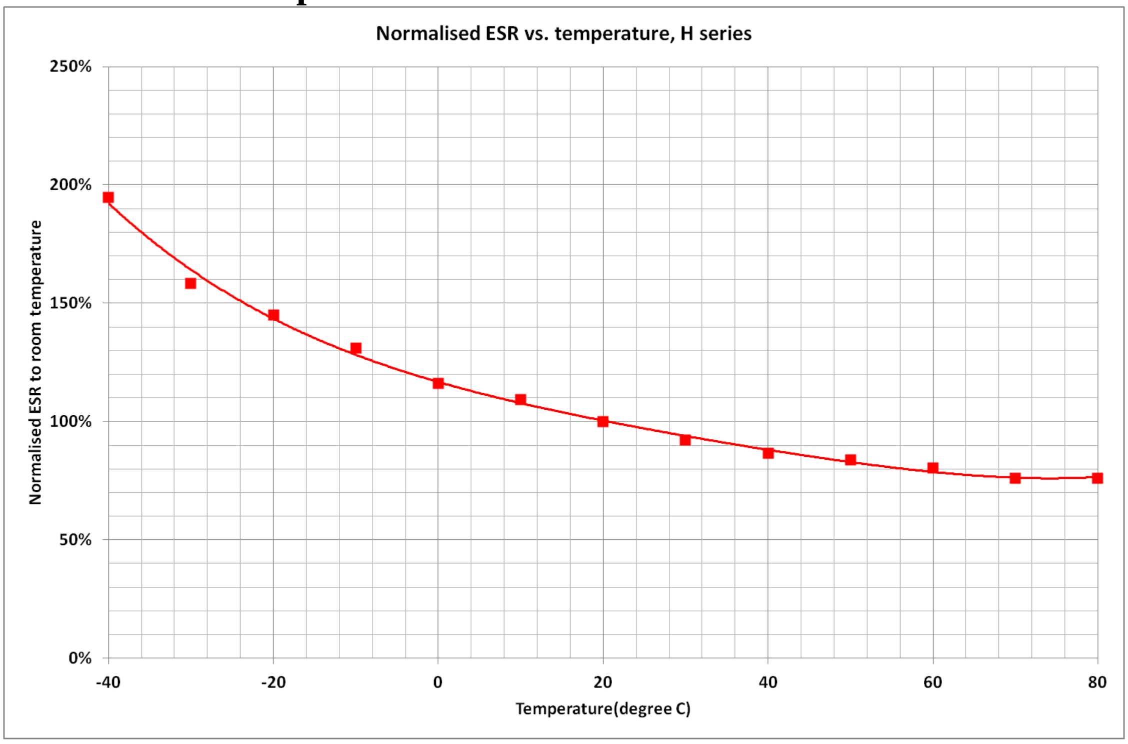

Figure 7: ESR change with temperature

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

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Frequency Response

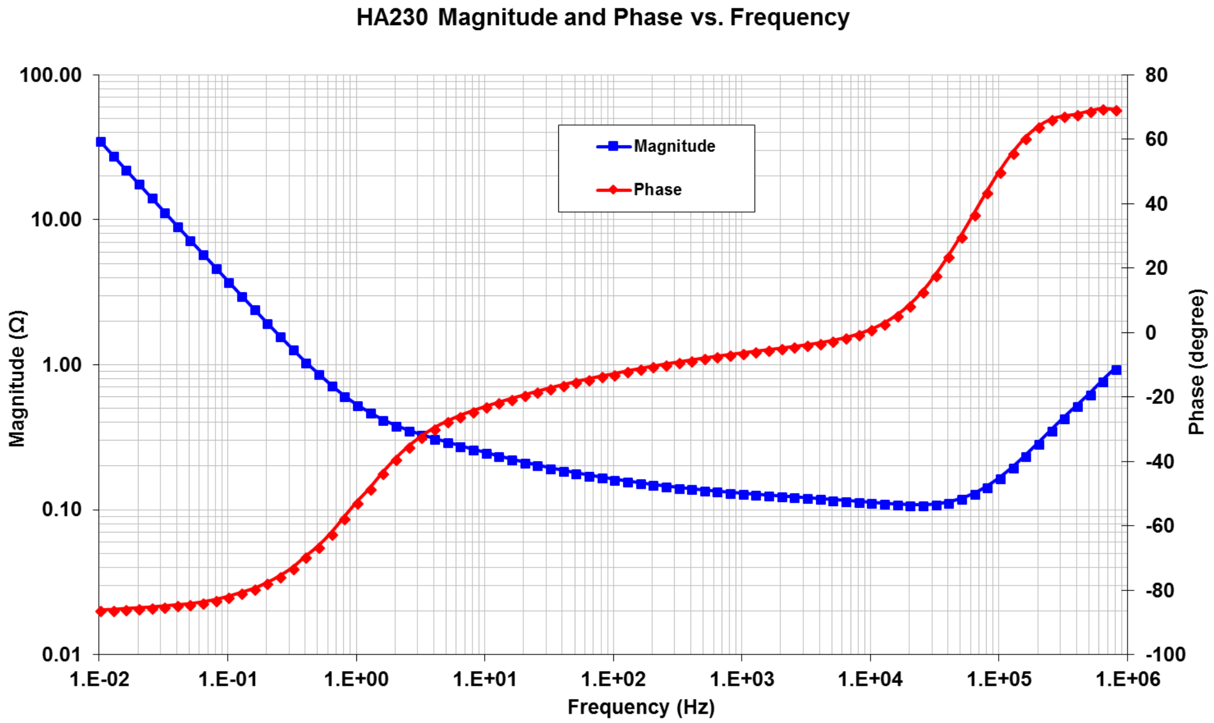

Fig 8: Frequency Response of Impedance (biased at 5.5V with a 50mV test signal)

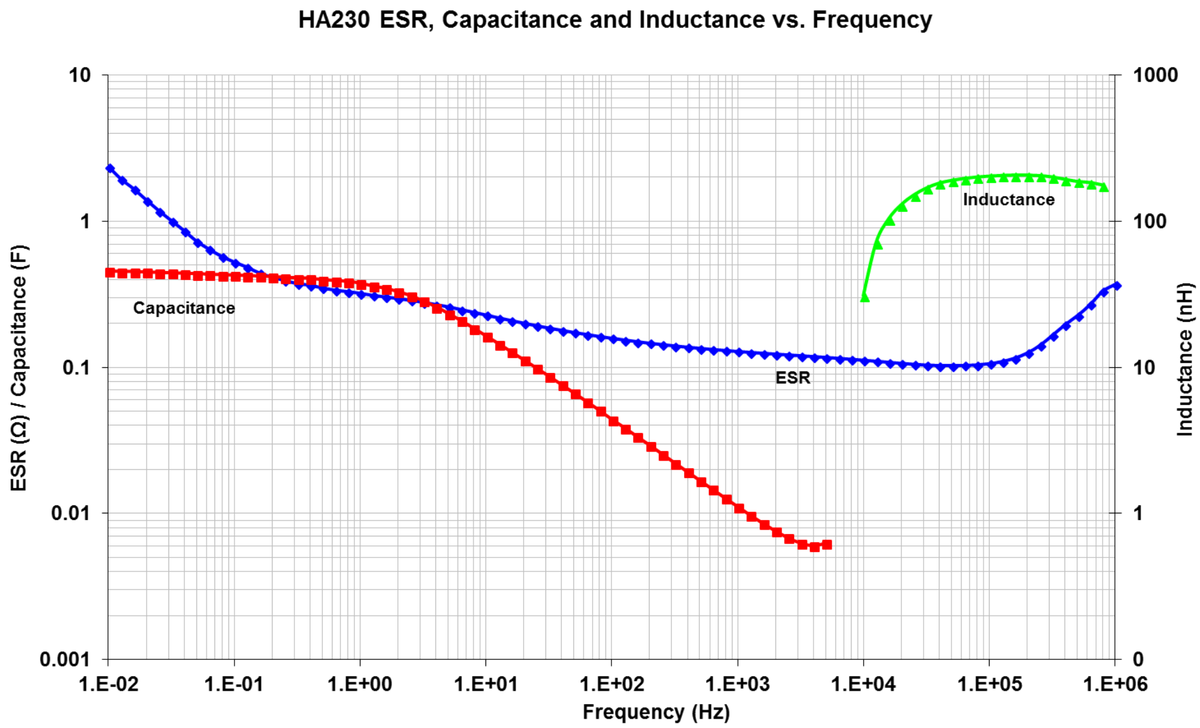

Fig 9: Frequency Response of ESR, Capacitance & Inductance

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/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.

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Leakage Current

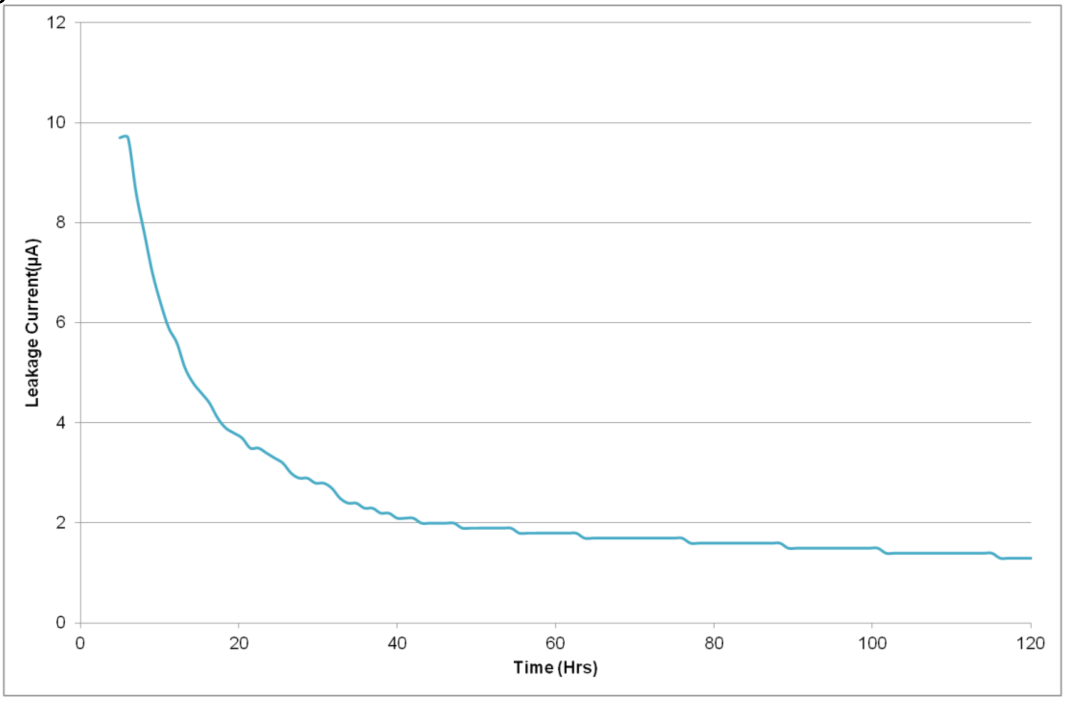

Fig 10: Leakage Current

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

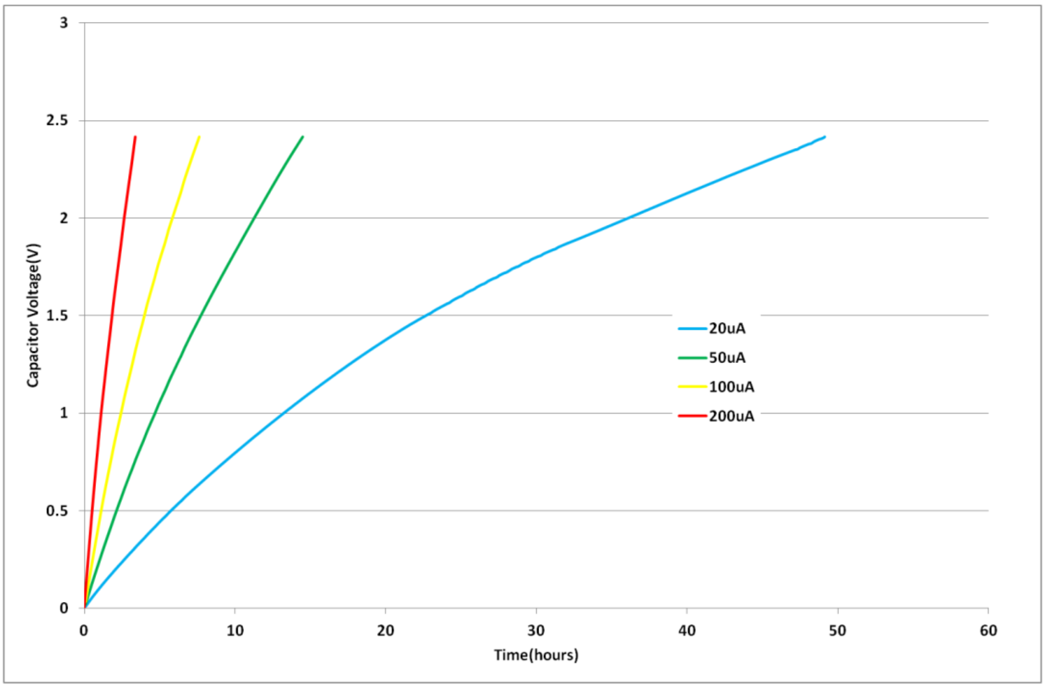

Fig 11: Charging an HA130 with low current

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 0.8F x 2.4V / 0.00002A = 26.7hrs 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.

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RMS Current

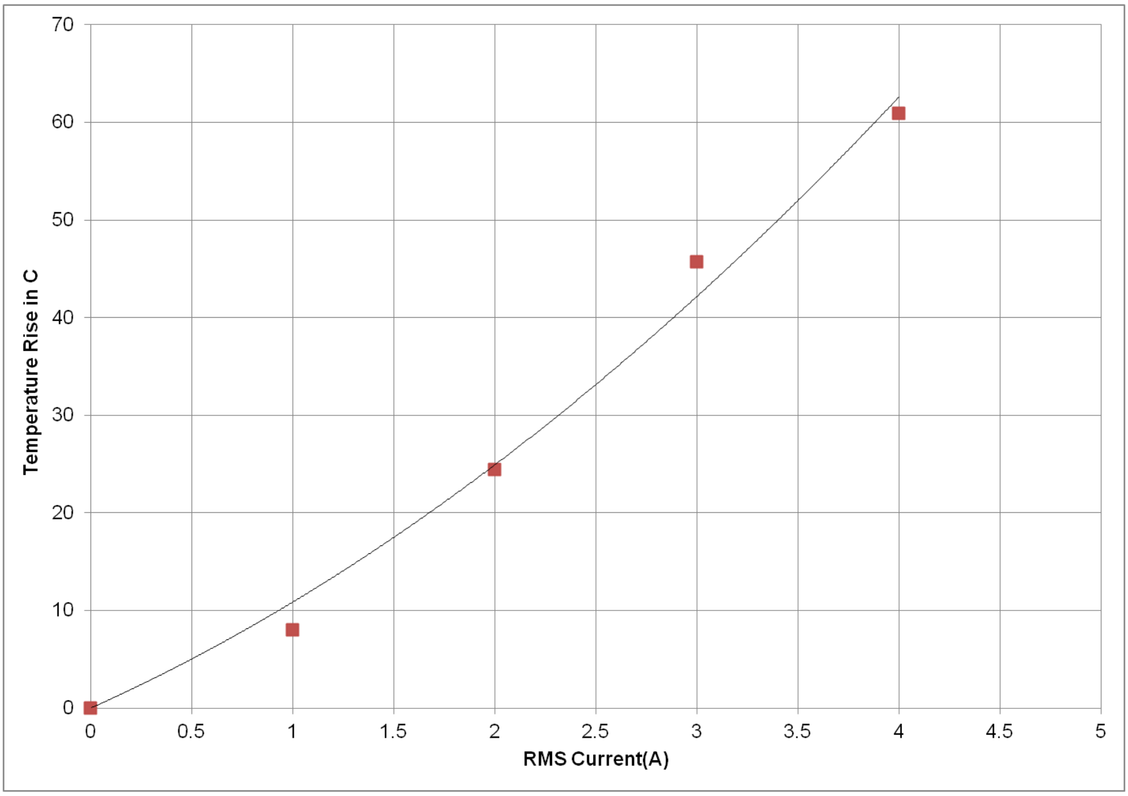

Fig 12: Temperature rise in HA230 with RMS current

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.

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