Appendices

Appendix A: Datasheet of 16 V Small Cell Module

FEATURES AND BENEFITS*

- 16V DC working voltage
- Resistive cell balancing
- Compact, light weight package
- Screw terminals

TYPICAL APPLICATIONS

- Wind turbine pitch control
- Small UPS systems

PRODUCT SPECIFICATIONS

ELECTRICAL	BMOD0058 E016 B02
Rated Capacitance[1]	58 F
Minimum Capacitance, initial[1]	58 F
Maximum Capacitance, initial[1]	70 F
Maximum ESR_{DC}, initial[1]	22 mΩ
Test Current for Capacitance and ESR_{DC}[1]	35 A
Rated Voltage	16 V
Absolute Maximum Voltage[2]	17 V
Absolute Maximum Current	170 A
Leakage Current at 25°C, maximum[3]	25 mA
Maximum Series Voltage	750 V
Capacitance of Individual Cells[9]	350 F
Maximum Stored Energy, Individual Cell[9]	0.35 Wh
Number of Cells	6

TEMPERATURE	
Operating Temperature (Cell Case Temperature)	
Minimum	-40°C
Maximum	65°C
Storage Temperature (Stored Uncharged)	
Minimum	-40°C
Maximum	70°C

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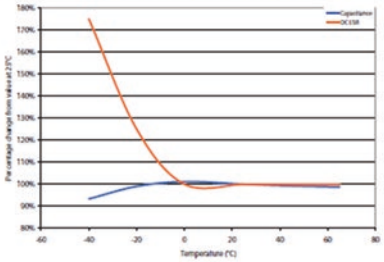
PRODUCT SPECIFICATIONS (Cont'd)

PHYSICAL	BMOD0058 E016 B02
Mass, typical	0.63 kg
Power Terminals	M5 Thread
Recommended Torque - Terminal	4 Nm
Vibration Specification	IEC60068-2-6
Shock Specification	IEC60068-2-27, -29
Environmental Protection	IP54
Cooling	Natural Convection
MONITORING / CELL VOLTAGE MANAGEMENT	
Internal Temperature Sensor	N/A
Temperature Interface	N/A
Cell Voltage Monitoring	N/A
Connector	N/A
Cell Voltage Management	Passive
POWER & ENERGY	
Usable Specific Power, P_d [4]	2,200 W/kg
Impedance Match Specific Power, P_{max} [5]	4,600 W/kg
Specific Energy, E_{max} [6]	3.3 Wh/kg
Stored Energy, E_{stored} [7,9]	2.1 Wh
SAFETY	
Short Circuit Current, typical (Current possible with short circuit from rated voltage. Do not use as an operating current.)	730 A
Certifications	RoHS, UL810a (640 Volts)
High-Pot Capability[10]	5,600 VDC

TYPICAL CHARACTERISTICS

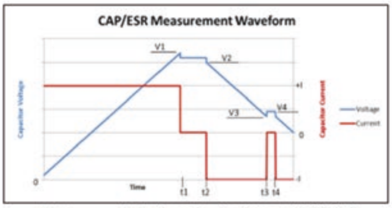
THERMAL CHARACTERISTICS	BMOD0058 E016 B02
Thermal Resistance (R_{ca}, All Cell Cases to Ambient), typical[8]	4.8°C/W
Thermal Capacitance (C_{th}), typical	420 J/°C
Maximum Continuous Current ($\Delta T = 15°C$)[8]	12 A_{RMS}
Maximum Continuous Current ($\Delta T = 40°C$)[8]	19 A_{RMS}
LIFE	
DC Life at High Temperature[1] (held continuously at Rated Voltage and Maximum Operating Temperature)	1,500 hours
Capacitance Change (% decrease from minimum initial value)	20%
ESR Change (% increase from maximum initial value)	100%
Projected DC Life at 25°C[1] (held continuously at Rated Voltage)	10 years
Capacitance Change (% decrease from minimum initial value)	20%
ESR Change (% increase from maximum initial value)	100%
Shelf Life (Stored uncharged at 25°C)	4 years

ESR AND CAPACITANCE VS TEMPERATURE



NOTES

1. Capacitance and ESR_{DC} measured at 25°C using specified test current per waveform below.
2. Absolute maximum voltage, non-repeated. Not to exceed 1 second.
3. After 72 hours at rated voltage. Initial leakage current can be higher.
4. Per IEC 62391-2, $P_d = \dfrac{0.12V^2}{ESR_{DC} \times mass}$
5. $P_{max} = \dfrac{V^2}{4 \times ESR_{DC} \times mass}$
6. $E_{max} = \dfrac{\frac{1}{2} CV^2}{3{,}600 \times mass}$
7. $E_{stored} = \dfrac{\frac{1}{2} CV^2}{3{,}600}$
8. $\Delta T = I_{RMS}^2 \times ESR \times R_{ca}$
9. Per United Nations material classification UN3499, all Maxwell ultracapacitors have less than 10 Wh capacity to meet the requirements of Special Provisions 361. Both individual ultracapacitors and modules composed of those ultracapacitors shipped by Maxwell can be transported without being treated as dangerous goods (hazardous materials) under transportation regulations.
10. Duration = 60 seconds. Not intended as an operating parameter.



$V1 = V_{rated}$ $t2 - t1 = 15$ seconds   Capacitance = I x (t3-t2)/(V2-V3)

$V3 = 0.5 \times V_{rated}$ $t4 - t3 = 5$ seconds   ESR = (V4 - V3)/I

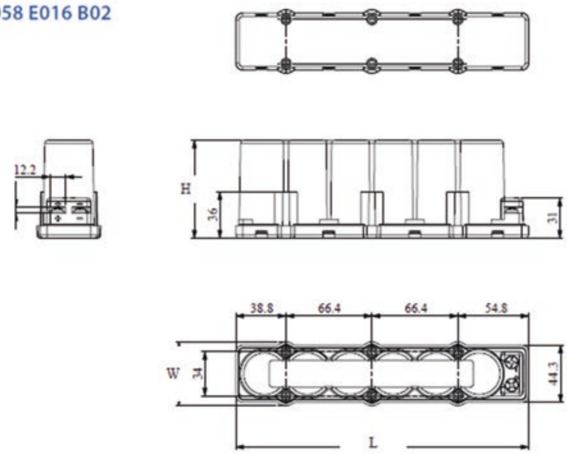
MOUNTING RECOMMENDATIONS

Recommended mounting screw M4. Maximum torque on mounting screws 4 Nm. All 6 mounting locations must be utilized to meet vibration specifications.

MARKINGS

Products are marked with the following information: Rated capacitance, rated voltage, product number, name of manufacturer, positive and negative terminal, and serial number.

BMOD0058 E016 B02



Part Description	Dimensions (mm) L (±0.5mm)	W (±0.5m)	H (±0.5mm)	Package Quantity
BMOD0058 E016 B02	226.5	49.5	76.0	10

Appendix B: The M-File Program in MATLAB for Calculates the Values of LCL Filter Components

% System parameters	
$P_n = 5000$	% Inverter power: 5000 W
$E_n = 250$	% Grid voltage: 250 V
$V_{dc} = 280$	% DC link voltage: 280 V
$f_n = 60$	% Grid frequency: 60 Hz
$w_n = 2*p_i*f_n$	
$f_{sw} = 10{,}000$	% Switching frequency: 10000 Hz
$w_{sw} = 2*p_i*f_{sw}$	% Base values
$Z_b = (E_n\hat{}2)/P_n$	
$C_b = 1/(w_n*Z_b)$	% Filter parameters
delta_Ilmax = 0.1*((P_n*sqrt(2))/E_n)	
$L_i = V_{dc}/(16*f_{sw}*$delta_Ilmax)	% Inverter side inductance
$x = 0.05$	
$C_f = x*C_b$	%Filter capacitor
$r = 0.6$	% Calculation of the factor, r, between L_{inv} and L_g
$L_g = r*L_i$	% Grid side inductance (including transformer inductance)
w_{res} = sqrt(($L_i + L_g$)/($L_i*L_g*C_f$))	% Calculation of w_{res}, resonance frequency of the filter
$f_{res} = w_{res}/(2*p_i)$	
$R_d = 1/(3*w_{res}*C_f)$	% Damping resistance

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