

DATASHEET PRELIMINARY

# DMHA14R5V353M4ATA0,

## 4.5V, 35mF, 300mΩ, -40°C to +85°C

Revision 1.4, June 2020



## Electrical Specifications

Table 1: Absolute Maximum Ratings

Parameter	Name	Conditions	Min	Typical	Max	Units
Terminal Voltage	$V_{peak}$				4.5	V
Temperature	$T_{max}$		-40		+85	°C

Table 2: Electrical Characteristics

Note that the DMHA14R5V353M4ATA0 is actually 2 independent cells, with 2 terminals for each cell. Referring to the mechanical drawing, for one cell the negative terminal is labelled (-) and the positive terminal labelled (bal 1), while for the other cell the negative terminal is labelled (bal 2) and the positive terminal labelled (+). The user can connect the 2 cells in series or in parallel, or as 2 individual supercapacitor cells. If connected in series then connect (bal 1) to (bal 2). If connected in parallel then (-) must be connected to (bal 2) and (bal 1) must be connected to (+). The table gives the electrical characteristics for the different configurations.

Parameter	Name	Conditions	Min	Typical	Max	Units
As 2 cells connected in series						
Terminal Voltage	$V_n$		0		4.5	V
Capacitance	C	DC, 23°C	28	35	42	mF
ESR	ESR	AC, 1kHz		300		mΩ
Leakage Current	$I_L$	4.5V, 23°C 120hrs			2	μA
RMS Current	$I_{RMS}$	25°C			2.2	A
Peak Current <sup>1</sup>	$I_P$	23°C			10	A

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

## DMHA14R5V353M4ATA0 DATASHEET PRELIMINARY

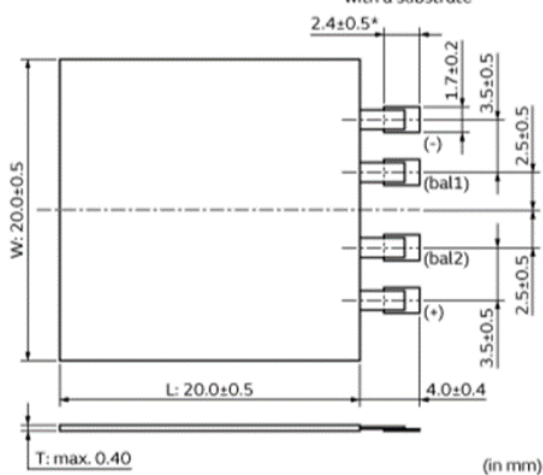
Parameter	Name	Conditions	Min	Typical	Max	Units
As 2 cells connected in parallel						
Terminal Voltage	V <sub>n</sub>		0		2.25	V
Capacitance	C	DC, 23°C	112	140	168	mF
ESR	ESR	AC, 1kHz		75		mΩ
Leakage Current	I <sub>L</sub>	4.5V, 23°C 120hrs			4	μA
RMS Current	I <sub>RMS</sub>	25°C			4.4	A
Peak Current <sup>1</sup>	I <sub>P</sub>	23°C			20	A
As 2 individual cells, specification for 1 cell.						
Terminal Voltage	V <sub>n</sub>		0		2.25	V
Capacitance	C	DC, 23°C	56	70	84	mF
ESR	ESR	AC, 1kHz		150		mΩ
Leakage Current	I <sub>L</sub>	4.5V, 23°C 120hrs			2	μA
RMS Current	I <sub>RMS</sub>	25°C			2.2	A
Peak Current <sup>1</sup>	I <sub>P</sub>	23°C			10	A

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

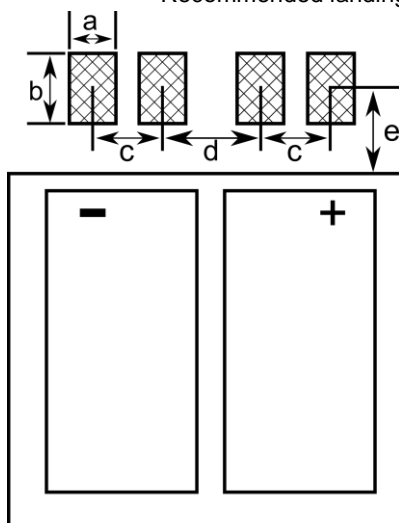
Table 3: Mechanical specification

Length (mm)	Width (mm)	Thickness "T" (mm)
20 ± 0.5mm	20 ± 0.5	0.4 (max)

Package mechanical drawing \* Length of area in contact with a substrate



Recommended landing pads

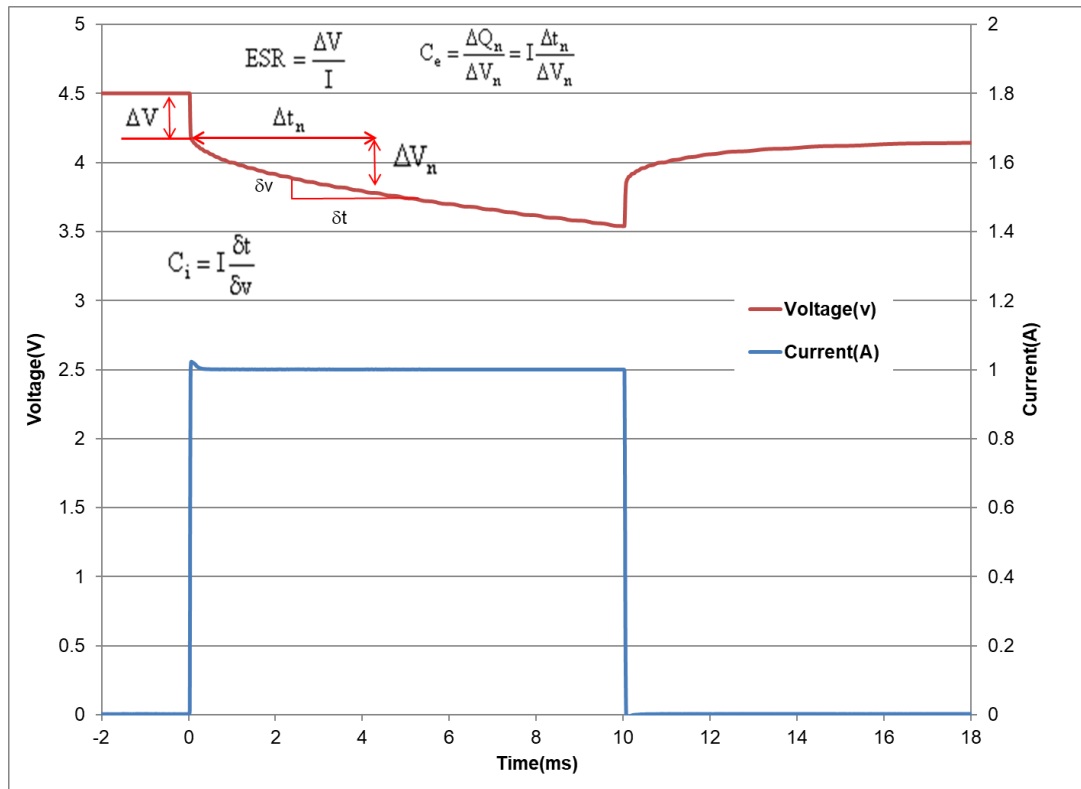


a = 2.2mm  
b = 3.6mm  
c = 3.5mm  
d = 5mm  
e = 4mm

Mechanical drawing and recommended landing pad for DMHA14R5V353M4ATA0

## 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  $0.01\text{ sec}$ .



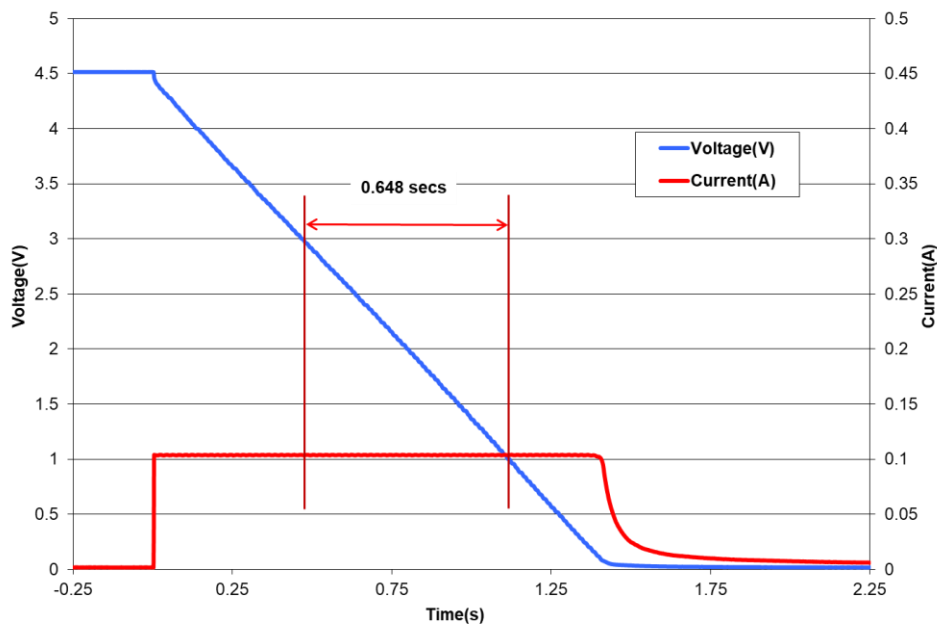
**Figure 1: Effective capacitance, instantaneous capacitance and ESR for DMHA14R5V353M4ATA0**

The ESR is found by dividing the instantaneous voltage step ( $\Delta V$ ) by  $I$ . In this example  $= (4.502\text{V} - 4.205\text{V})/1\text{A} = 297\text{m}\Omega$ .

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  $V_{2\text{ms}} = (4.205\text{ V} - 3.916\text{V}) = 289\text{mV}$ . Therefore  $C_e(2\text{ms}) = 1\text{A} \times 2\text{ms} / 289\text{mV} = 6.9\text{mF}$ . After 10ms, the voltage drop  $= 4.205\text{ V} - 3.540\text{V} = 665\text{mV}$ . Therefore  $C_e(10\text{ms}) = 1\text{ A} \times 10\text{ms} / 665\text{mV} = 15\text{mF}$ . The DC capacitance of the DMHA14R5V353M4ATA0 as 2 cells in series  $= 35\text{mF}$ . Note that  $\Delta V$ , or voltage drop due to load current  $\times$  ESR (Equivalent Series Resistance), 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.

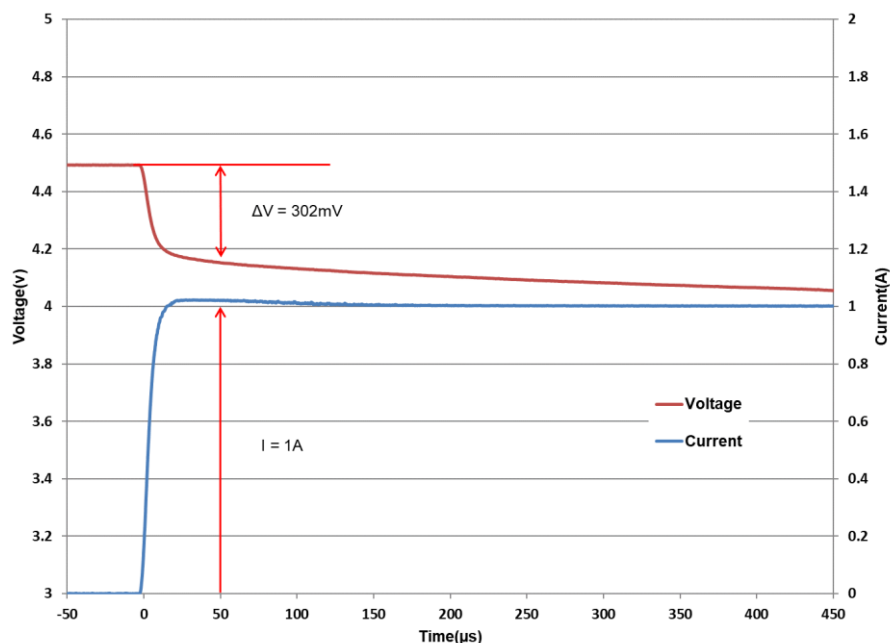
## Measurement of DC Capacitance



**Fig 2: Measurement of DC Capacitance for a DMHA14R5V353M4ATA0**

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,  $C = 0.1A \times 0.648s / 2V = 32.4mF$ , which is well within the 35mF +/- 20% tolerance for a DMHA14R5V353M4ATA0 cell.

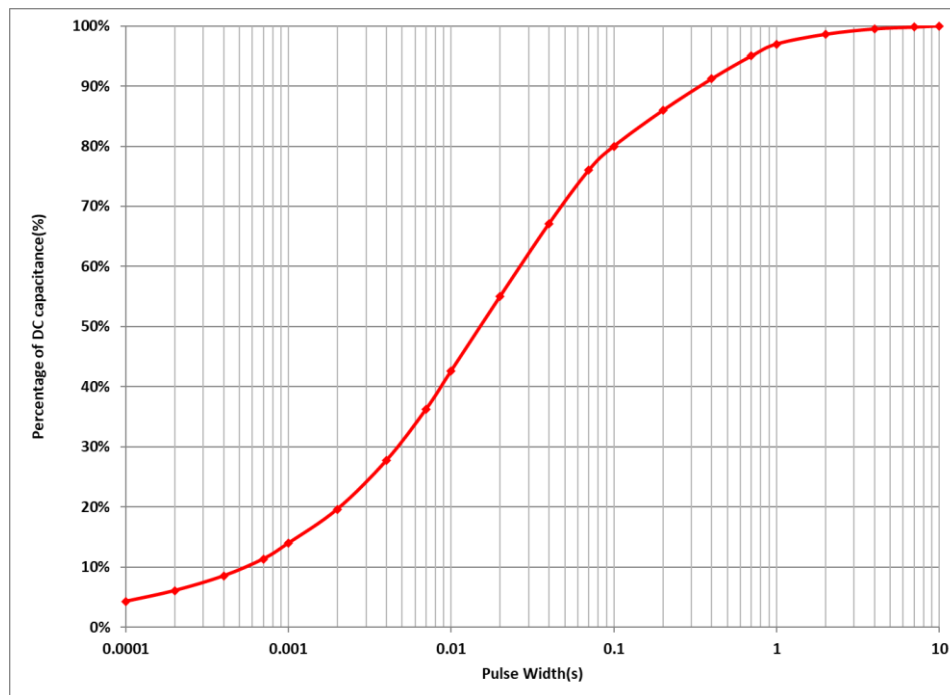
## Measurement of ESR



**Fig 3: Measurement of ESR for a DMHA14R5V353M4ATA0**

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  $302mV/1A = 302m\Omega$ .

## Effective Capacitance



**Figure 4: Effective Capacitance**

Fig 4 shows the effective capacitance for the DMH @ 23°C. This shows that for a 1msec PW, you will measure 14% of DC capacitance or 4.9mF. At 10msecs you will measure 43% 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  $C_{eff}(10\text{msecs}) = 43\% \text{ of DC capacitance} = 15.1\text{mF}$ , so  $V_{drop} = 1\text{A} \times \text{ESR} + 1\text{A} \times \text{duration} / C = 1\text{A} \times 300\text{m}\Omega + 1\text{A} \times 10\text{ms} / 15.1\text{mF} = 962\text{mV}$ . The next section on pulse response shows how the effective capacitance is sufficient for even short pulse widths.

## Pulse Response

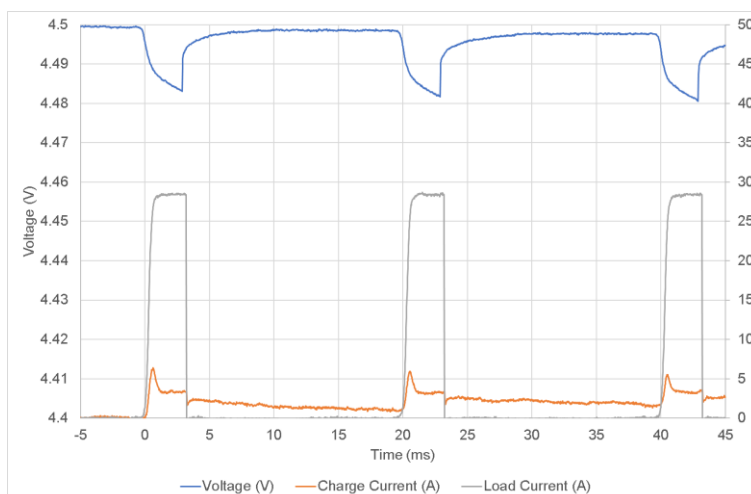


Fig 5 shows that the DMHA14R5V353M4ATA0 supercapacitor does an excellent job supporting a simulated BLE initialization and transmission pulse, drawing a current pulse of ~30mA for 3ms with a charge current limited to 3mA. At first glance, the freq response of Fig 8 indicates the supercapacitor would not support a 3ms pulse, but the  $C_{eff}$  of 8mF coupled with the low ESR supports this pulse train with only ~20mV droop in the supply rail.

**Fig 5: DMHA14R5V353M4ATA0 Pulse Response with simulated BLE pulse load**

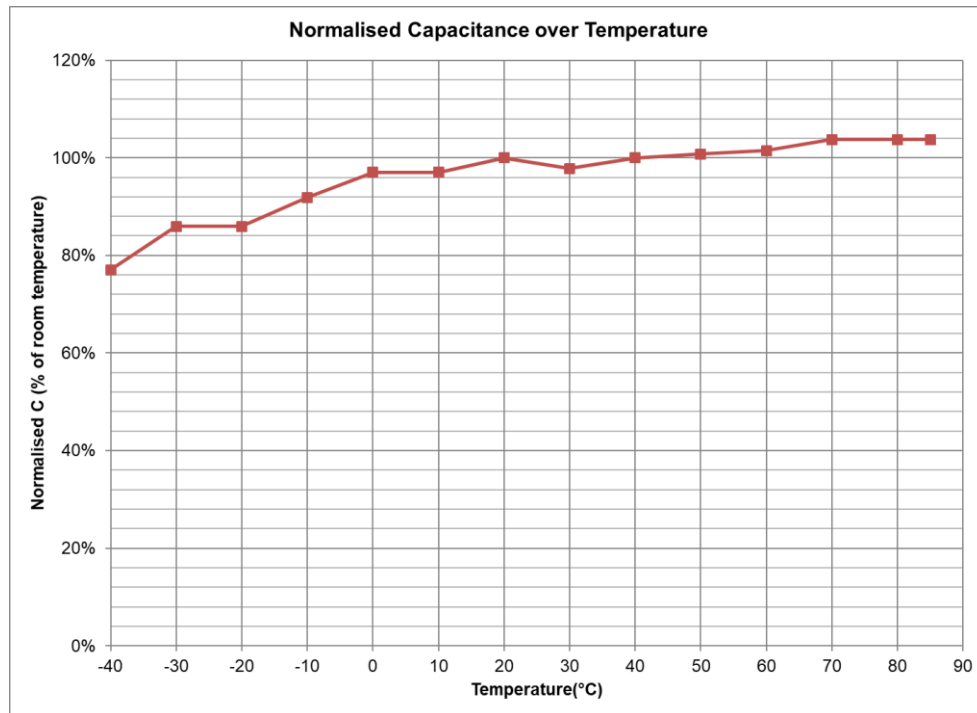
**DC Capacitance variation with temperature****Figure 6: Capacitance change with temperature**

Fig 6 shows that capacitance at -40°C is  $\sim 0.75 \times C$  at room temp, and that  $C$  at 85°C is  $\sim 1.1 \times C$  at room temperature.

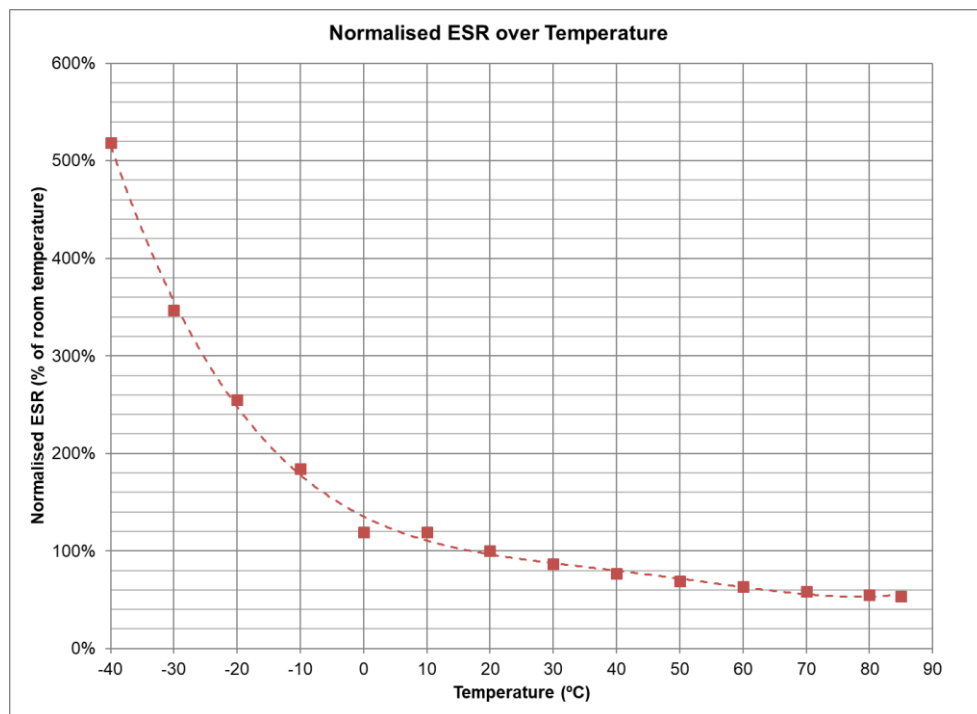
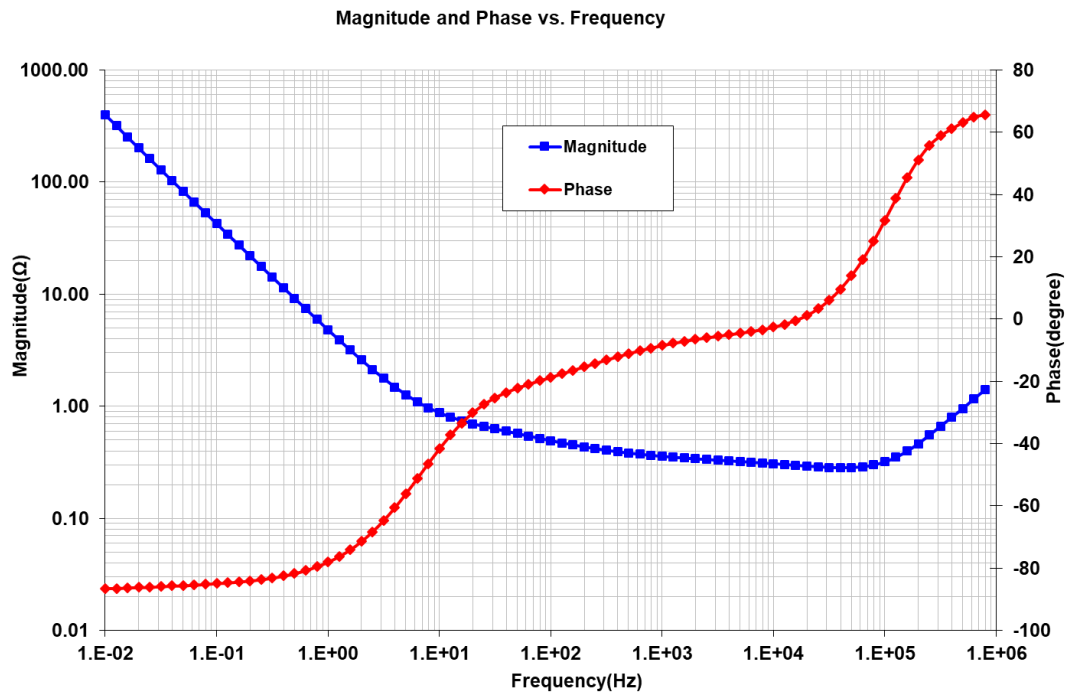
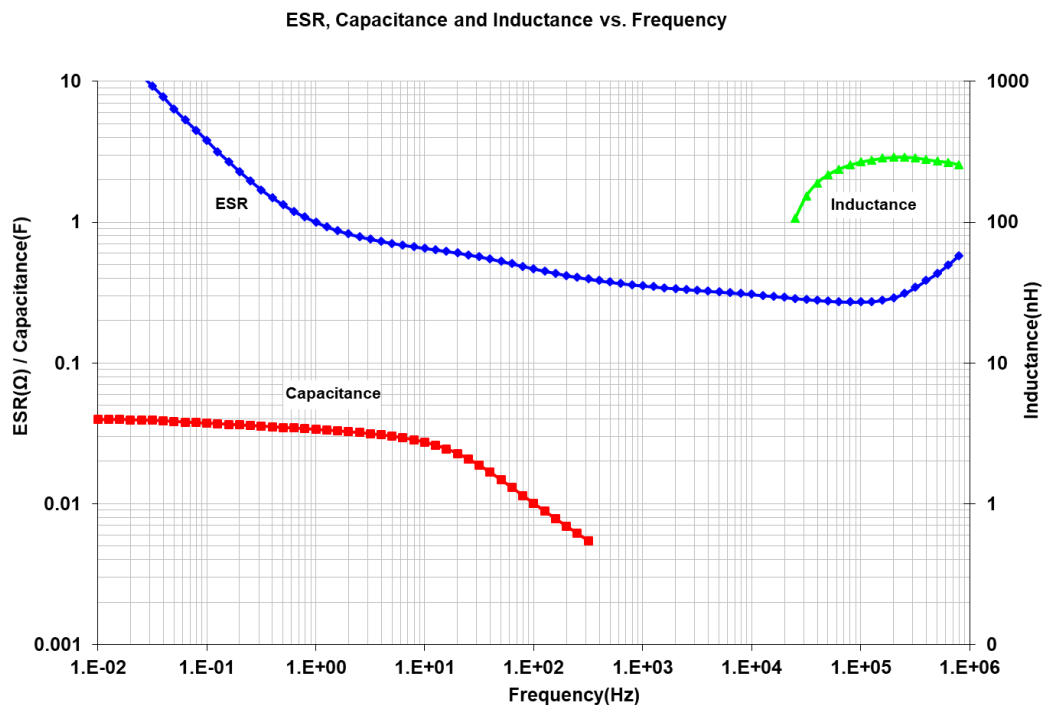
**ESR variation with temperature****Figure 7: ESR change with temperature**

Fig 7 shows that ESR at -40°C is  $\sim 5.2 \times$  ESR at room temp, and that ESR at 70°C is  $\sim 0.53 \times$  ESR at room temperature.

## Frequency Response



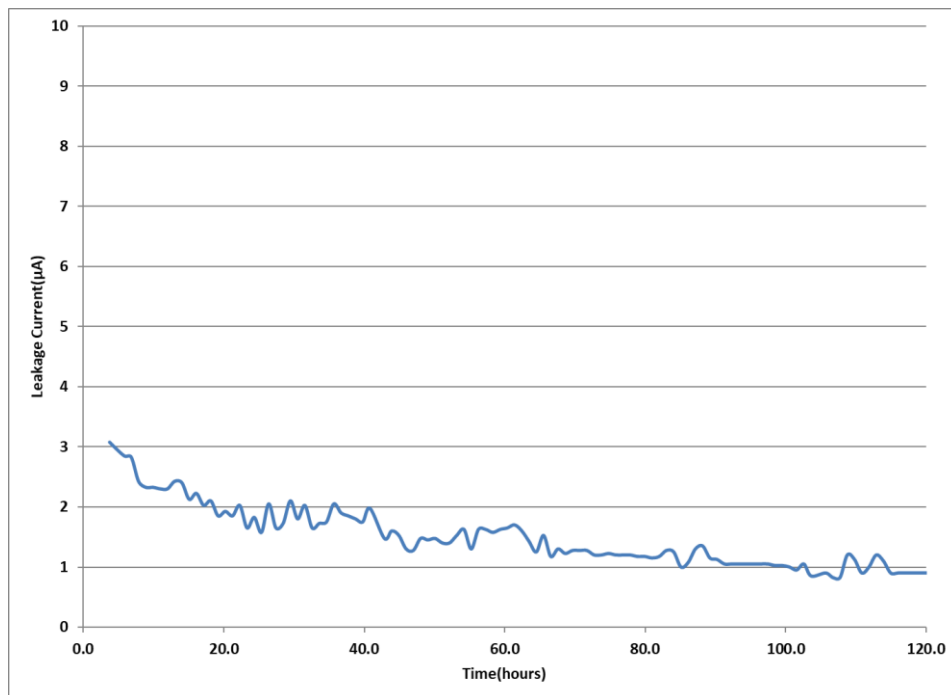
**Fig 8: Frequency Response of Impedance (biased at 4.5V with a 50mV test signal)**



**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  $1/\text{freq}$  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 pulse width.

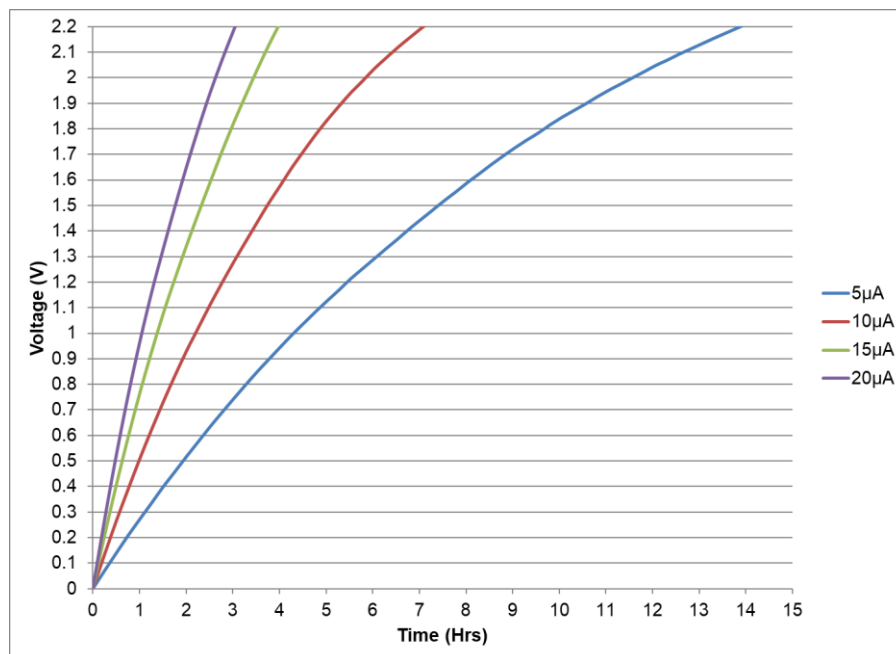
## Leakage Current



**Fig 10: Leakage Current**

Fig 10 shows the leakage current for DMHA14R5V353M4ATA0 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.

## Charge Current



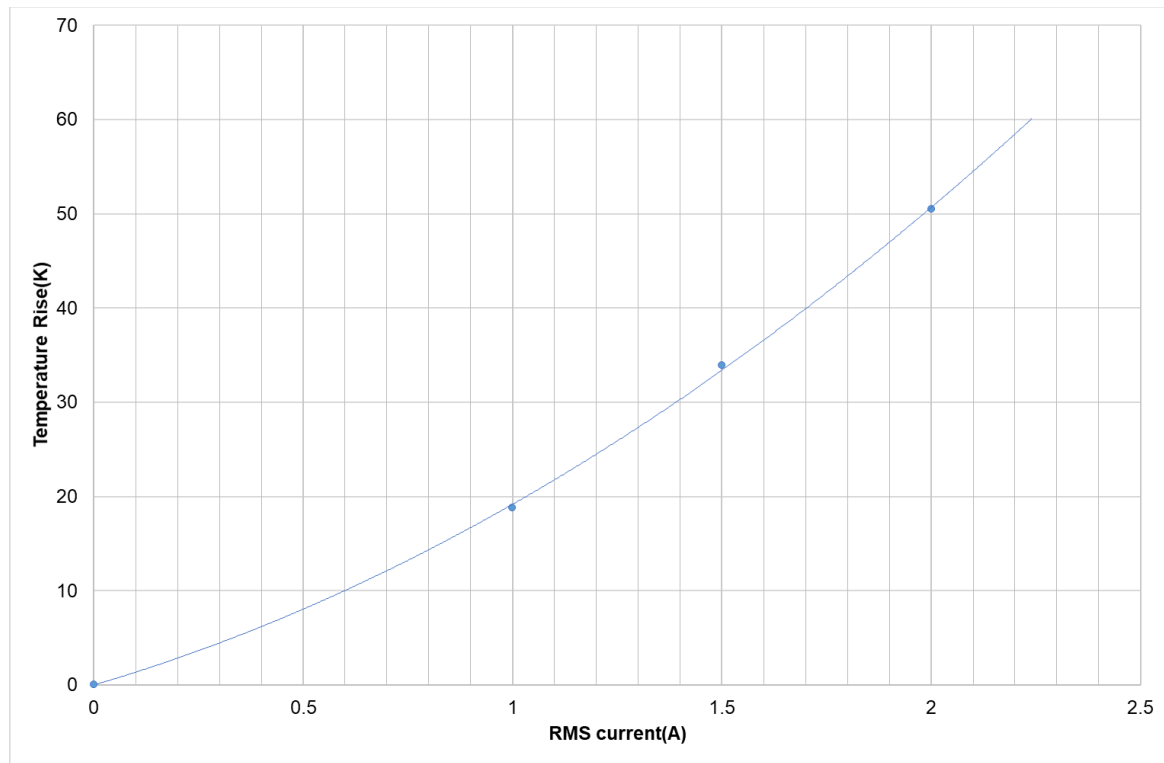
**Fig 11: Charging an DMHA14R5V353M4ATA0 with low current**

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, charging a single cell, it should take  $0.070F \times$



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$2.2\text{V} / 5\mu\text{A} = 8.6$  hrs to charge a 70mF supercapacitor to 2.2V at 5 $\mu\text{A}$ , but Fig 11 shows it took 13.8hrs.

**RMS Current**

**Fig 12: Temperature rise in DMHA14R5V353M4ATA0 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 85°C, then the maximum RMS current should be limited to 1.85A, which causes a 45°C temperature increase.

**Storage**

CAP-XX recommends storing supercapacitors in their original packaging in an air-conditioned room, preferably at < 30°C and < 60% relative humidity. CAP-XX supercapacitors can be stored at any temperature not exceeding their maximum operating temperature but storage at continuous high temperature and humidity is not recommended and will cause premature ageing.

Do not store supercapacitors in the following environments:

- High temperature / high humidity
- Direct sunlight
- In direct contact with water, salt, oil or other chemicals
- In direct contact with corrosive materials, acids, alkalis or toxic gases
- Dusty environment
- In environments subjected to shock and vibration

## **Cautions before use**

CAP-XX supercapacitors are “burned in” during production, and have a defined polarity, as shown by the positive terminal marked on the face of the product. Reversing the polarity of the device will not damage the device but may cause a rise in the ESR and will void the warranty. Please verify the orientation of the supercapacitor in accordance with the product markings before assembly.

CAP-XX supercapacitors are heat-sensitive. Over-heating of the supercapacitor may result in a degradation of performance and useful life.

CAP-XX supercapacitors must only be used within their rated voltage range. Over-voltage may cause swelling and eventually, product failure.

CAP-XX supercapacitors are fully discharged when shipped. Devices should be handled and soldered in a discharged state.

## **Soldering and Assembling**

CAP-XX supercapacitors are designed for direct soldering onto the PCB. Soldering the terminals to the PCB will ensure the highest contact reliability and lowest contact resistance. Do NOT solder directly to the device casing. This will cause permanent internal damage to the supercapacitor.

CAP-XX supercapacitors are NOT SUITABLE for infrared reflow soldering, hot-air reflow soldering, or wave soldering. They should be mounted as a secondary operation, using a manual soldering iron, a hot bar soldering jig, conductive adhesive, ultrasonic welding or laser welding.

CAP-XX recommends the use of a water-soluble flux, or a no-clean (low residue) flux, and low temperature solder compounds.

Please solder under the following conditions:

- Solder Type: Resin flux cored solder wire (ø1.2mm)
- Solder: Lead-free solder: Sn-3Ag-0.5Cu
- Soldering iron temperature at 350°C±10°C
- Solder iron wattage: 70W or less
- Soldering time: 3 to 4sec.
- The same terminal should be soldered 3 or less times.

If a hot-air gun is used to reflow the solder during a re-mount or de-mount, care must be taken to prevent excessive heating of the package adjacent to the solder terminals. Allow at least 15 sec between successive soldering attempts for the device to cool down.

Please consult CAP-XX if you wish to wash the device after soldering.

## Vibration and Shock Testing

### Shock

CAP-XX has undertaken tests to determine the effects of repeated shocks on both the mechanical integrity and electrical performance of its supercapacitors:

Charge to rated voltage at 500mA for min. 30min

- Type: Half-Sine
- Amplitude: 500G
- Duration: 1ms
- No. of cycles: 3 in each direction (18 in total)
- No. of axes: 3, orthogonal

Results: No electrical or mechanical degradation observed.

*Note that this test was undertaken on the standard product with adhesive mounting tape (Nitto No.5000NS). To achieve the highest levels of resistance to shock, CAP-XX recommends the use of an adhesive mounting tape on the underside of the device.*

### Vibration

CAP-XX has undertaken tests to determine the effects of sustained vibration on both the mechanical integrity and electrical performance of its supercapacitors:

Charge to rated voltage at 500mA for min. 30min

- Type: Sinusoidal
- Frequency: 10 ~ 500Hz/10G
- Amplitude: 1.5mm
- Sweep Rate: 1octave/min
- No. of cycles: 10 in each direction
- No. of axes: 3, orthogonal

Results: No electrical or mechanical degradation observed.

*Note that this test was undertaken on the standard product with adhesive mounting tape (Nitto No.5000NS). To achieve the highest levels of resistance to shock, CAP-XX recommends the use of an adhesive mounting tape on the underside of the device.*

### Drop Test

CAP-XX has undertaken tests to determine the effects of repeated drops on both the mechanical integrity and electrical performance of its supercapacitors:

Supercapacitor is discharged

- Mount product to 150g box with adhesive mounting tape (Nitto No.5000NS)
- Drop the box from 0.25m / 0.5m / 1.0m / 1.5m
- Repeat 3 times for 6 sides (18 in total)

Results: No electrical or mechanical degradation observed.