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GW101 / GW201 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 GW101 is a single cell supercapacitor. The GW201 is a dual cell supercapacitor with two GW101 cells in series, so GW201 capacitance = Capacitance of GW101/2 and GW201 ESR = 2 x GW101 ESR.

Table 1: Absolute Maximum Ratings

Parameter	Name		Conditions	Min	Typical	Max	Units
Terminal Voltage	Vpeak	GW101		0		2.75	V
		GW201				5.5	
Temperature	Tmax			-40		+70	°C

Table 2: Electrical Characteristics

Parameter	Name		Conditions	Min	Typical	Max	Units
Terminal Voltage	Vn	GW101		0		2.5	V
		GW201		0		5.0	
Capacitance	C	GW101	DC, 23°C	740	800	960	mF
		GW201		320	400	480	
ESR	ESR	GW101	DC, 23°C		30	36	mΩ
		GW201			55	66	
Leakage Current	I_L		2.3V, 23°C 120hrs		1	2	µA
RMS Current	I_{RMS}		23°C			6	A
Peak Current[1]	I_P		23°C			30	A

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

Table 3: Thickness

GW101F	**1.3mm**	No adhesive tape on underside of the supercapacitor	**GW101G**	**1.4mm**	Adhesive tape on underside, release tape removed
GW201F	**2.7mm**		**GW201G**	**2.8mm**	

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 secs.

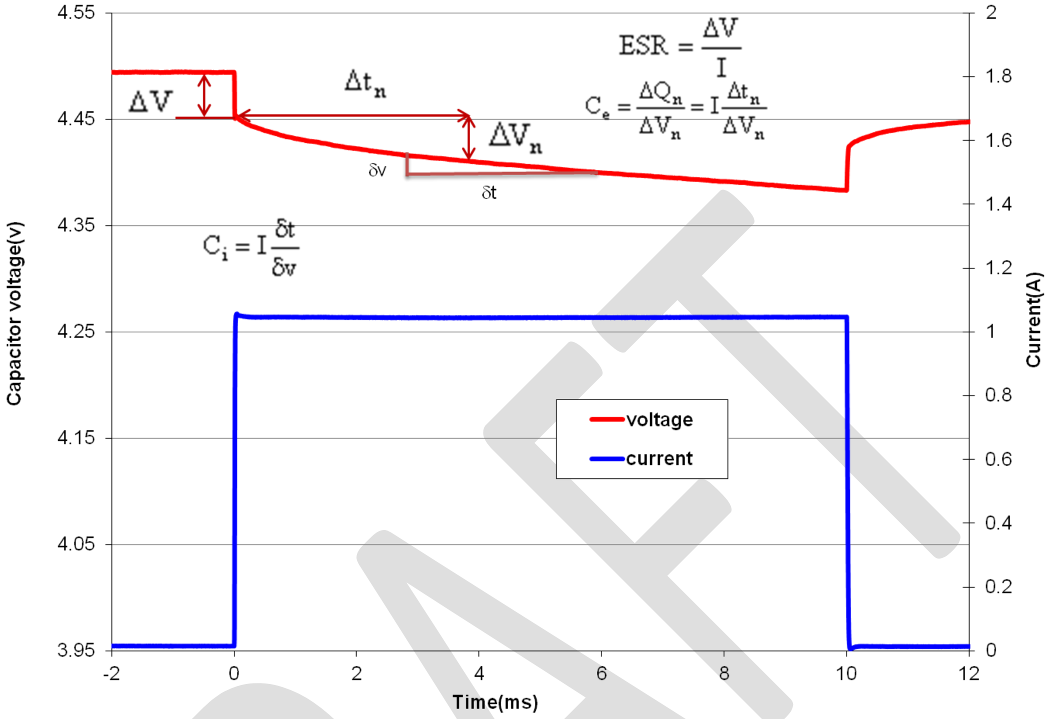

Figure 1: Effective capacitance, instantaneous capacitance and ESR for a GW201

The ESR is found by dividing the instantaneous voltage step (ΔV) by I. In this example = (4.494V-4.457 V)/1.02A = 36mΩ.

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 $Ce(\Delta t_n) = I \times \Delta t_n/\Delta V_n$. 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} = (4.457V – 4.422 V) = 35mV. Therefore Ce(2ms) = 1.02A x 2ms/35mV = 58.3mF. After 10ms, the voltage drop = 4.457 V – 4.383V = 74mV. Therefore Ce(10ms) = 1.02A x 10ms/74mV = 138mF. The DC capacitance of a GW201 = 400mF. 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.

Measurement of DC Capacitance

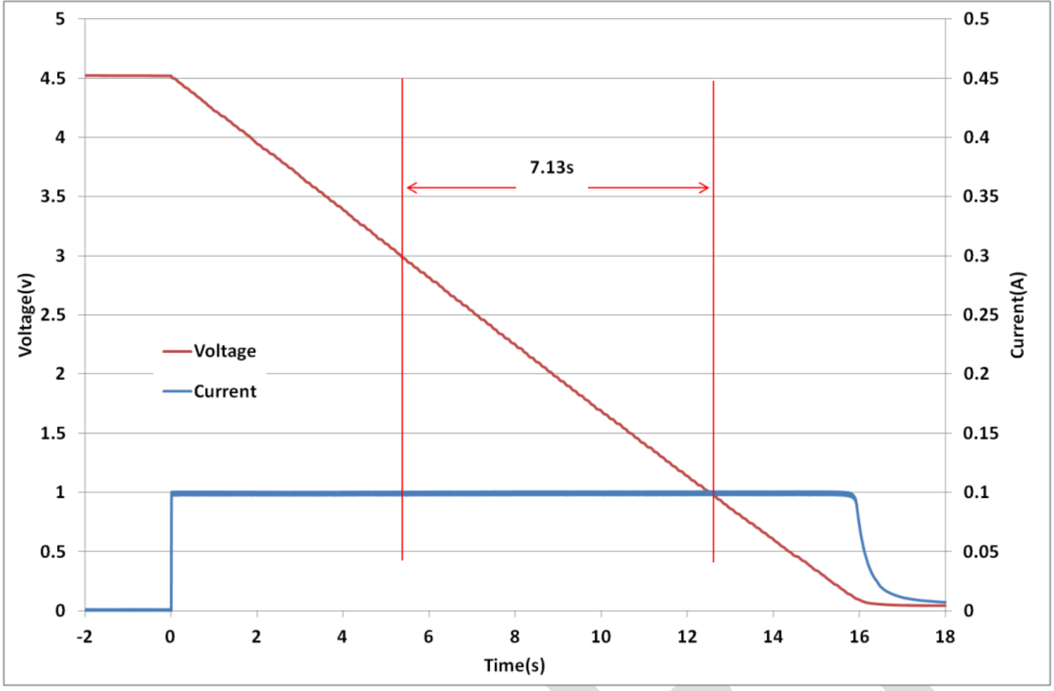

Fig 2: Measurement of DC Capacitance for a GW201

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 7.13s /2V = 356.5mF, which is well within the 400mF +/- 20% tolerance for a GW201 cell.

Measurement of ESR

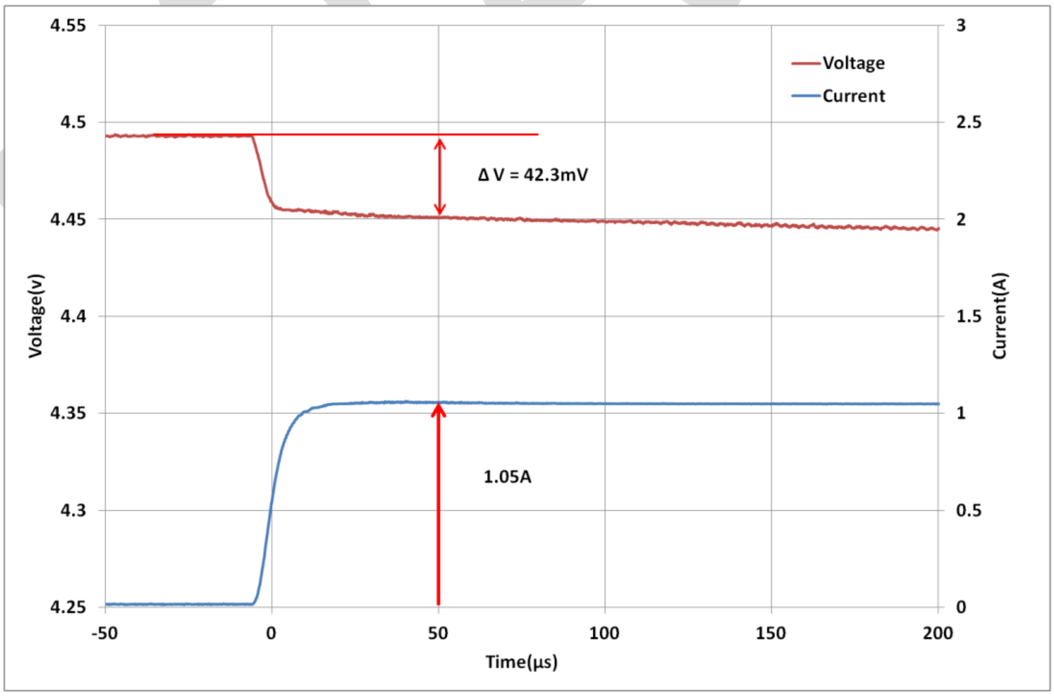

Fig 3: Measurement of ESR for a GW201

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 42.3mV/1.05A = 40.3mΩ.

Effective Capacitance

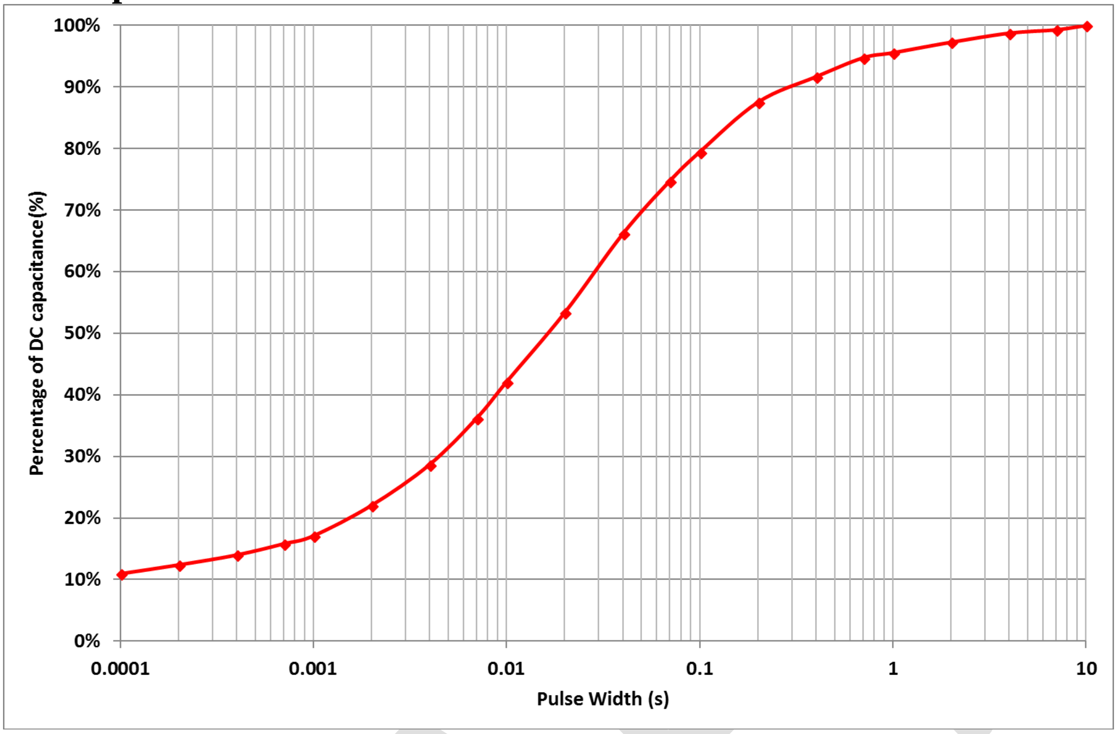

Figure 4: Effective Capacitance

Fig 4 shows the effective capacitance for the GW101, GW201 @ 23°C. This shows that for a 1ms PW, you will measure 17% of DC capacitance or 136mF for a GW101 or 68mF for a GW201. At 10ms you will measure 42% of the DC capacitance, and at 100ms you will measure 79% 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) = 42% of DC capacitance = 168mF for a GW201, so Vdrop = 1A x ESR + 1A x duration/C = 1A x 55mΩ + 1A x 10ms / 168mF = 115mV. The next section on pulse response shows how the effective capacitance is sufficient for even short pulse widths.

Pulse Response

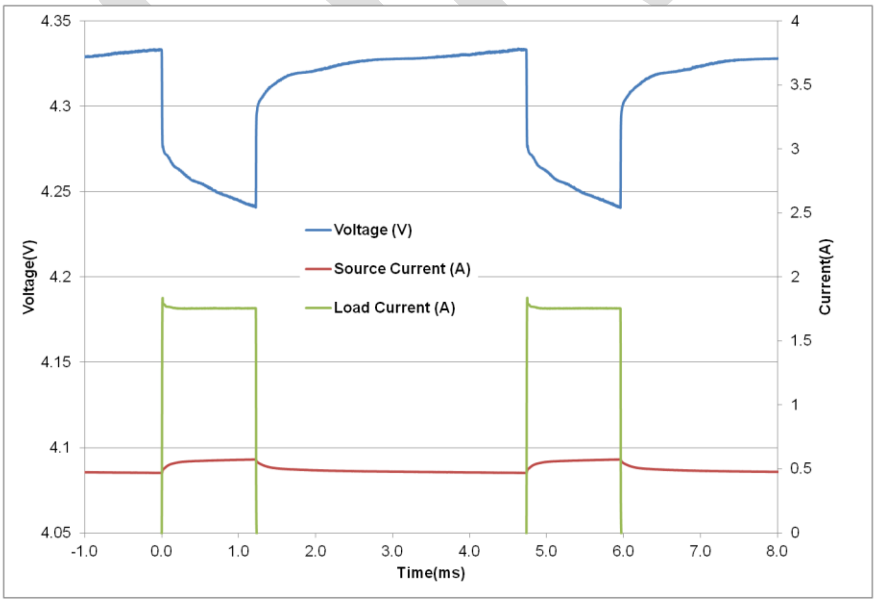

Fig 5: GW201 Pulse Response with GPRS Class 10 Pulse Train

Fig 5 shows that the GW201 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 Ceff of 56mF coupled with the low ESR supports this pulse train with only ~93mV droop in the supply rail.

DC Capacitance variation with temperature

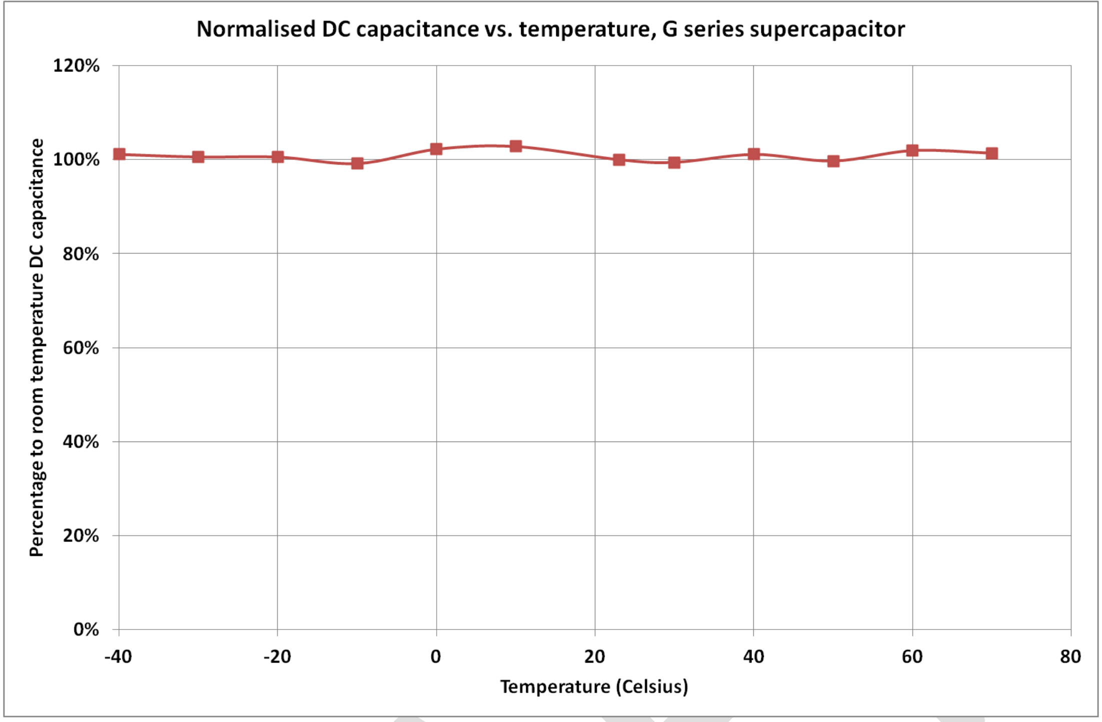

Figure 6: Capacitance change with temperature

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

ESR variation with temperature

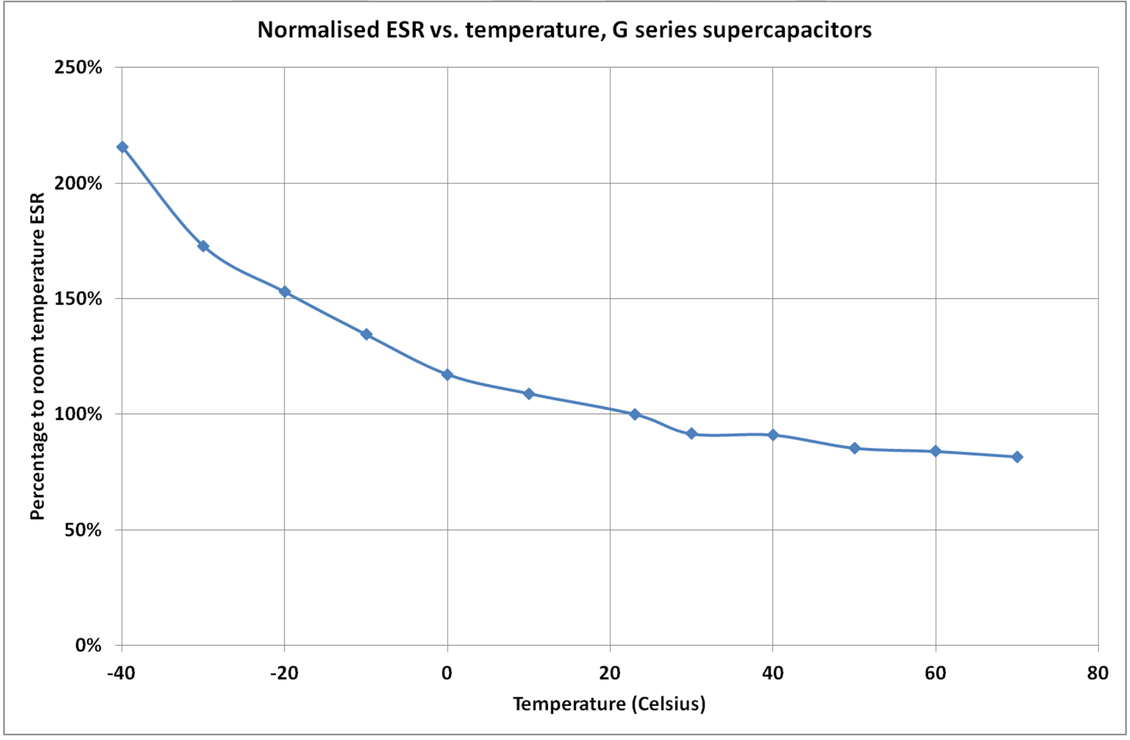

Figure 7: ESR change with temperature

Fig 7 shows that ESR at -40°C is ~2.2 x ESR at room temp, and that ESR at 70ºC is ~0.80 x ESR at room temperature.

Frequency Response

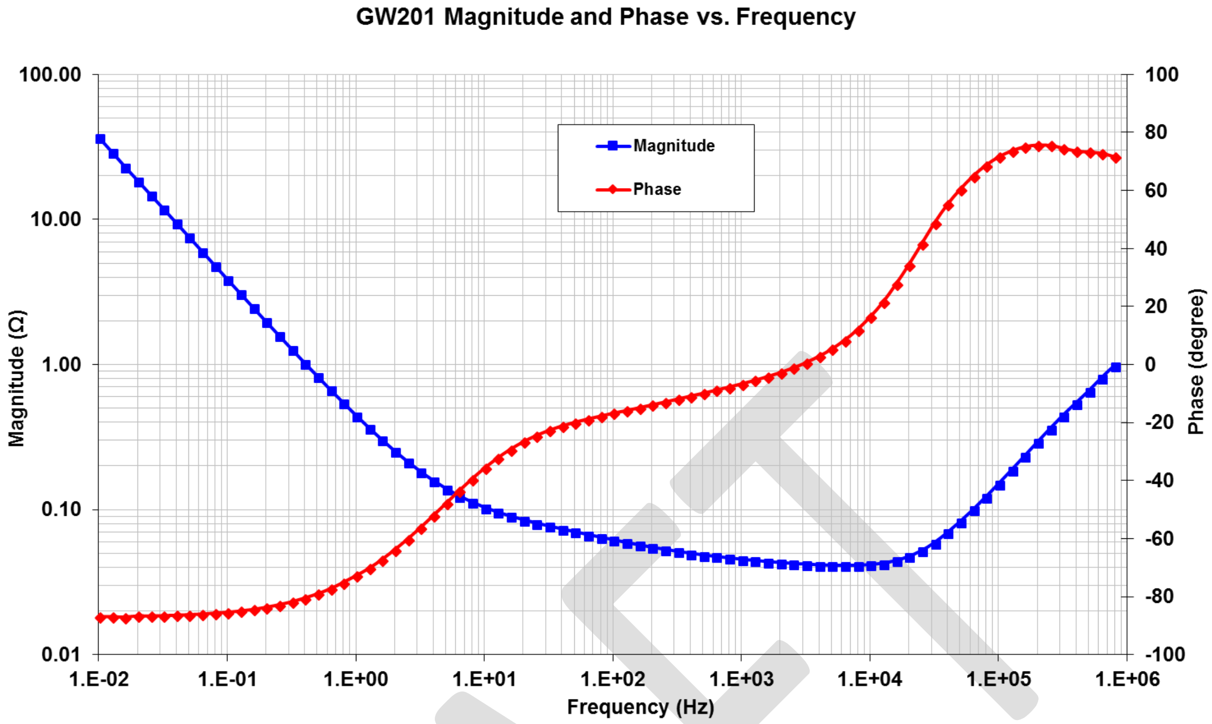

Fig 8: Frequency Response of Impedance (biased at 5V with a 50mV test signal)

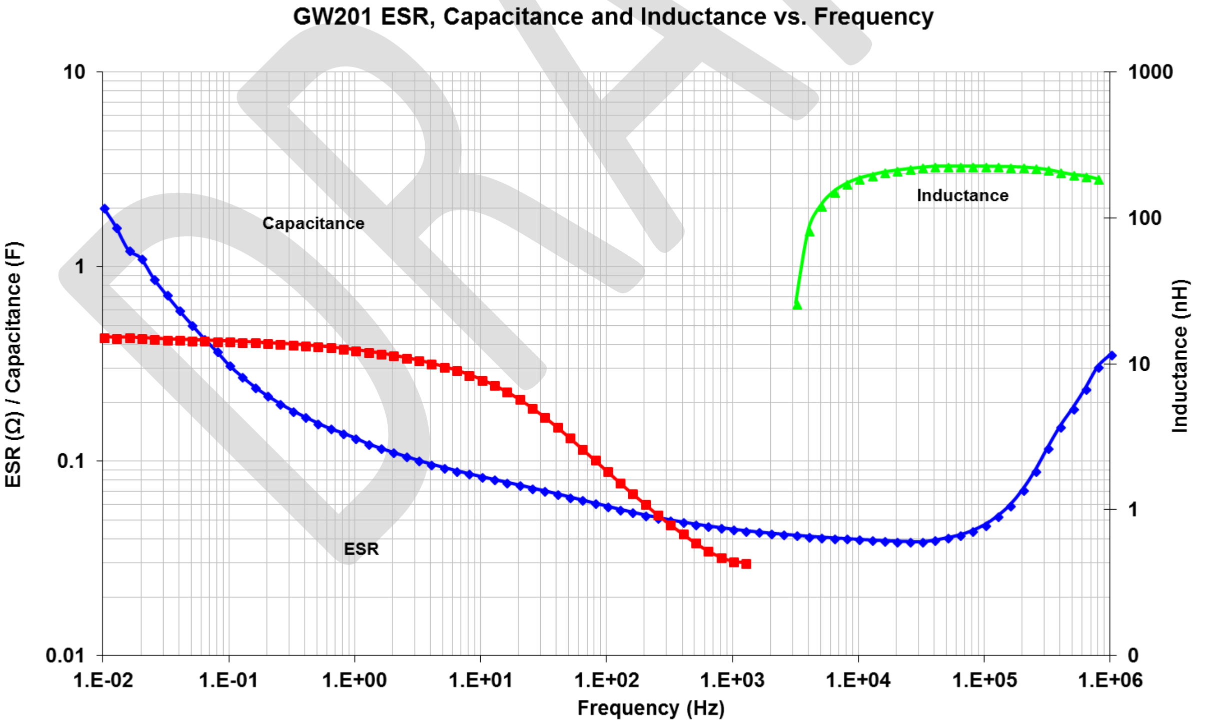

Fig 9: Frequency Response of ESR, Capacitance & Inductance

Fig 8 shows the supercapacitor behaves as an ideal capacitor until approx 6 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

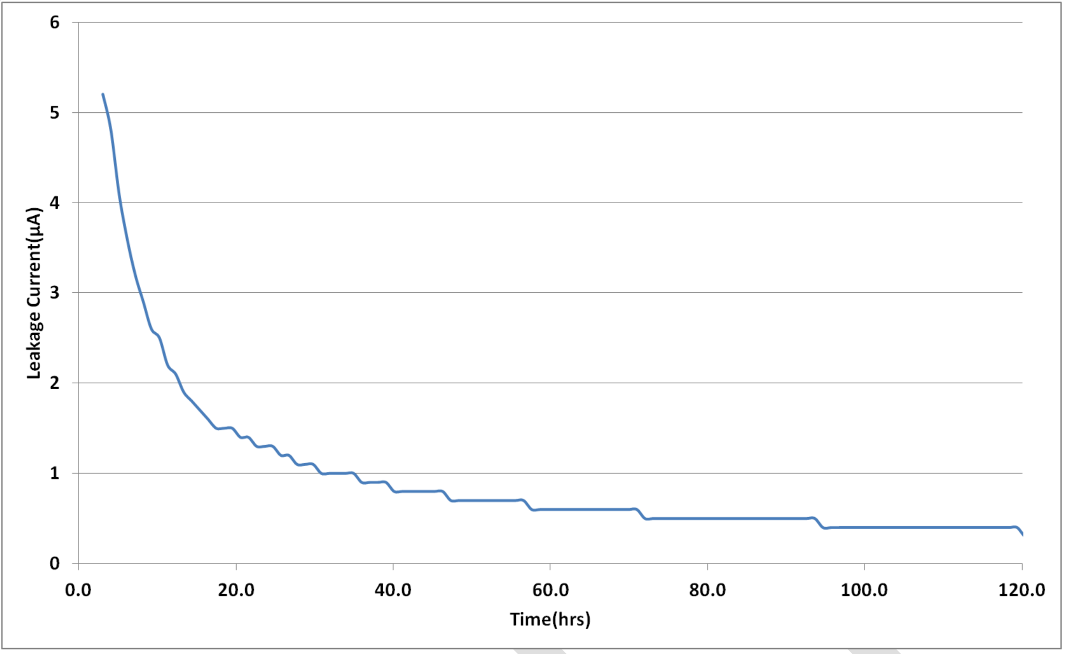

Fig 10: Leakage Current

Fig 10 shows the leakage current for GW101 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

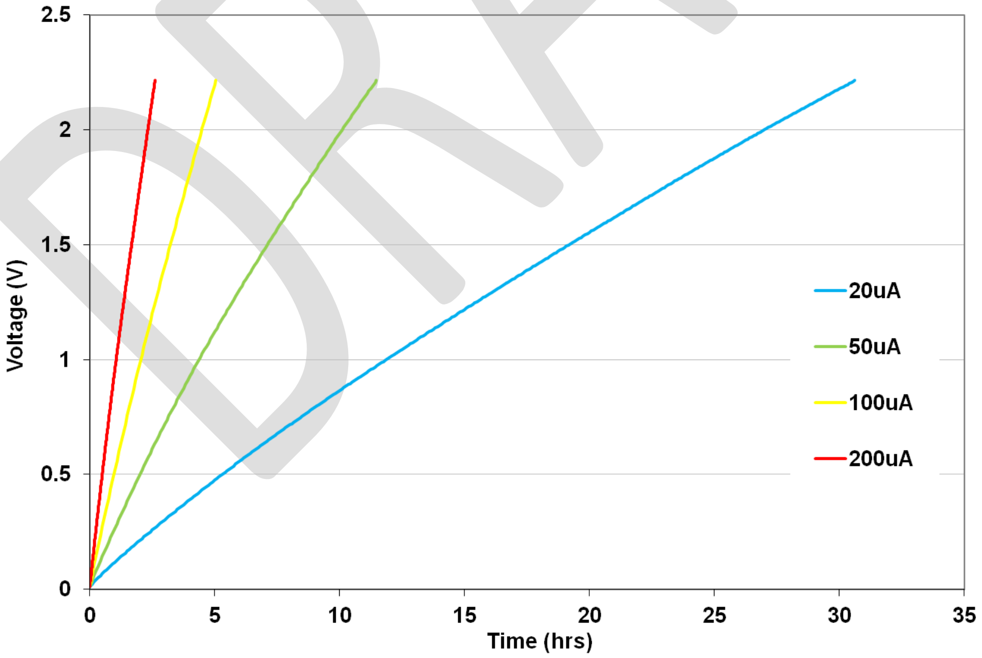

Fig 11: Charging an GW101 with low current

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 0.7F x 2.3V / 0.00002A = 22.4hrs to charge a 0.7F supercapacitor to 2.3V at 20µA, but Fig 11 shows it took 30hrs. At 100µA charging occurs at a rate close to the theoretical rate.

RMS Current

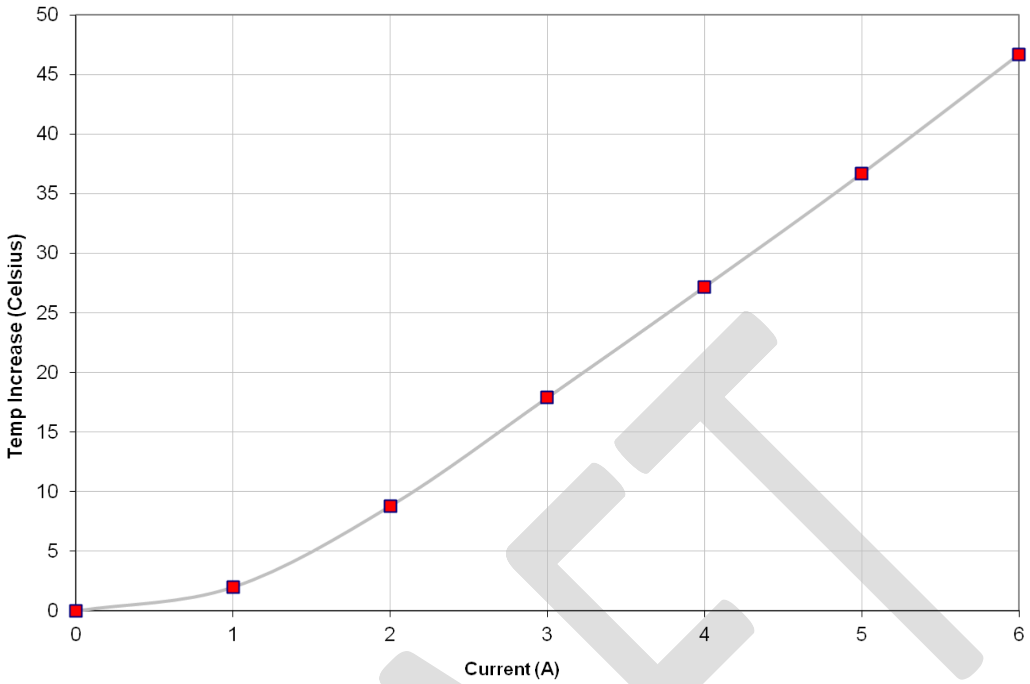

Fig 12: Temperature rise in GW201 with RMS current

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, and 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 4.3 A, 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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GW102 / GW202 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 GW102 is a single cell supercapacitor. The GW202 is a dual cell supercapacitor with two GW102 cells in series, so GW202 capacitance = Capacitance of GW102/2 and GW202 ESR = 2 x GW102 ESR.

Table 1: Absolute Maximum Ratings

Parameter	**Name**		**Conditions**	**Min**	**Typical**	**Max**	**Units**
Terminal Voltage	Vpeak	GW102		0		2.75	V
		GW202				5.5	
Temperature	Tmax			-40		+70	°C

Table 2: Electrical Characteristics

Parameter	**Name**		**Conditions**	**Min**	**Typical**	**Max**	**Units**
Terminal Voltage	Vn	GW102		0		2.5	V
		GW202		0		5.0	
Capacitance	C	GW102	DC, 23°C	320	400	480	mF
		GW202		160	200	240	
ESR	ESR	GW102	DC, 23°C		25	30	mΩ
		GW202			45	54	
Leakage Current	I_L		2.3V, 23°C 120hrs		1	2	µA
RMS Current	I_{RMS}		23°C			7.5	A
Peak Current[1]	I_P		23°C			30	A

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

Table 3: Thickness

GW102F	**1.3mm**	No adhesive tape on underside of the supercapacitor	**GW102G**	**1.4mm**	Adhesive tape on underside, release tape removed
GW202F	**2.7mm**		**GW202G**	**2.8mm**	

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.

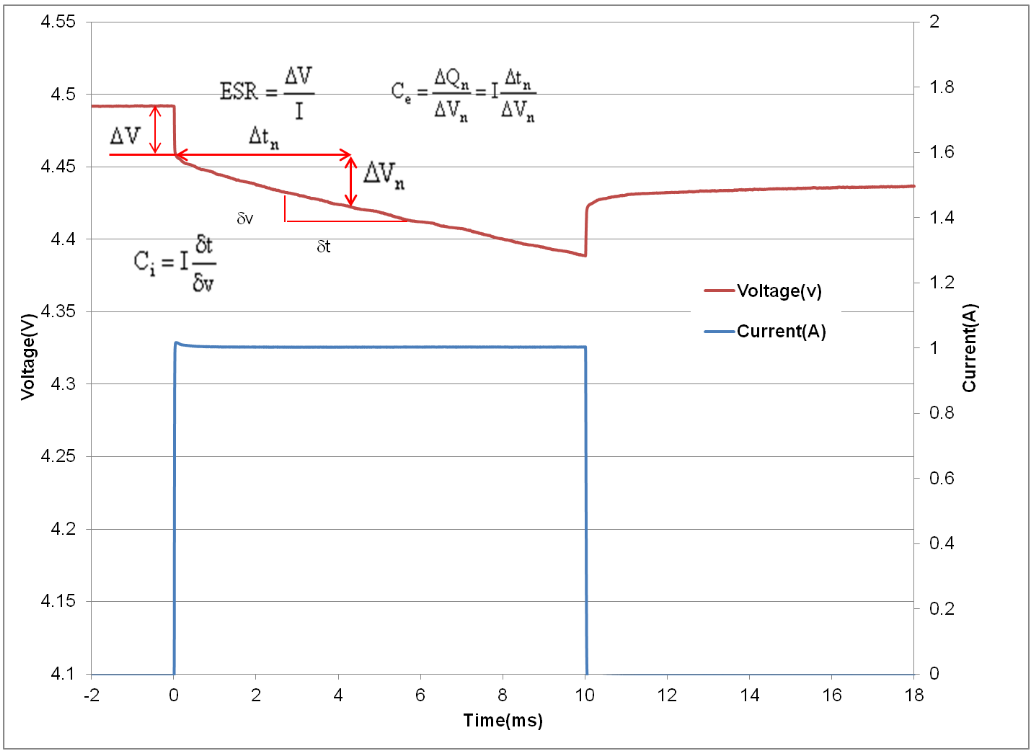

Figure 1: Effective capacitance, instantaneous capacitance and ESR for a GW202

The ESR is found by dividing the instantaneous voltage step (ΔV) by I. In this example = (4.49V - 4.46V)/1A = 30mΩ.

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(Δt_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(Δt_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} = (4.46 V – 4.437V) = 23mV. Therefore Ce(2ms) = 1A x 2ms/23mV = 87mF. After 10ms, the voltage drop = 4.46 V – 4.388V = 72mV. Therefore Ce(10ms) = 1 A x 10ms/72mV = 139mF. The DC capacitance of a GW202 = 0.2 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.

Measurement of DC Capacitance

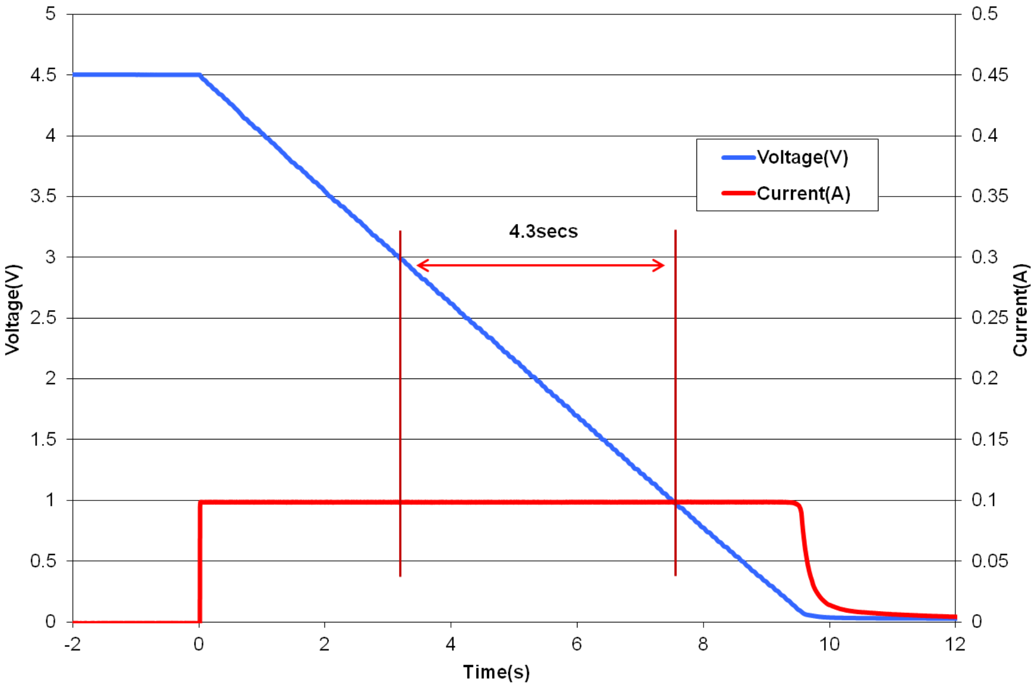

Fig 2: Measurement of DC Capacitance for a GW202

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 4.3s /2V = 215mF, which is well within the 200mF +/- 20% tolerance for a GW202 cell.

Measurement of ESR

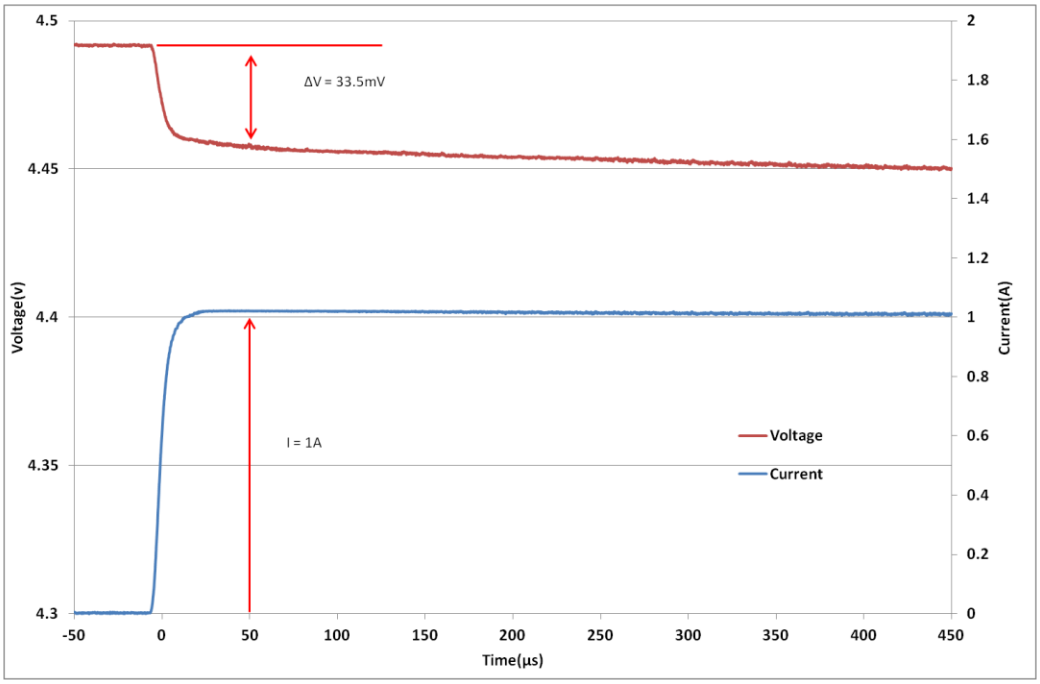

Fig 3: Measurement of ESR for a GW202

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 33.5mV/1A = 33.5mΩ.

Effective Capacitance

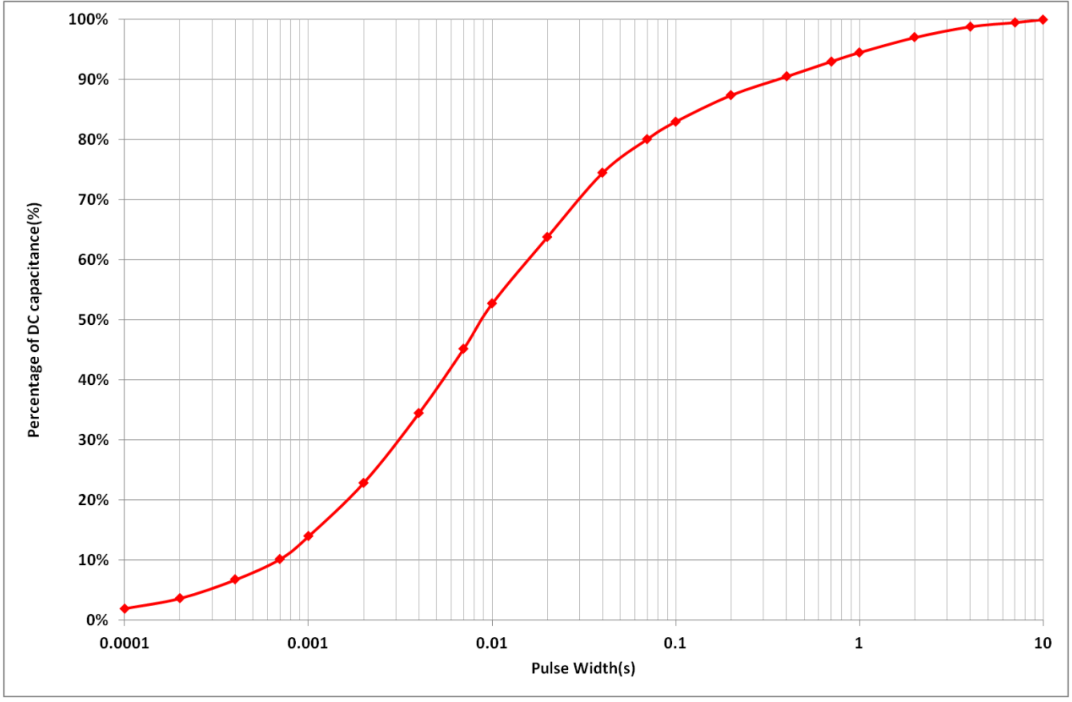

Figure 4: Effective Capacitance

Fig 4 shows the effective capacitance for the GW102, GW202 @ 23°C. This shows that for a 1msec PW, you will measure 14% of DC capacitance or 56mF for a GW102 or 28mF for a GW202. At 10msecs you will measure 53% of the DC capacitance, and at 100msecs you will measure 83% 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 10msecs, then you would use the Ceff(10msecs) = 53% of DC capacitance = 106mF for a GW202, so Vdrop = 1A x ESR + 1A x duration/C = 1A x 36mΩ + 1A x 10ms / 106mF = 130mV. The next section on pulse response shows how the effective capacitance is sufficient for even short pulse widths.

Pulse Response

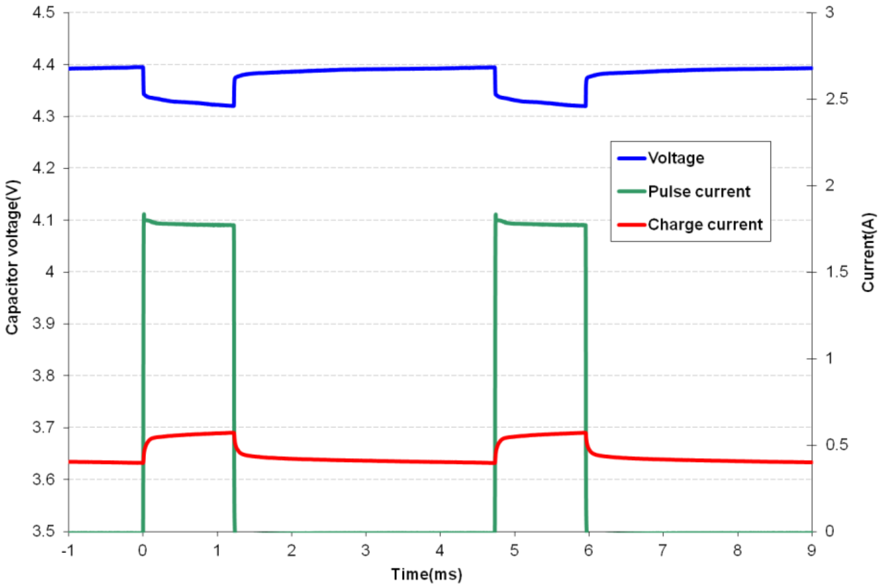

Fig 5 shows that the GW202 supercapacitor does an excellent job supporting a GPRS class 10 pulse train, drawing 1.8A for 1.1ms at 25% duty cycle. The source is current limited to 0.6A and the supercapacitor provides the 1.2A difference to achieve the peak current. At first glance the freq response of Fig 8 indicates the supercapacacitor would not support a 1ms pulse, but the Ceff of 28mF coupled with the low ESR supports this pulse train with only ~74mV droop in the supply rail.

Fig 5: GW202 Pulse Response with GPRS Class 10 Pulse Train

DC Capacitance variation with temperature

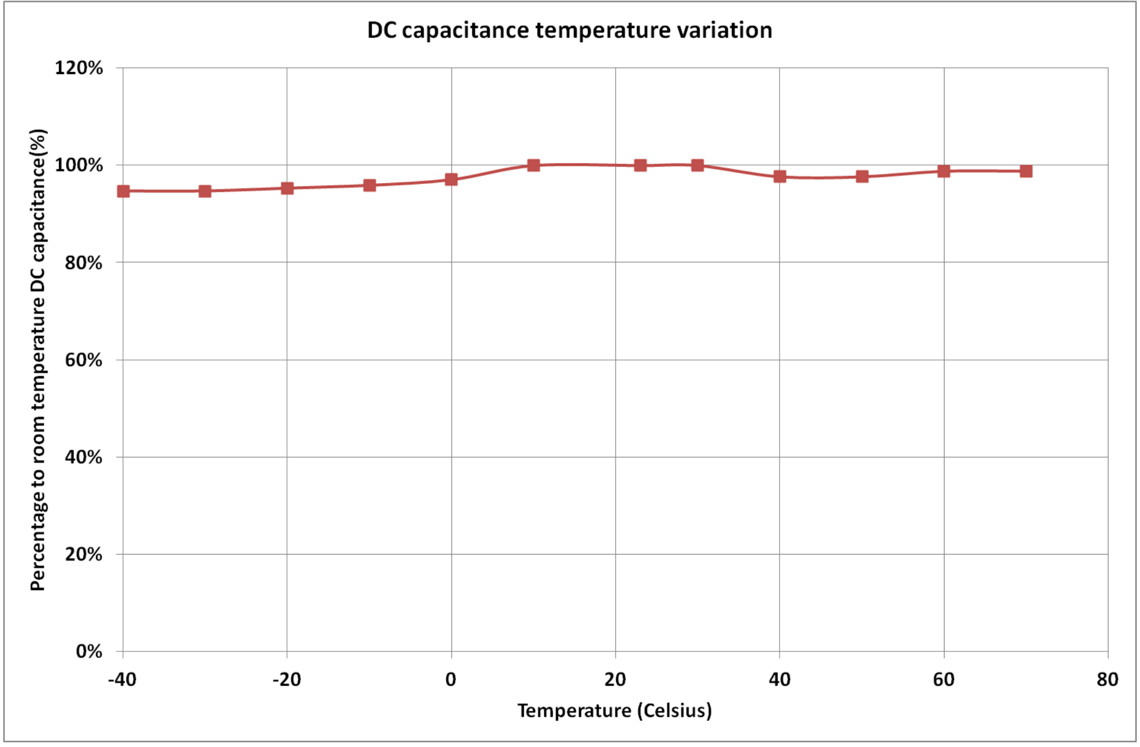

Figure 6: Capacitance change with temperature

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

ESR variation with temperature

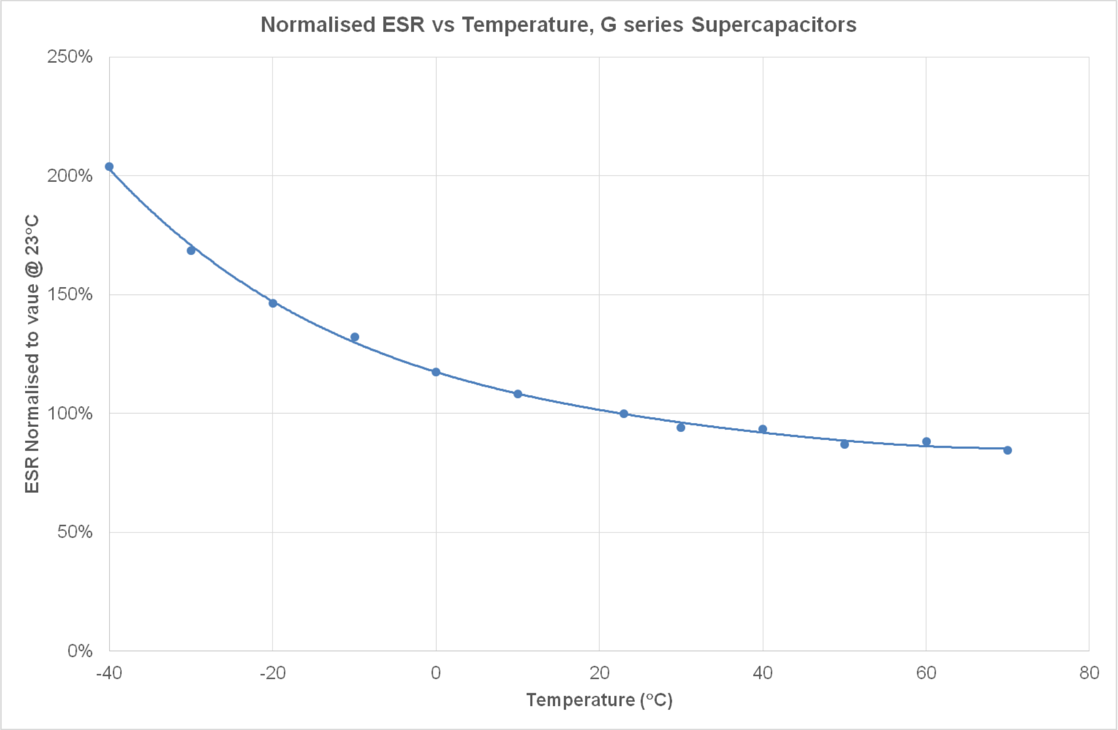

Figure 7: ESR change with temperature

Fig 7 shows that ESR at -40°C is ~2 x ESR at room temp, and that ESR at 70ºC is ~0.8 x ESR at room temperature.

Frequency Response

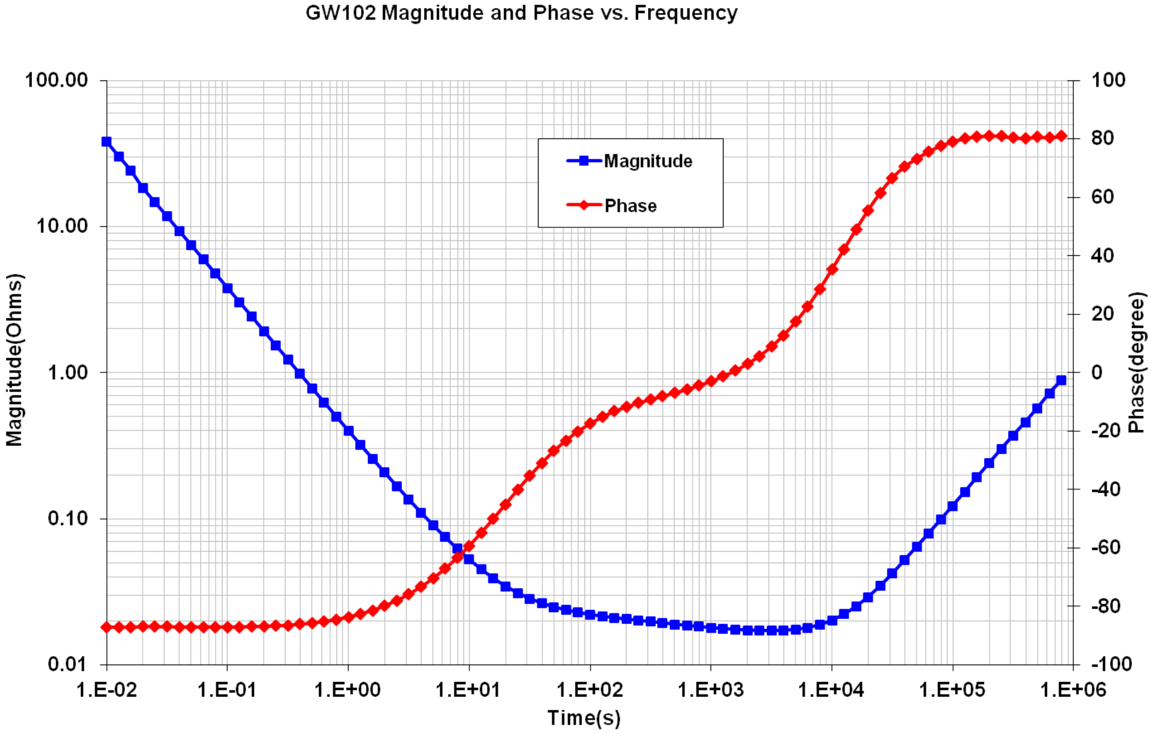

Fig 8: Frequency Response of Impedance (biased at 2.3V with a 50mV test signal)

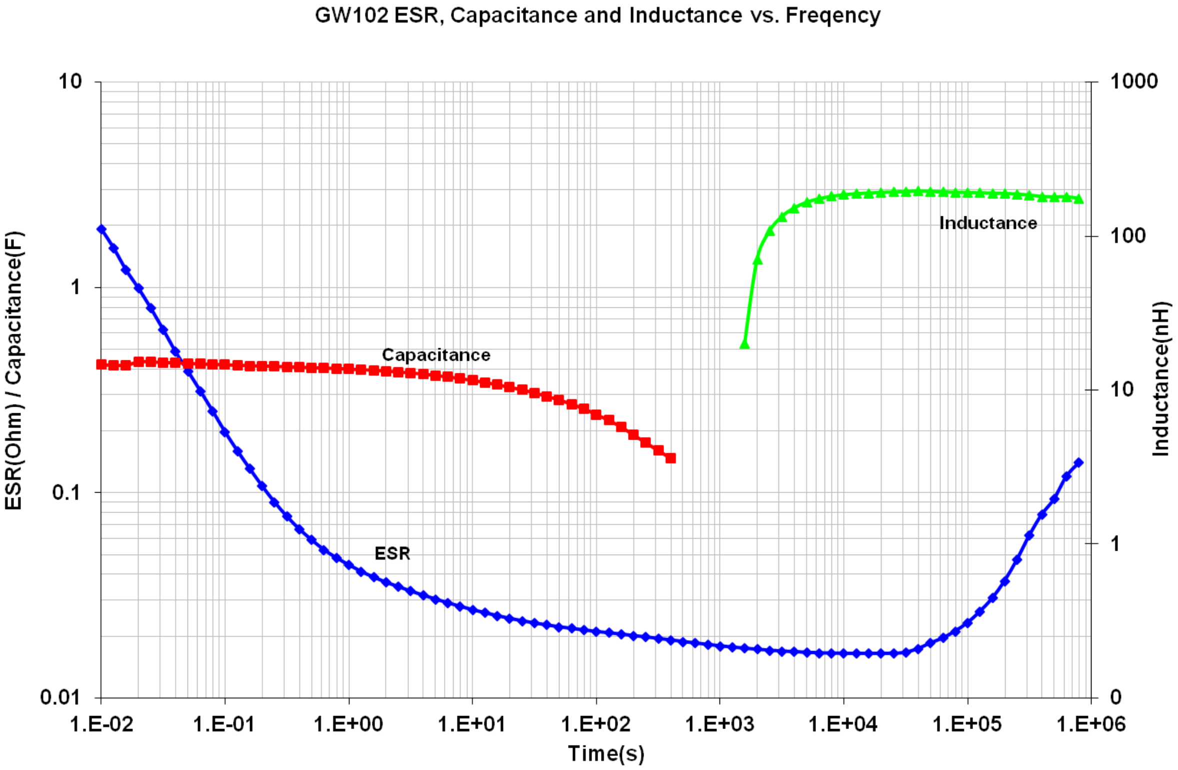

Fig 9: Frequency Response of ESR, Capacitance & Inductance

Fig 8 shows the supercapacitor behaves as an ideal capacitor until approx 20 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

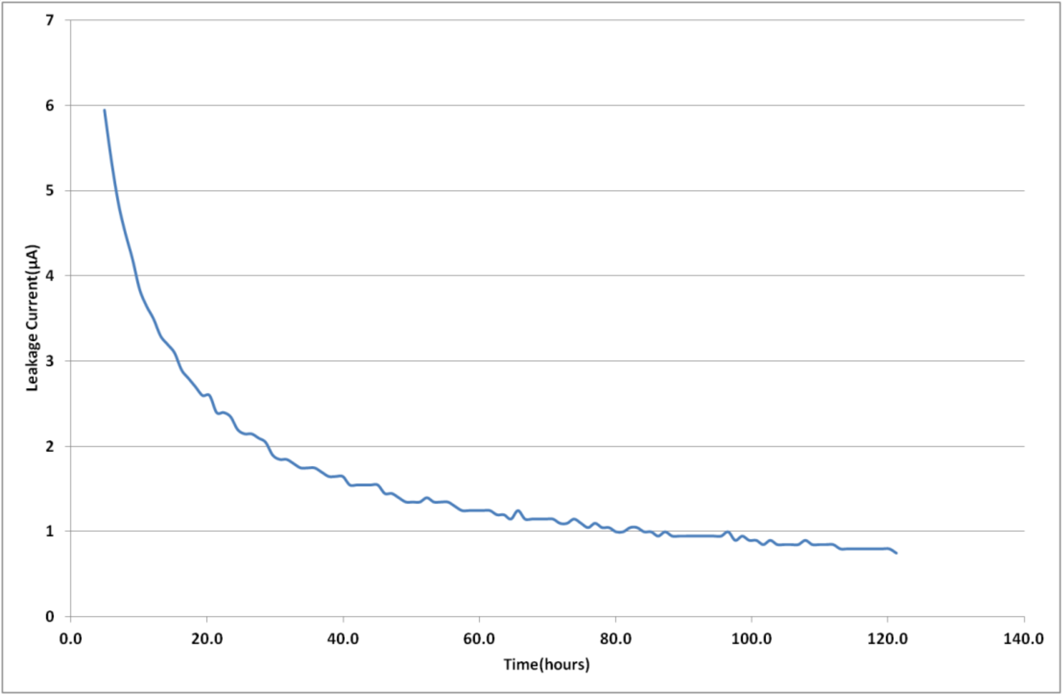

Fig 10: Leakage Current

Fig 10 shows the leakage current for GW102 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

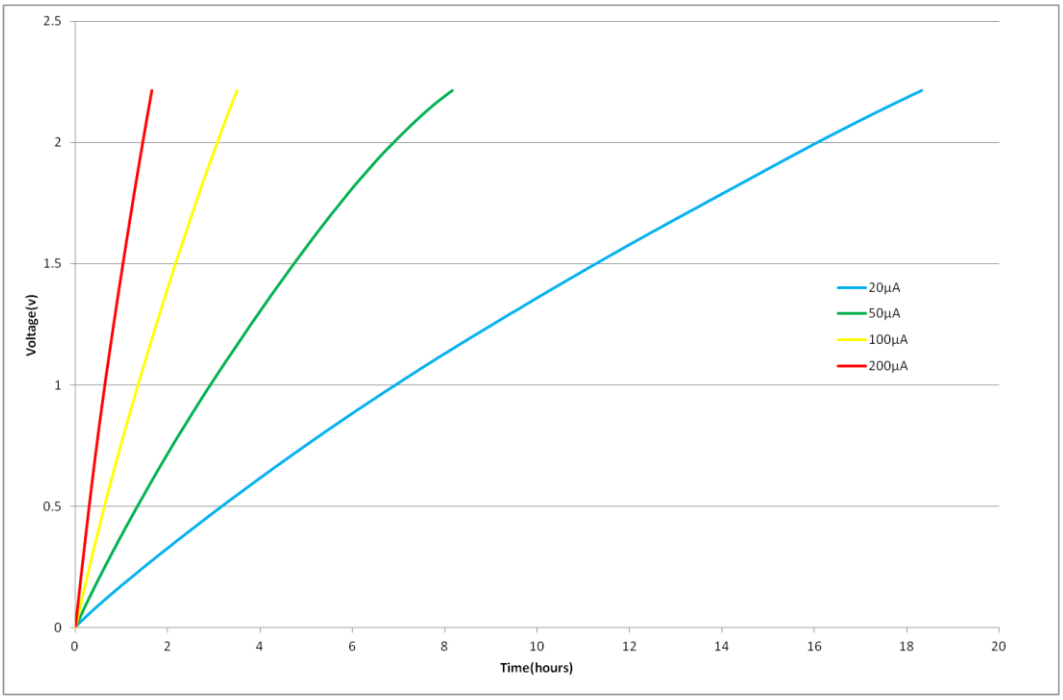

Fig 11: Charging a GW102 with low current

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 x 2.2V / 0.00002A = 12.2hrs to charge a 0.4 F supercapacitor to 2.2V at 20µA, but Fig 11 shows it took 19hrs. At 100µA charging occurs at a rate close to the theoretical rate.

RMS Current

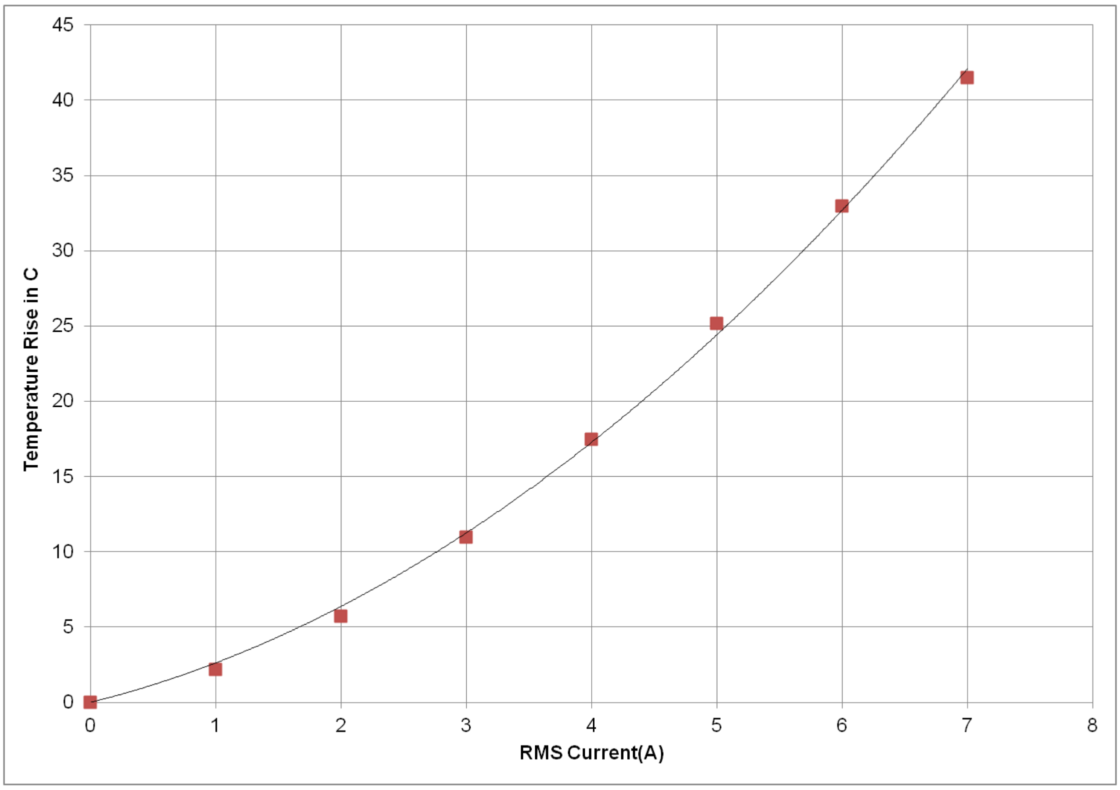

Fig 12: Temperature rise in GW202 with RMS current

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 5.5A, 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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GW103 / GW203 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 GW103 is a single cell supercapacitor. The GW203 is a dual cell supercapacitor with two GW103 cells in series, so GW203 capacitance = Capacitance of GW103/2 and GW203 ESR = 2 x GW103 ESR.

Table 1: Absolute Maximum Ratings

Parameter	Name		Conditions	Min	Typical	Max	Units
Terminal Voltage	Vpeak	GW103		0		2.75	V
		GW203				5.5	
Temperature	Tmax			-40		+70	°C

Table 2: Electrical Characteristics

Parameter	Name		Conditions	Min	Typical	Max	Units
Terminal Voltage	Vn	GW103		0		2.5	V
		GW203		0		5.0	
Capacitance	C	GW103	DC, 23°C	832	1040	1248	mF
		GW203		416	520	624	
ESR	ESR	GW103	DC, 23°C		20	24	mΩ
		GW203			40	48	
Leakage Current	I_L		2.3V, 23°C 120hrs		1	2	µA
RMS Current	I_{RMS}		23°C			7.5	A
Peak Current[1]	I_P		23°C			30	A

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

Table 3: Thickness

GW103F	**1.7mm**	No adhesive tape on underside of the supercapacitor	**GW103G**	**1.8mm**	Adhesive tape on underside, release tape removed
GW203F	**3.4mm**		**GW203G**	**3.5mm**	

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.

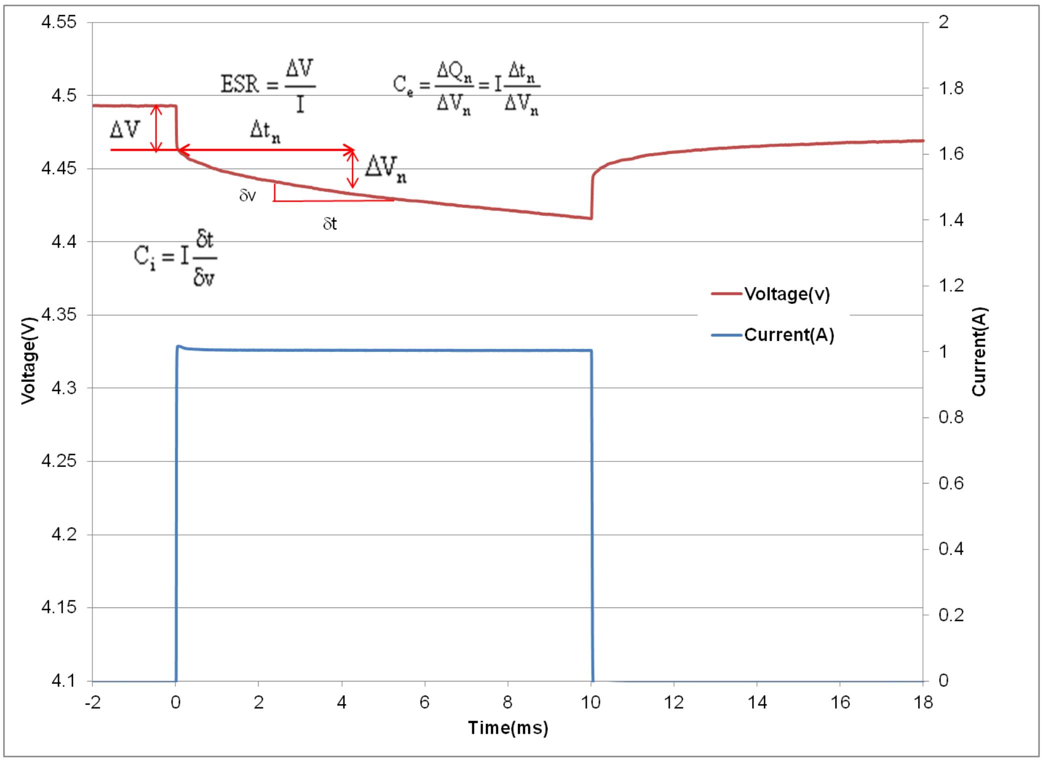

Figure 1: Effective capacitance, instantaneous capacitance and ESR for a GW203

The ESR is found by dividing the instantaneous voltage step (ΔV) by I. In this example = (4.49V - 4.465V)/1A = 25mΩ.

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} = (4.465 V – 4.442V) = 23mV. Therefore Ce(2ms) = 1A x 2ms/23mV = 87mF. After 10ms, the voltage drop = 4.465 V – 4.416V = 49mV. Therefore Ce(10ms) = 1 A x 10ms/49mV = 204mF. The DC capacitance of a GW203 = 0.52 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.

Measurement of DC Capacitance

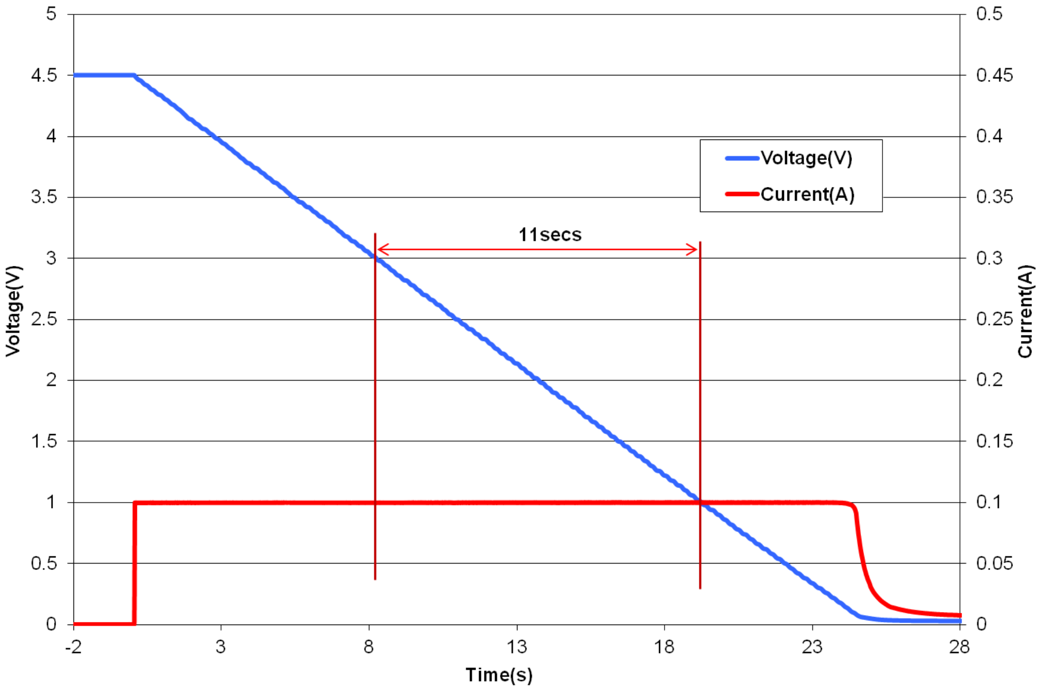

Fig 2: Measurement of DC Capacitance for a GW203

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 11s /2V = 550mF, which is well within the 520mF +/- 20% tolerance for a GW203 cell.

Measurement of ESR

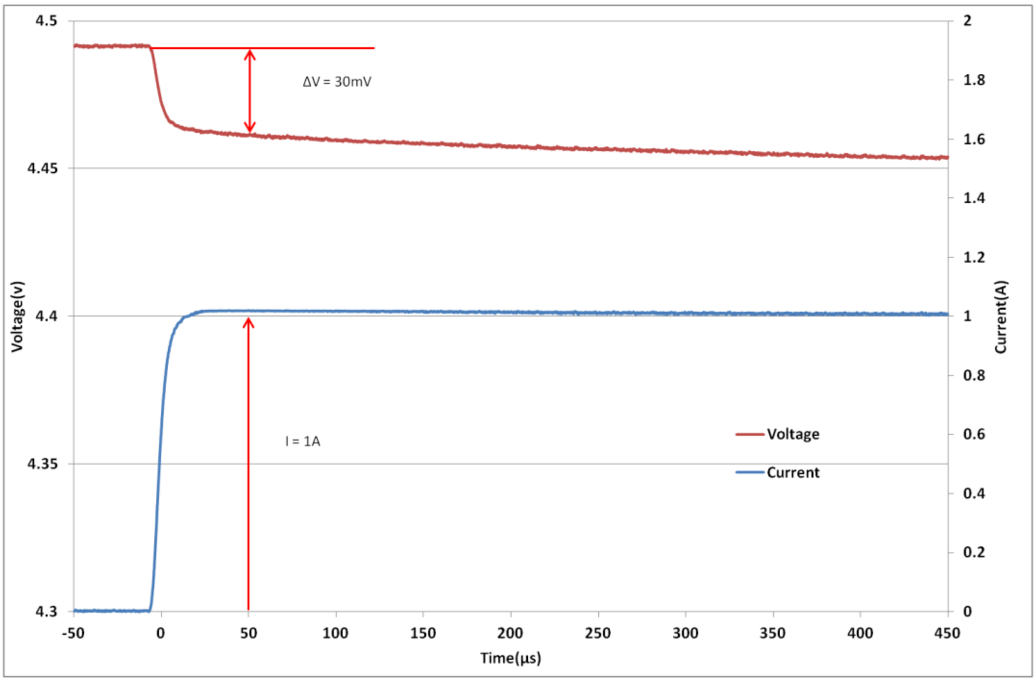

Fig 3: Measurement of ESR for a GW203

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 30mV/1A = 30mΩ.

Effective Capacitance

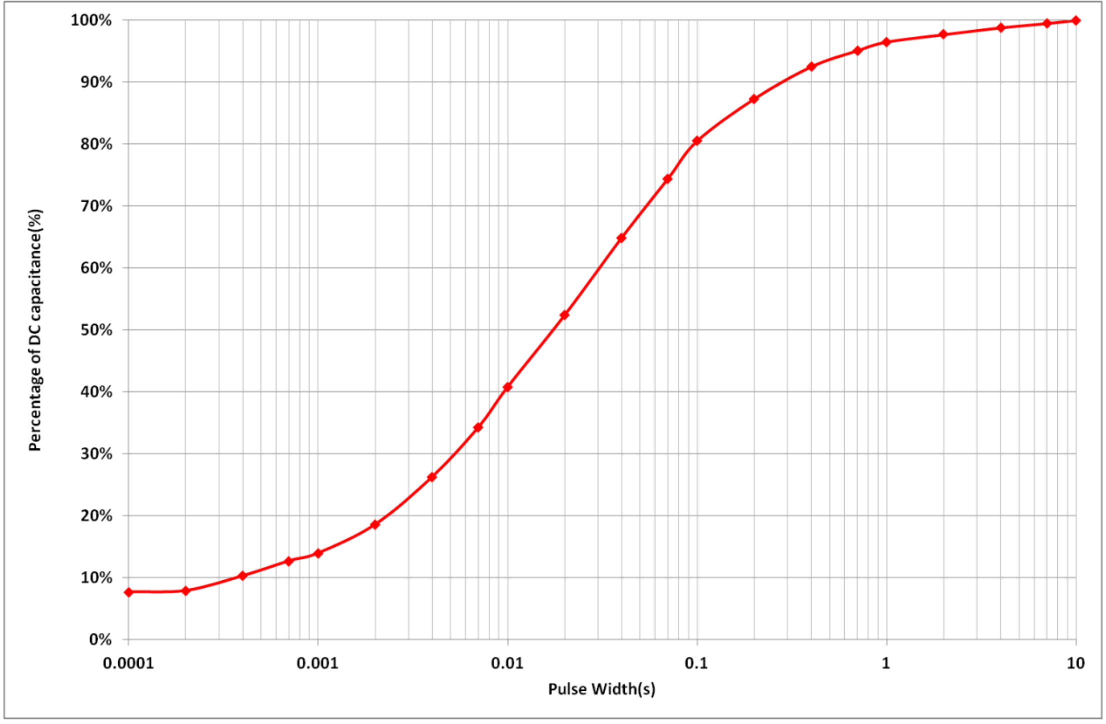

Figure 4: Effective Capacitance

Fig 4 shows the effective capacitance for the GW103, GW203 @ 23°C. This shows that for a 1msec PW, you will measure 14% of DC capacitance or 145.6mF for a GW103 or 72.8mF for a GW203. At 10msecs you will measure 41% of the DC capacitance, and at 100msecs 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 10msecs, then you would use the Ceff(10msecs) = 41% of DC capacitance = 213.2mF for a GW203, so Vdrop = 1A x ESR + 1A x duration/C = 1A x 36mΩ + 1A x 10ms / 213.2mF = 82.9mV. The next section on pulse response shows how the effective capacitance is sufficient for even short pulse widths.

Pulse Response

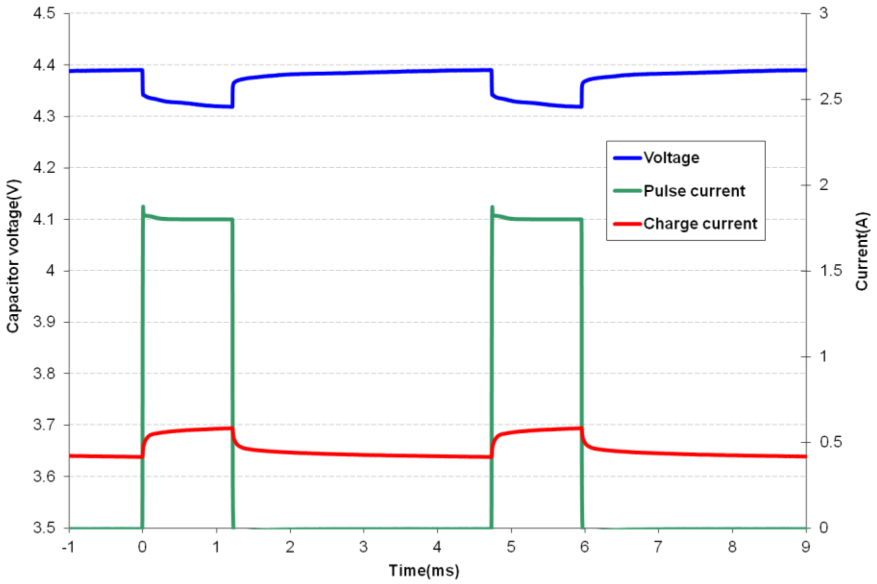

Fig 5 shows that the GW203 supercapacitor does an excellent job supporting a GPRS class 10 pulse train, drawing 1.8A for 1.1ms at 25% duty cycle. The source is current limited to 0.6A and the supercapacitor provides the 1.2A difference to achieve the peak current. At first glance the freq response of Fig 8 indicates the supercapacacitor would not support a 1ms pulse, but the Ceff of 72.8mF coupled with the low ESR supports this pulse train with only ~80mV droop in the supply rail.

Fig 5: GW203 Pulse Response with GPRS Class 10 Pulse Train

DC Capacitance variation with temperature

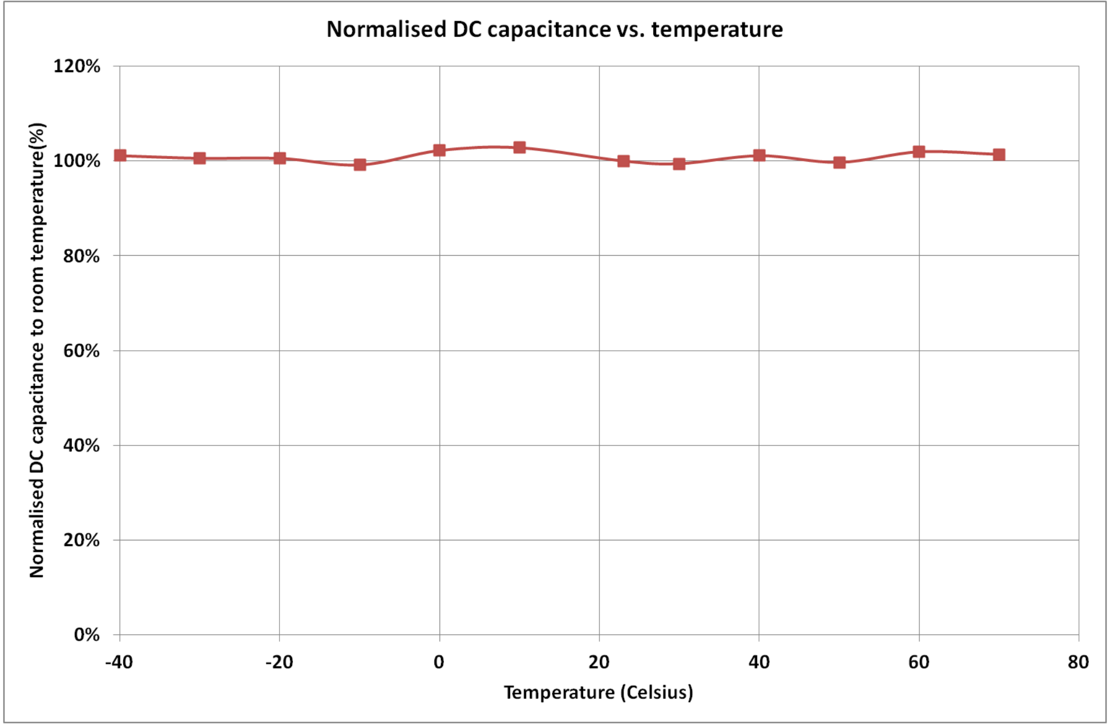

Figure 6: Capacitance change with temperature

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

ESR variation with temperature

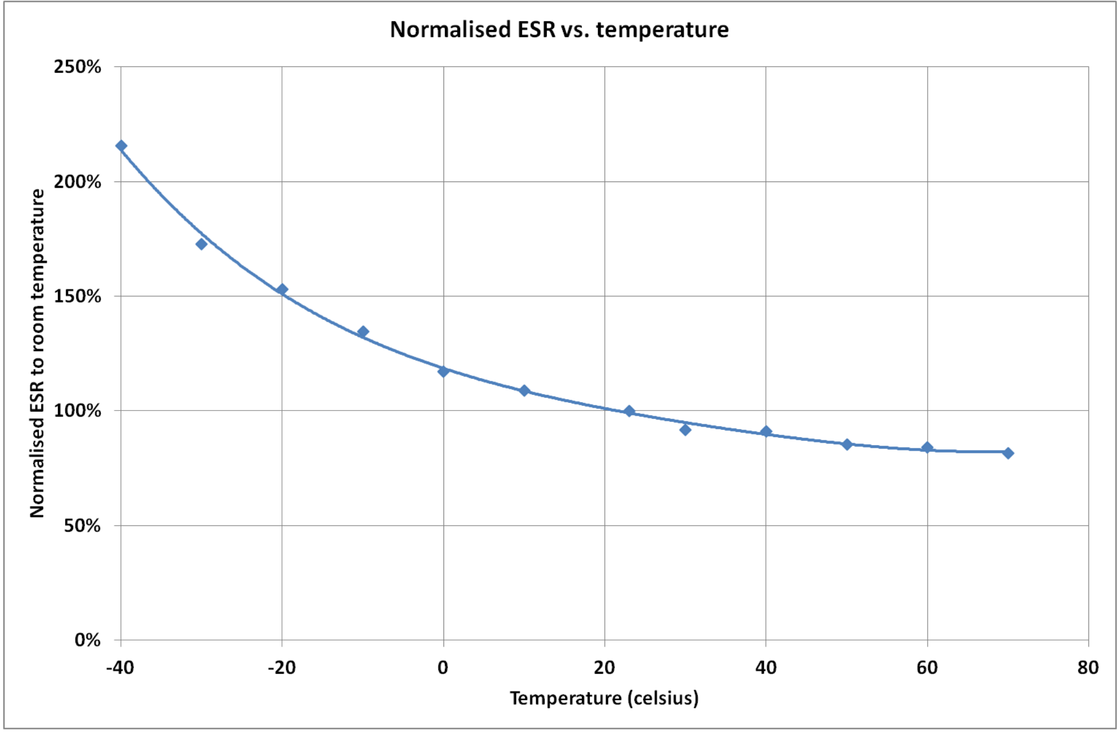

Figure 7: ESR change with temperature

Fig 7 shows that ESR at -40°C is ~2.2 x ESR at room temp, and that ESR at 70ºC is ~0.8 x ESR at room temperature.

Frequency Response

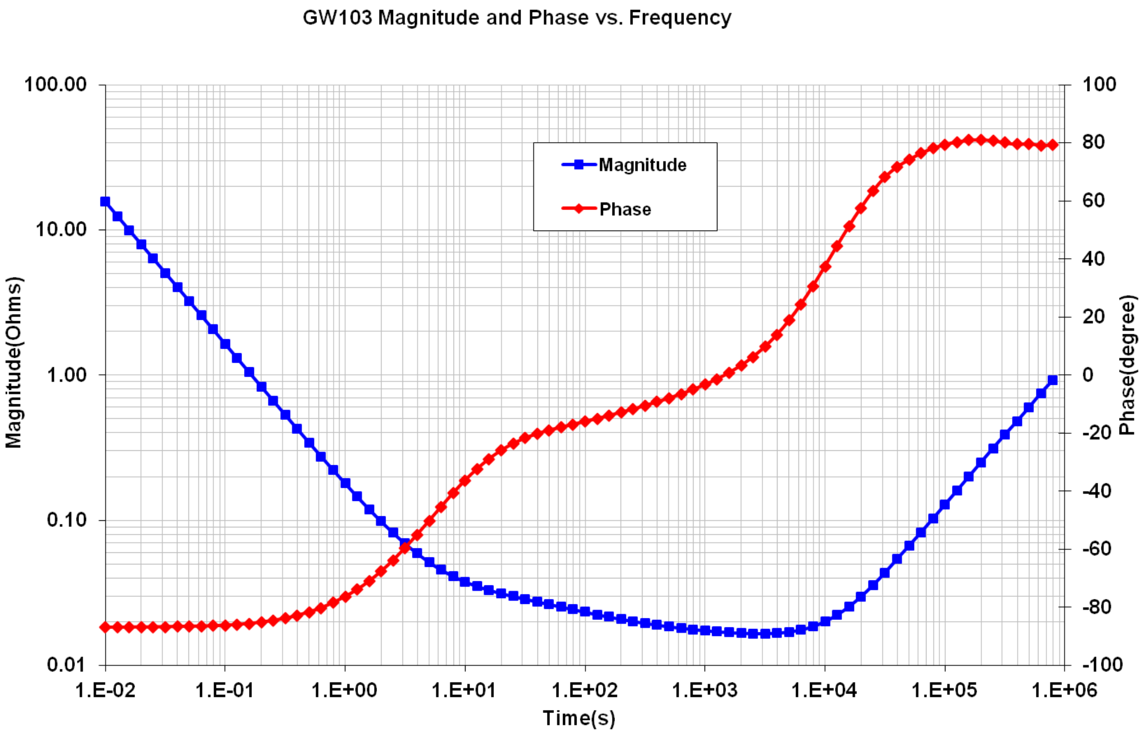

Fig 8: Frequency Response of Impedance (biased at 2.3V with a 50mV test signal)

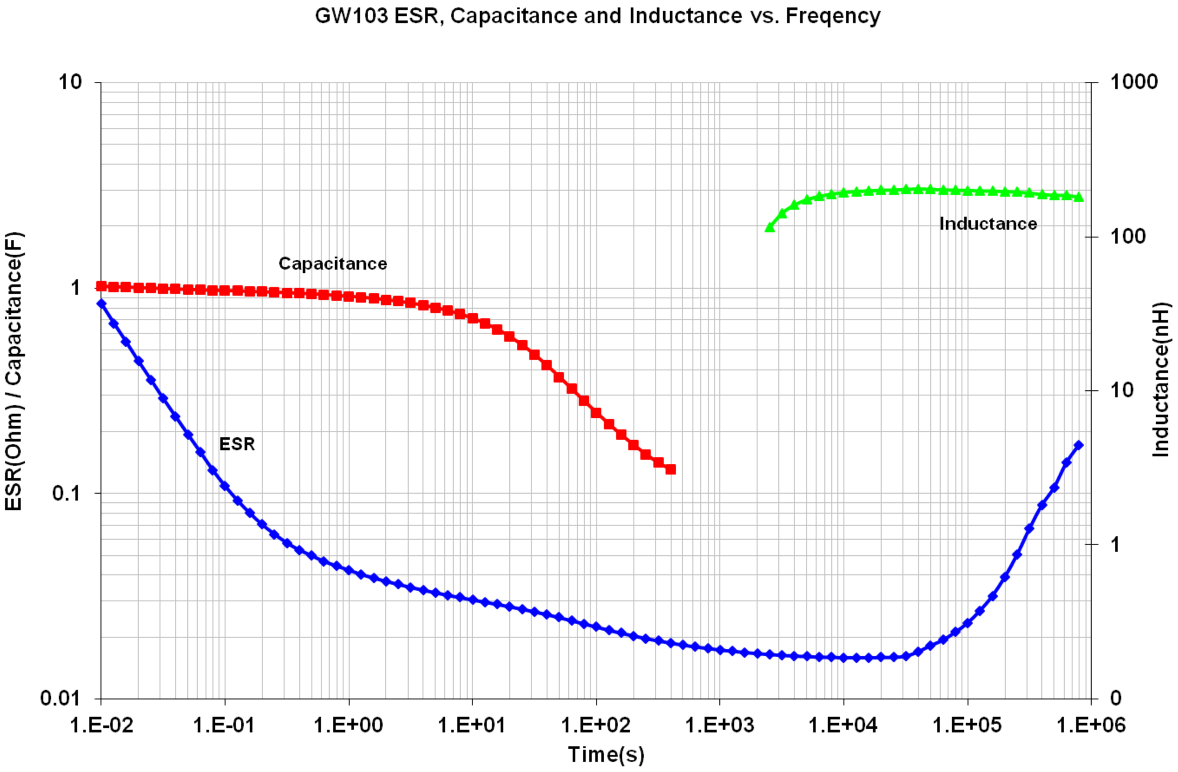

Fig 9: Frequency Response of ESR, Capacitance & Inductance

Fig 8 shows the supercapacitor behaves as an ideal capacitor until approx 7 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

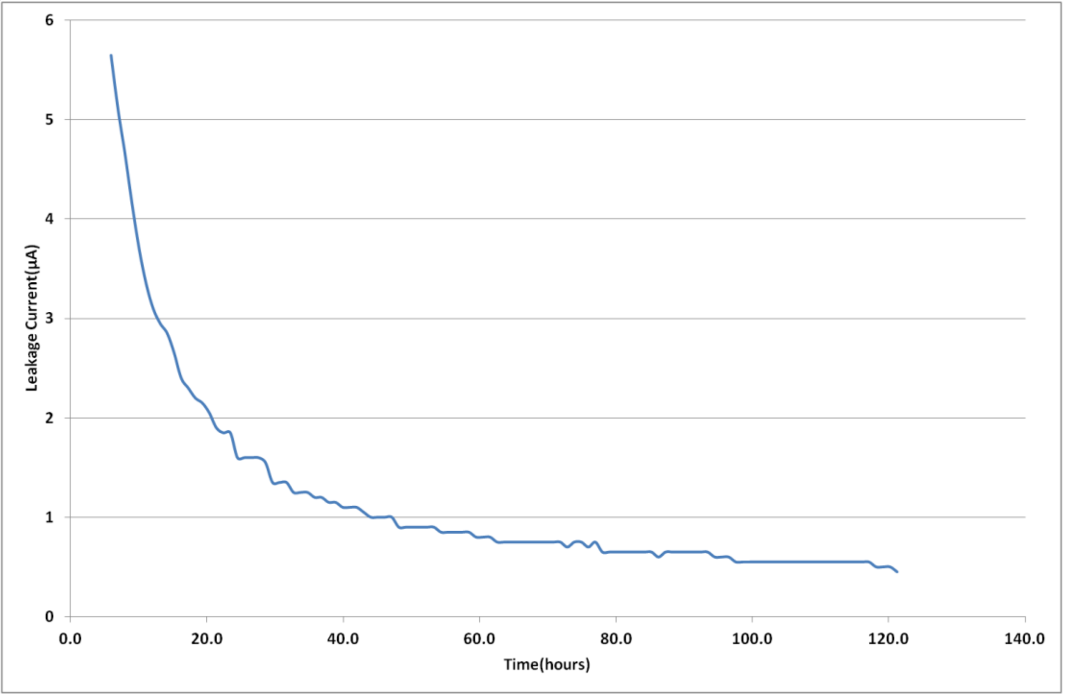

Fig 10: Leakage Current

Fig 10 shows the leakage current for GW103 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

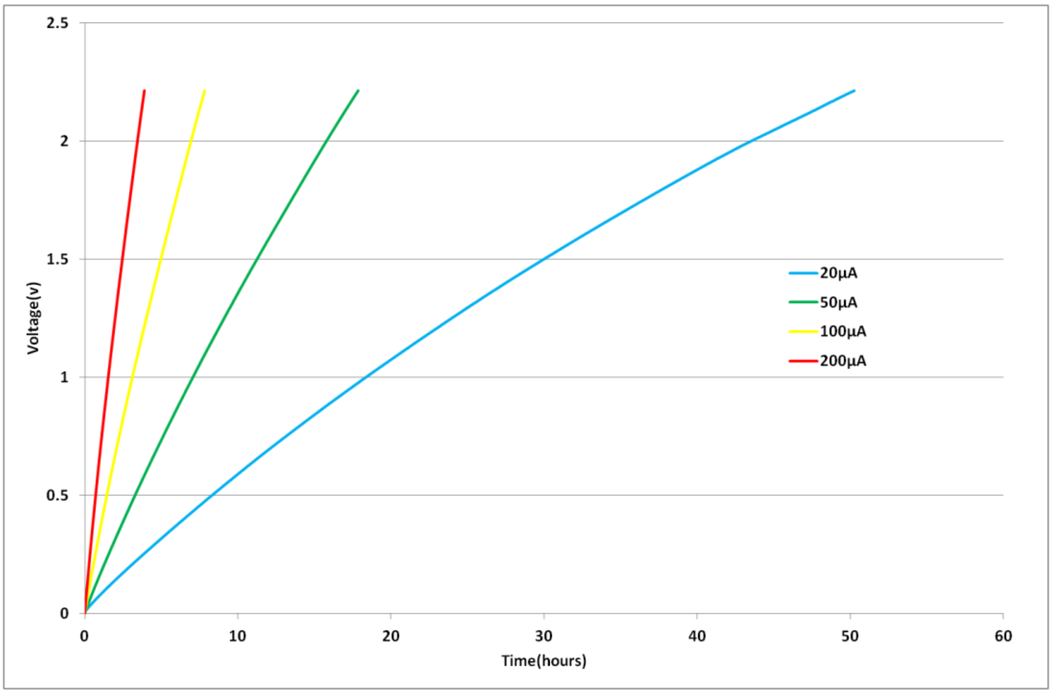

Fig 11: Charging a GW103 with low current

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 1.04F x 2.2V / 0.00002A = 31.8hrs to charge a 1.04 F supercapacitor to 2.2V at 20µA, but Fig 11 shows it took 52hrs. At 100µA charging occurs at a rate close to the theoretical rate.

RMS Current

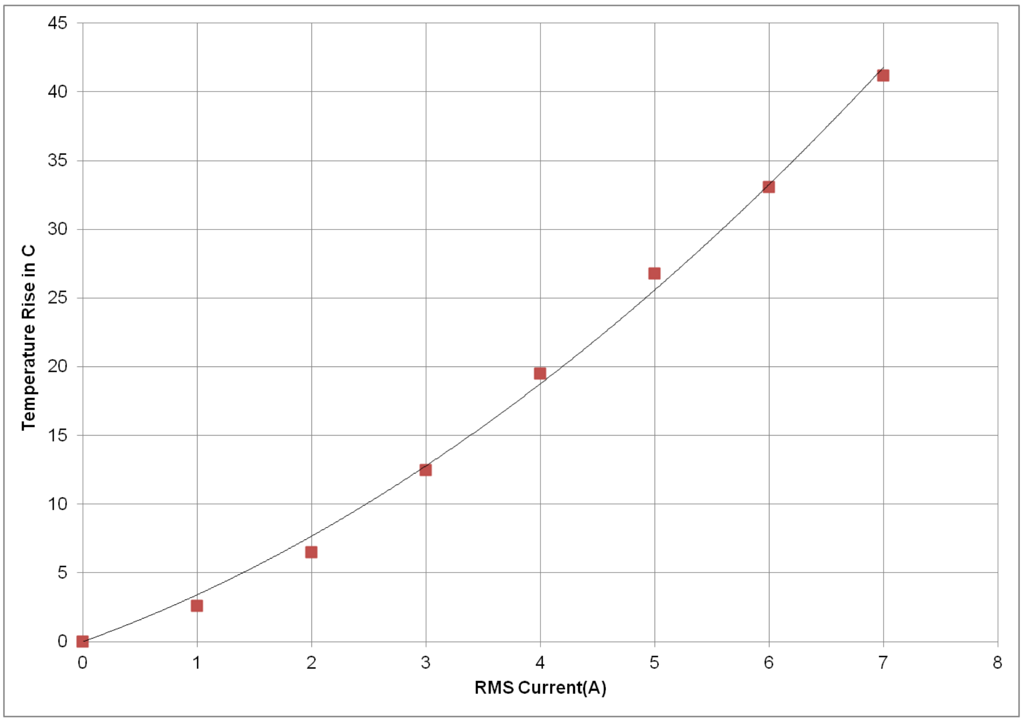

Fig 12: Temperature rise in GW203 with RMS current

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 5.5A, 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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GW109 / GW209 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 GW109 is a single cell supercapacitor. The GW209 is a dual cell supercapacitor with two GW109 cells in series, so GW209 capacitance = Capacitance of GW109/2 and GW209 ESR = 2 x GW109 ESR.

Table 1: Absolute Maximum Ratings

Parameter	**Name**		**Conditions**	**Min**		**Max**	**Units**
Terminal Voltage	Vpeak	GW109		0		2.75	V
		GW209				5.5	
Temperature	Tmax			-40		+70	°C

Table 2: Electrical Characteristics

Parameter	**Name**		**Conditions**	**Min**	**Typical**	**Max**	**Units**
Terminal Voltage	Vn	GW109		0		2.5	V
		GW209		0		5.0	
Capacitance	C	GW109	DC, 23°C	256	320	384	mF
		GW209		128	160	192	
ESR	ESR	GW109	DC, 23°C		30	36	mΩ
		GW209			55	66	
Leakage Current	I_L		2.3V, 23°C 120hrs		0.5	1	µA
RMS Current	I_{RMS}		23°C			6	A
Peak Current[1]	I_P		23°C			30	A

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

Table 3: Thickness

GW109F	**1.0mm**	No adhesive tape on underside of the supercapacitor	**GW109G**	**1.1mm**	Adhesive tape on underside, release tape removed
GW209F	**2.1mm**		**GW209G**	**2.2mm**	

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 secs.

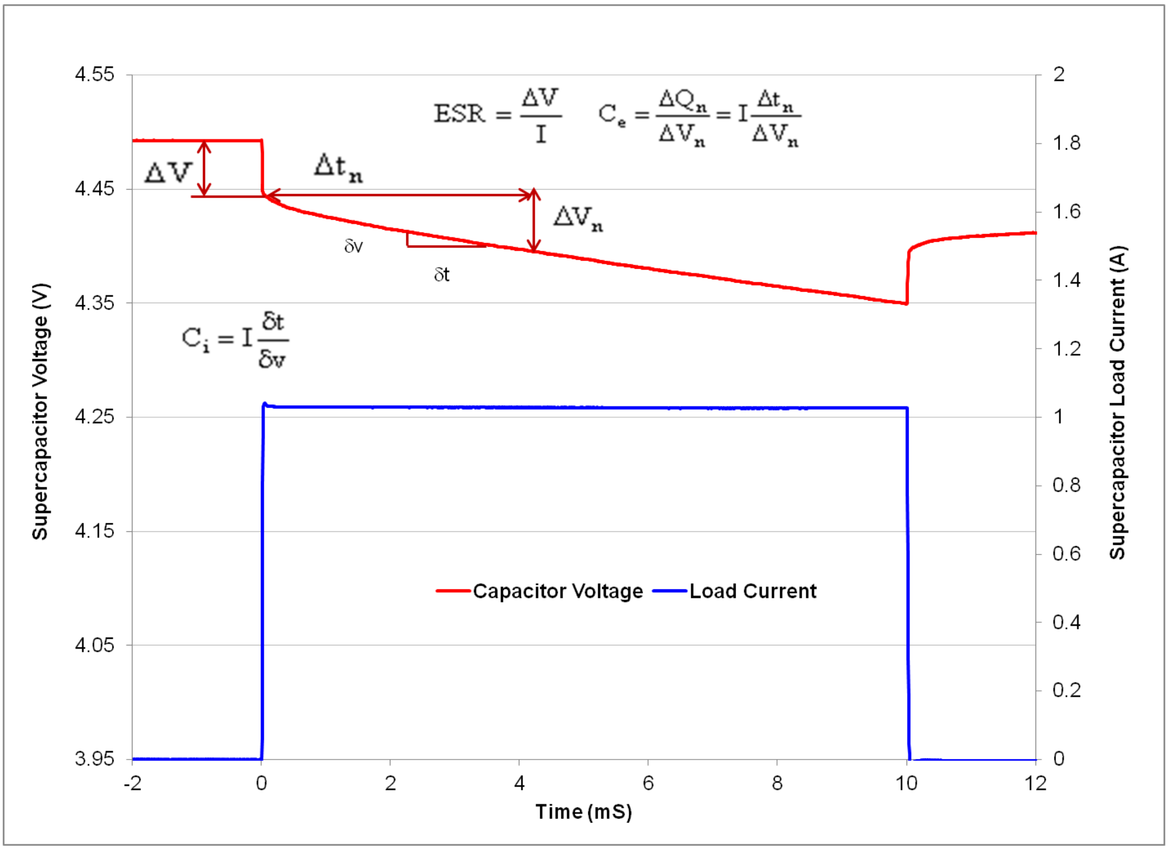

Figure 1: Effective capacitance, instantaneous capacitance and ESR for a GW209

The ESR is found by dividing the instantaneous voltage step (ΔV) by I. In this example = (4.492V-4.447V)/1.03A = 43.7mΩ.

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 $Ce(\Delta t_n) = I \times \Delta t_n/\Delta V_n$. 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} = (4.447V – 4.414V) = 33mV. Therefore Ce(2ms) = 1.03A x 2ms/33mV = 62.4mF. After 10ms, the voltage drop = 4.447 V – 4.349V = 98mV. Therefore Ce(10ms) = 1.03A x 10ms/98mV = 105mF. The DC capacitance of a GW209 = 160mF. 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.

Measurement of DC Capacitance

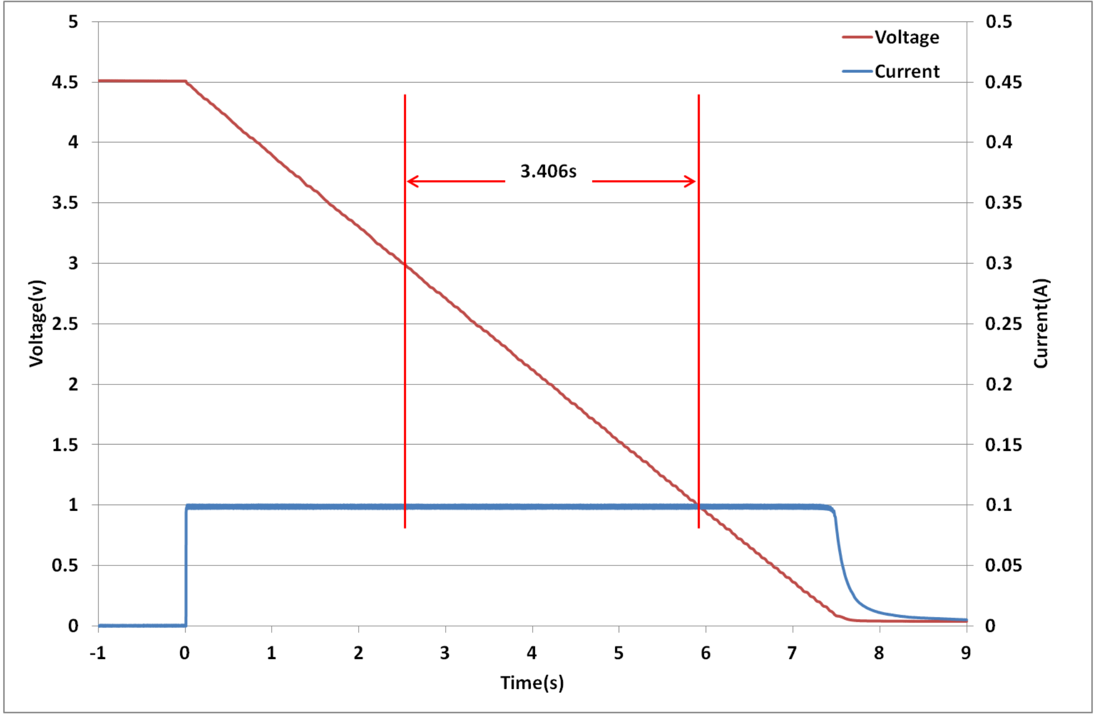

Fig 2: Measurement of DC Capacitance for a GW209

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 3.406s /2V = 170.3mF, which is well within the 160mF +/- 20% tolerance for a GW209 cell.

Measurement of ESR

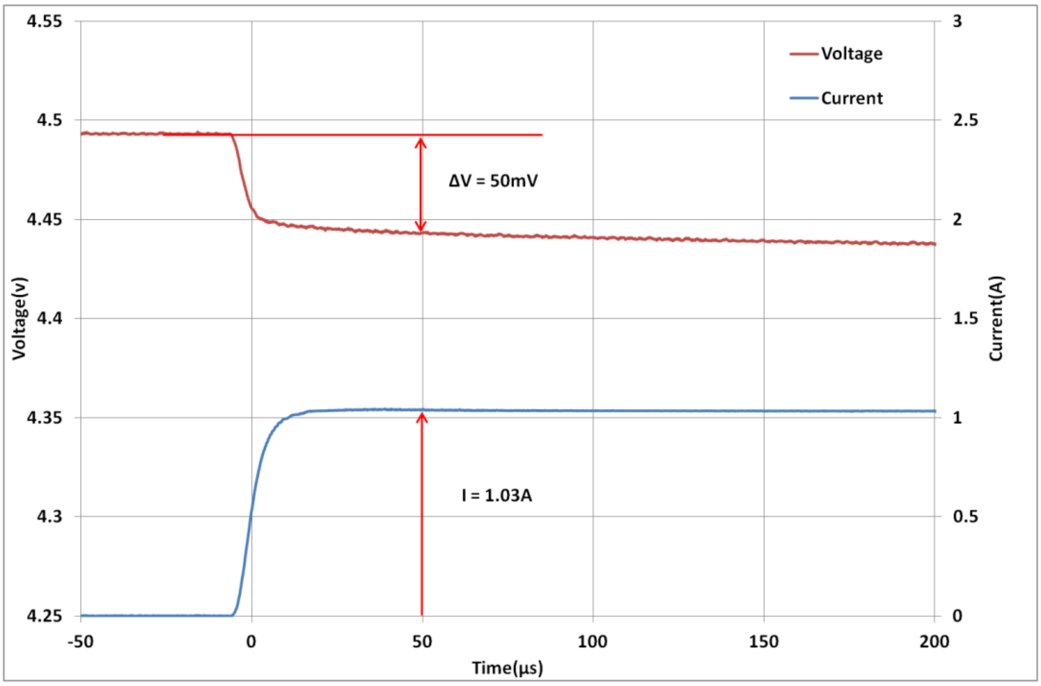

Fig 3: Measurement of ESR for a GW209

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 50mV/1.03A = 48.5mΩ.

Effective Capacitance

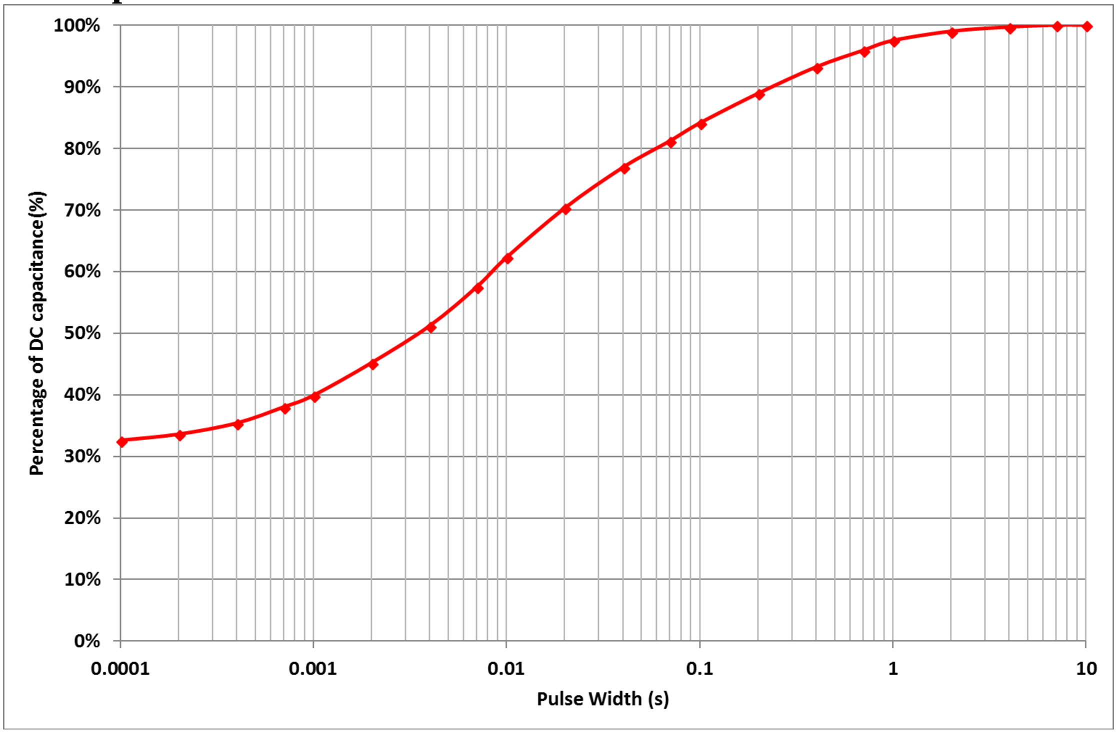

Figure 4: Effective Capacitance

Fig 4 shows the effective capacitance for the GW109, GW209 @ 23°C. This shows that for a 1ms PW, you will measure 40% of DC capacitance or 128mF for a GW109 or 64mF for a GW209. At 10ms you will measure 62% of the DC capacitance, and at 100msecs you will measure 84% 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) = 62% of DC capacitance = 99mF for a GW209, so Vdrop = 1A x ESR + 1A x duration/C = 1A x 55mΩ + 1A x 10ms / 99mF = 156mV. The next section on pulse response shows how the effective capacitance is sufficient for even short pulse widths.

Pulse Response

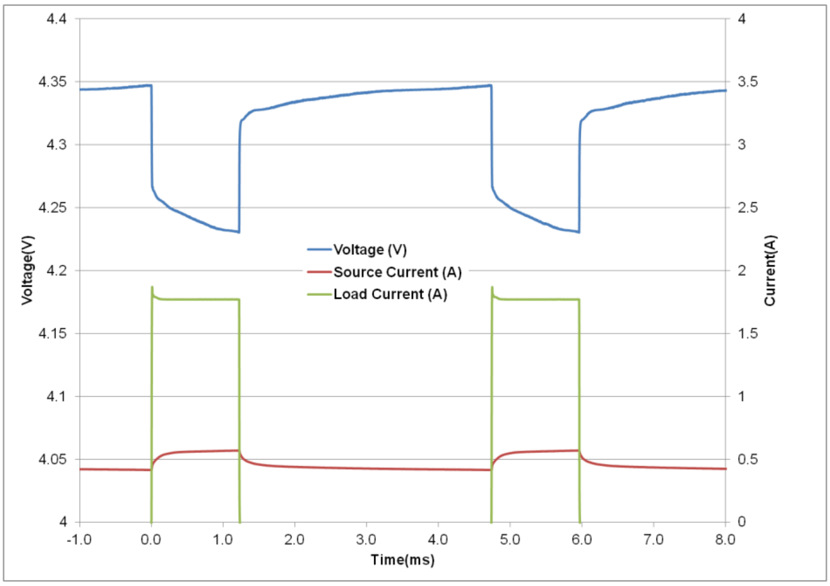

Fig 5 shows that the GW209 supercapacitor does an excellent job supporting a GPRS class 10 pulse train, drawing 1.8A for 1.1ms at 25% duty cycle. The source is current limited to 0.6A and the supercapacitor provides the 1.2A difference to achieve the peak current. At first glance the freq response of Fig 8 indicates the supercapacacitor would not support a 1ms pulse, but the Ceff of 31.6mF coupled with the low ESR supports this pulse train with only ~117mV droop in the supply rail.

Fig 5: GW209 Pulse Response with GPRS Class 10 Pulse Train

DC Capacitance variation with temperature

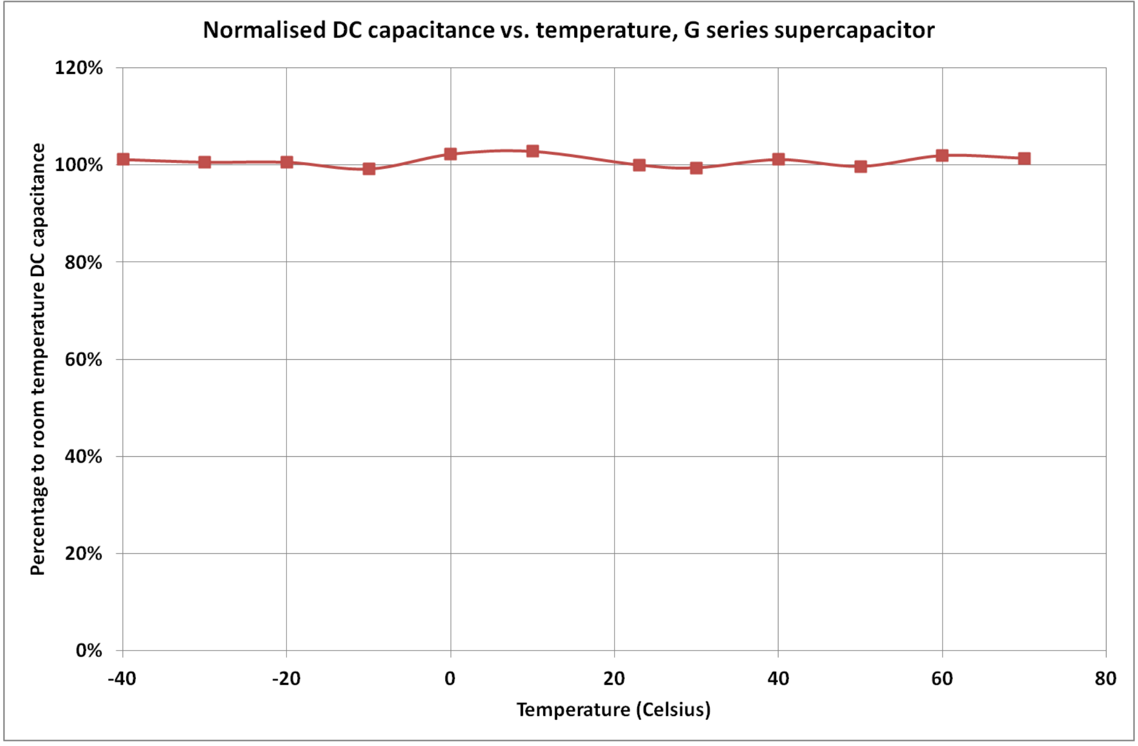

Figure 6: Capacitance change with temperature

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

ESR variation with temperature

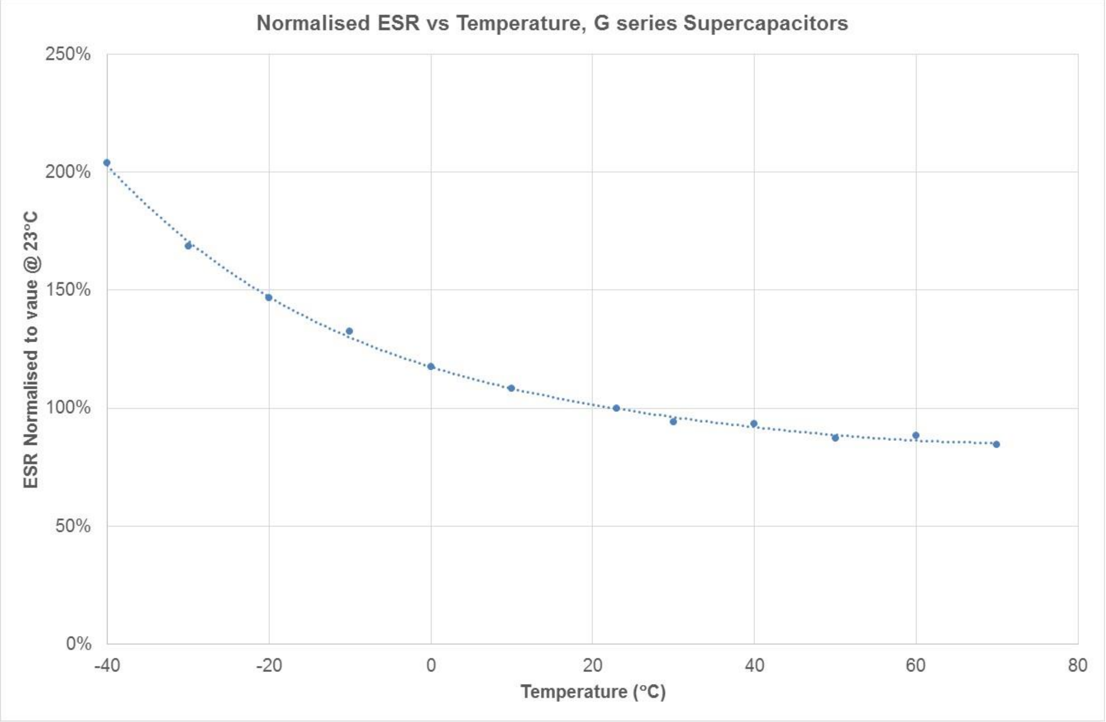

Figure 7: ESR change with temperature

Fig 7 shows that ESR at -40°C is ~2 x ESR at room temp, and that ESR at 70ºC is ~0.8 x ESR at room temperature.

Frequency Response

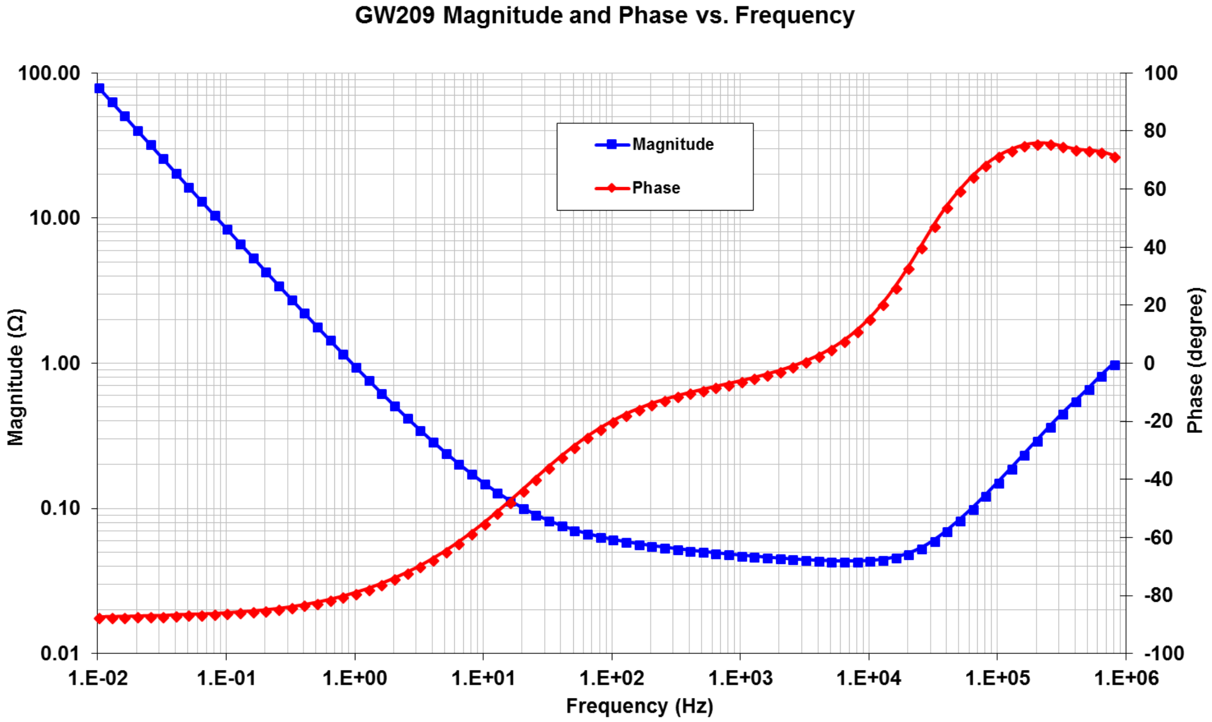

Fig 8: Frequency Response of Impedance (biased at 5V with a 50mV test signal)

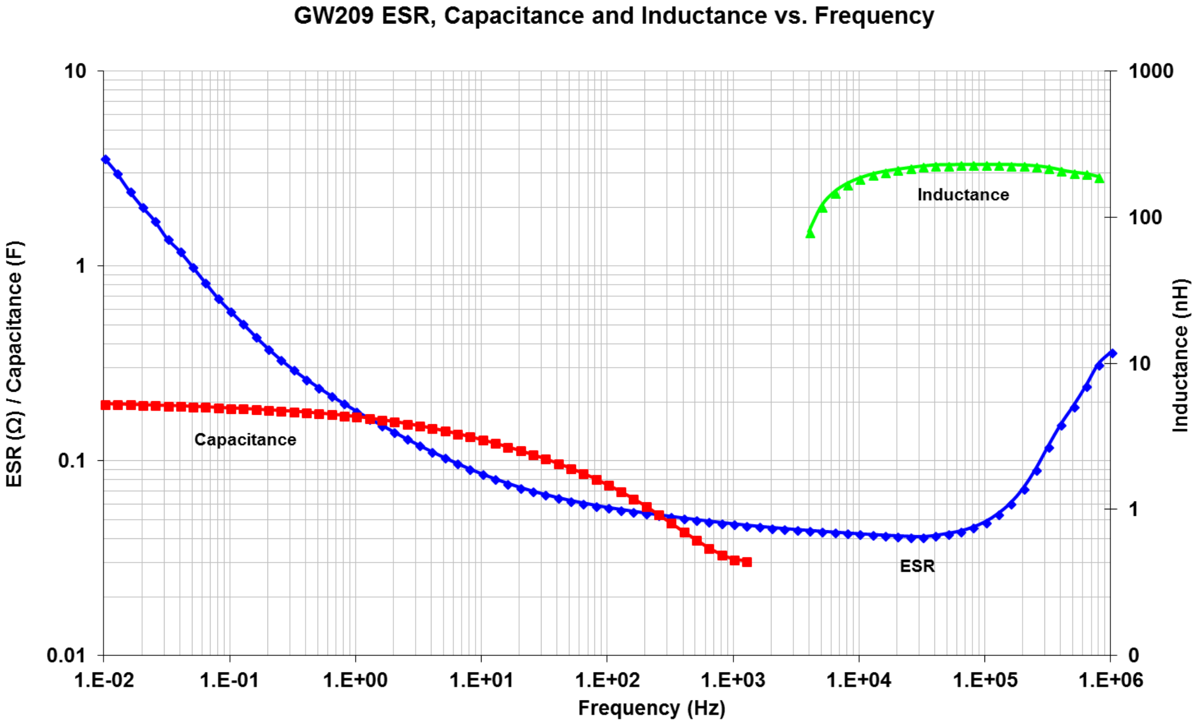

Fig 9: Frequency Response of ESR, Capacitance & Inductance

Fig 8 shows the supercapacitor behaves as an ideal capacitor until approx 20 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

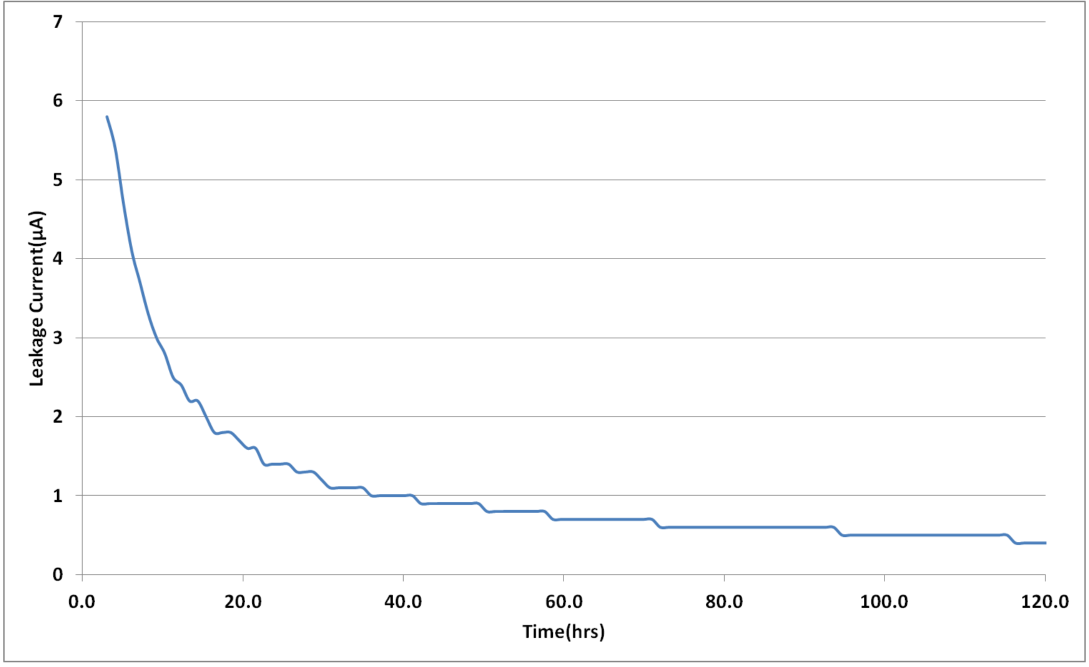

Fig 10: Leakage Current

Fig 10 shows the leakage current for GW109 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

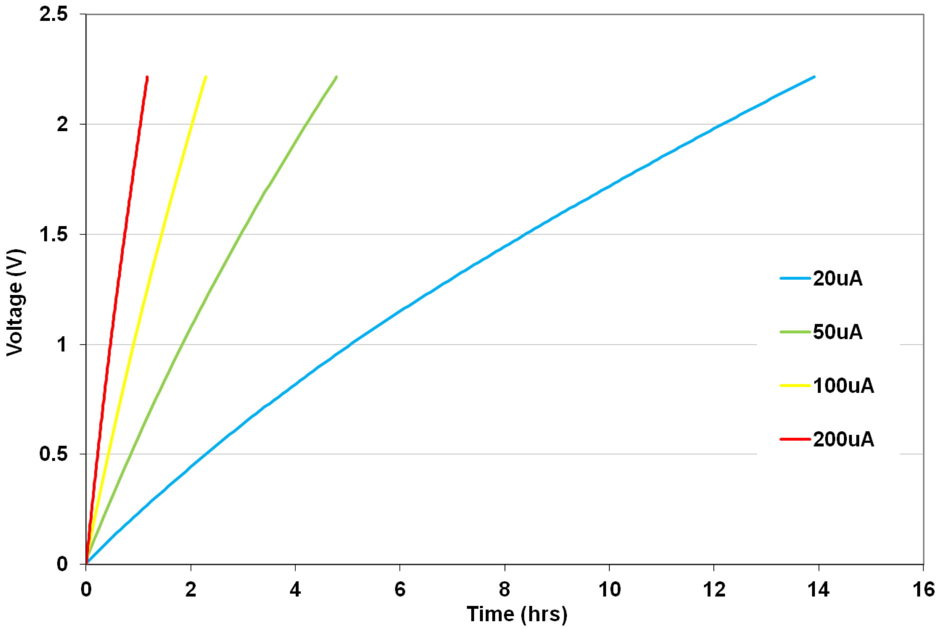

Fig 11: Charging an GW109 with low current

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 0.32F x 2.3V / 0.00002A = 10 hrs to charge a 0.16F supercapacitor to 2.3V at 20µA, but Fig 11 shows it took 14hrs. At 100µA charging occurs at a rate close to the theoretical rate.

RMS Current

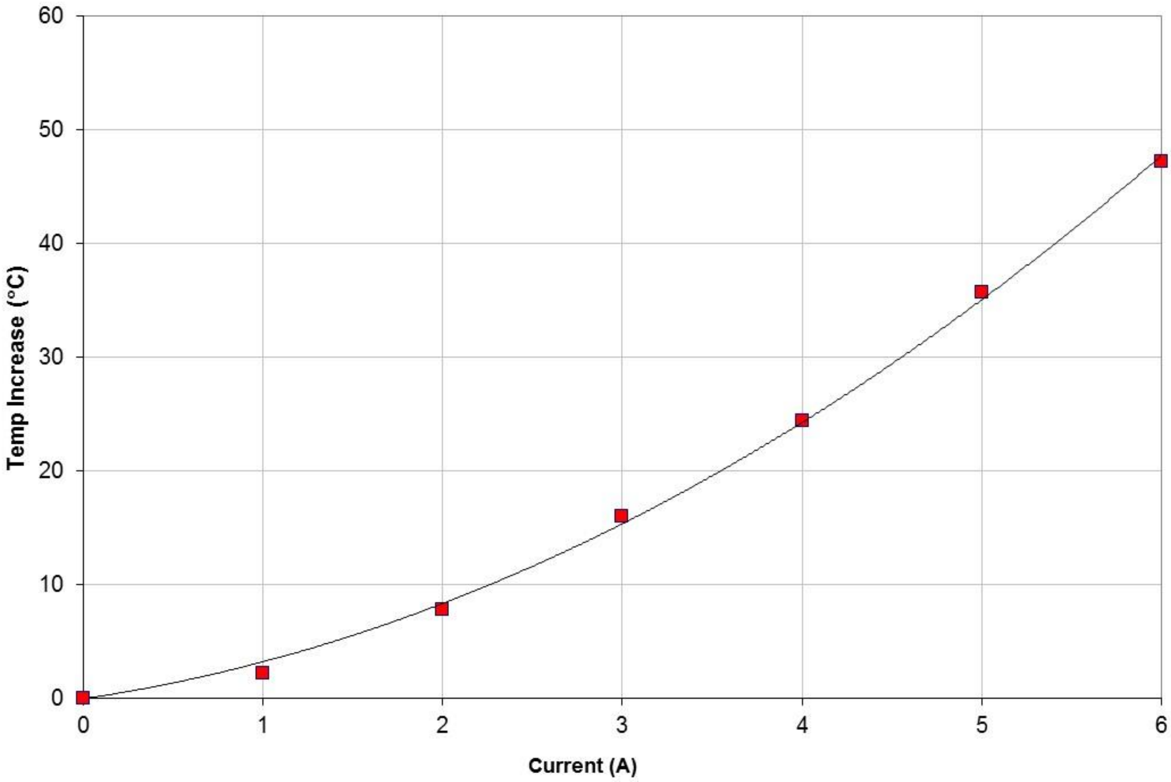

Fig 12: Temperature rise in GW209 with RMS current

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, and 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 4.5A, which causes a 30°C temperature increase.

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