

160V 6F MODULE

Wind Pitch Control Energy Storage



Maxwell Technologies' 160V module is designed to provide energy storage for emergency pitch control and maximize the energy generation of a wind turbine. Based on ultracapacitor technology, the 160V module can considerably reduce turbine maintenance and life cycle costs, improve reliability and lower the overall cost of energy. Scalable in series and parallel configuration, the product can meet a majority of the new and existing pitch power delivery requirements.

Ultracapacitors are the technology of choice for electric pitch control systems because of their longer operating lifetime, low maintenance requirements and superior cold weather performance when compared to batteries.

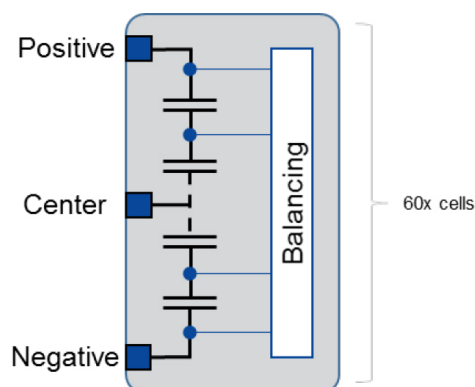
FEATURES AND BENEFITS

- Rated at 160V, 5.8F
- 2,000 hours DC life at maximum operating temperature and voltage*
- Designed for up to 500,000 cycles*
- Turnkey solution with passive cell balancing
- Compact and lightweight package
- Screw terminals and center voltage tap

TYPICAL APPLICATIONS

- Wind turbine pitch control
- Small UPS systems
- Industrial applications
- Heavy duty machinery

PRODUCT BLOCK DIAGRAM



ORDERING INFORMATION

Model Number	BMOD0006 E160 C02
Part Number	133855
Package Quantity	3

*Typical results may vary. Additional terms and conditions, including the limited warranty, apply at the time of purchase. See the warranty details for applicable operating use and requirements.

PRODUCT SPECIFICATIONS & CHARACTERISTICS

Values are referenced at T_A = room temperature and V_R = 160V rated voltage (unless otherwise noted). Min and Max values indicate product specifications. Typical results will vary and are provided for reference. Additional terms and conditions, including the limited warranty, apply at the time of purchase.

Symbol	Parameter	Conditions	Min	Typical	Max	Unit
ELECTRICAL						
C_R	Initial Rated Capacitance	Note 1	5.8	6.1	—	F
	Initial Capacitance Range/Box	3 modules per box	—	±0.05	—	F
R_S	Initial Equivalent Series Resistance (ESR)	Note 1	—	188	240	mΩ
V_R	Maximum Rated Voltage		—	—	160	V
V_{MAX}	Absolute Maximum Voltage	Non-repeated. Not to exceed 1 second	—	170	—	V
—	Maximum String Voltage	For series of modules	—	750	—	V
I_{DCMAX}	Maximum Continuous Current	$\Delta T_{CELL} = I_{RMS} \times R_S \times R_{th}$ - $\Delta T = 15^\circ C$	—	7	—	A_{RMS}
		- $\Delta T = 40^\circ C$	—	12	—	
I_{ACMAX}	Maximum Peak Current		—	170	—	A
I_{SHORT}	Short Circuit Current	Calculated from V_R and R_S Do not use as operating current	—	670	—	A
I_{LEAK}	Leakage Current	After 72 hours at $25^\circ C$	—	—	25	mA
LIFE						
t_{AGING}	Accelerated Aging	At $V_R = 160V$ and $T_A = 65^\circ C$ (Note 1)	—	2,000	—	hours
		- Capacitance change ΔC from C_R	—	20	—	%
		- Resistance change ΔR from R_S	—	100	—	%
t_{LIFE}	Projected Life Time	At $V_R = 160V$ and $T_A = 25^\circ C$ (Note 1)	—	10	—	years
		- Capacitance change ΔC from C_R	—	20	—	%
		- Resistance change ΔR from R_S	—	100	—	%
n_{LIFE}	Projected Cycle Life	At $V_R = 160V$ and $T_A = 25^\circ C$ (Note 1)	—	500,000	—	cycles
		- Capacitance change ΔC from C_R	—	20	—	%
		- Resistance change ΔR from R_S	—	100	—	%
t_{SHELF}	Shelf Life	Stored uncharged at $25^\circ C$	—	4	—	years
POWER & ENERGY						
P_d	Usable Specific Power	Per IEC 62391-2, $P_d = \frac{0.12 \times V^2}{ESR_{DC0} \times Mass}$	—	2,500	—	W/kg
P_{MAX}	Impedance Match Specific Power	$P_{MAX} = \frac{V^2}{4 \times ESR_{DC0} \times Mass}$	—	5,200	—	W/kg
E_{MAX}	Specific Energy	$E_{MAX} = \frac{\frac{1}{2} CV^2}{3,600 \times Mass}$	—	4.0	—	Wh/kg
E_{STORED}	Stored Energy	$E_{STORED} = \frac{\frac{1}{2} CV^2}{3,600}$ (Note 2)	—	20.6	—	Wh
TEMPERATURE						
T_A	Operating Temperature	Cell Case Temperature	-40	—	65	$^\circ C$
T_{STG}	Storage Temperature	Stored Uncharged @ < 50% Relative humidity (RH)	—	—	25	$^\circ C$
R_{th}	Thermal Resistance		—	1.1	—	$^\circ C/W$
C_{th}	Thermal Capacitance		—	4,800	—	J/ $^\circ C$
—	Cooling		Natural Convection			—

PRODUCT SPECIFICATIONS & CHARACTERISTICS (Cont'd)

Values are referenced at T_A = room temperature and V_R = 160V rated voltage (unless otherwise noted). Min and Max values indicate product specifications. Typical results will vary and are provided for reference. Additional terms and conditions, including the limited warranty, apply at the time of purchase.

Symbol	Parameter	Conditions	Min	Typical	Max	Unit
PHYSICAL						
m	Mass		–	5.1	–	kg
F _{M5}	Recommended Torque on Power Terminals	M5 Thread	–	2.2	4	Nm
F _{M4}	Recommended Torque on Monitoring Terminal	M4 Thread	–	1.2	2	Nm
–	Vibration Specification		IEC 60068-2-6			–
–	Shock Specification		IEC 60068-2-27			–
–	Environmental Protection		IP50			–
–	Insulation Resistance	Per IEC60068-2-78 At T _A =40°C, 90% relative humidity	–	400	–	mΩ
CELL VOLTAGE MANAGEMENT						
–	Cell Voltage Monitoring		At Terminal and Voltage Center Tap			–
–	Cell Voltage Management		Passive			–
SAFETY						
–	Certifications		UL810A, RoHS, REACH			
V _{HP}	High-Pot Capability	Duration = 60 seconds. Not intended as an operating condition.	–	5,600	–	VDC

TEST PROCEDURES

Notes:

- Measured at 25°C using specified test current waveform below:

$$\begin{aligned}
 V1 &= V_R & T2 - t1 &= 15\text{s} & \text{Capacitance} &= I \times (t3 - t2) / (V2 - V3) \\
 V3 &= 0.5 \times V_R & T4 - t3 &= 5\text{s} & \text{Resistance} &= (V4 - V3) / I
 \end{aligned}$$

$$\begin{aligned}
 V1 &= V_R & T2 - t1 &= 5\text{s} (I = 0) \\
 V2 &= 0.5 \times V_R & T4 - t3 &= 15\text{s} (I = 0)
 \end{aligned}$$

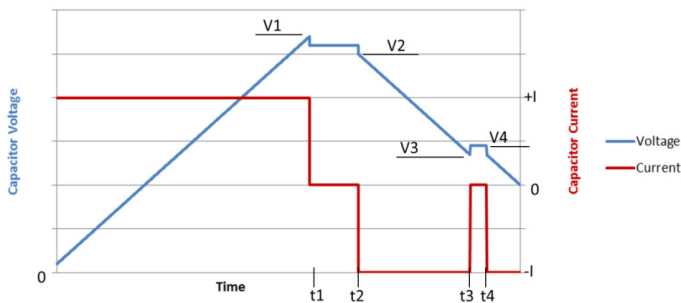


Figure 1: Capacitance & Resistance Measurement Waveform

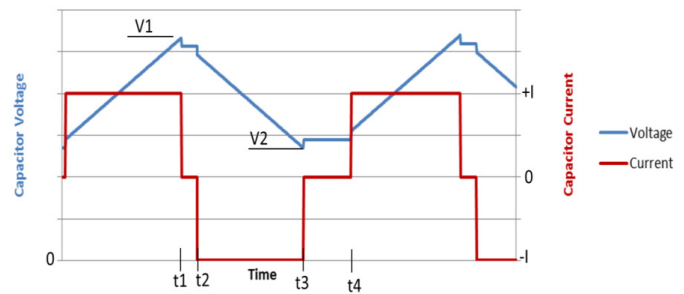


Figure 2: Cycle Life Measurement Waveform

- 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.

TYPICAL PERFORMANCE

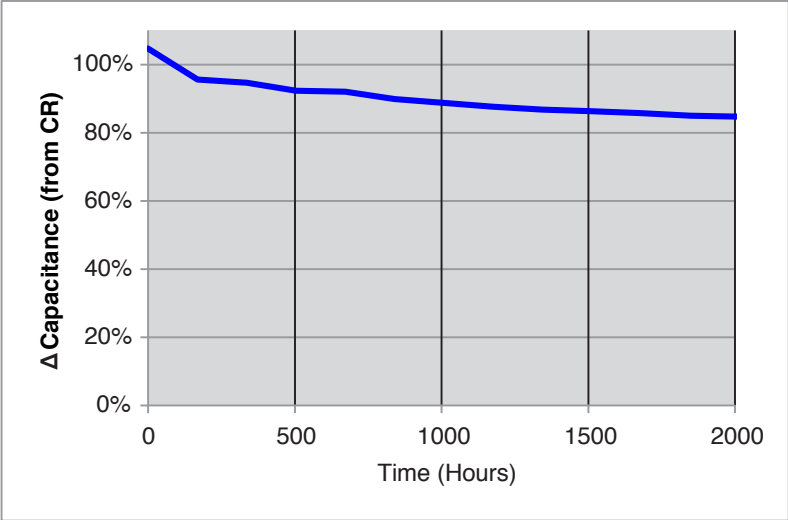


Figure 3: Accelerated Aging Capacitance Performance
 $V_R = 160V$, $T_A = 65^{\circ}C$

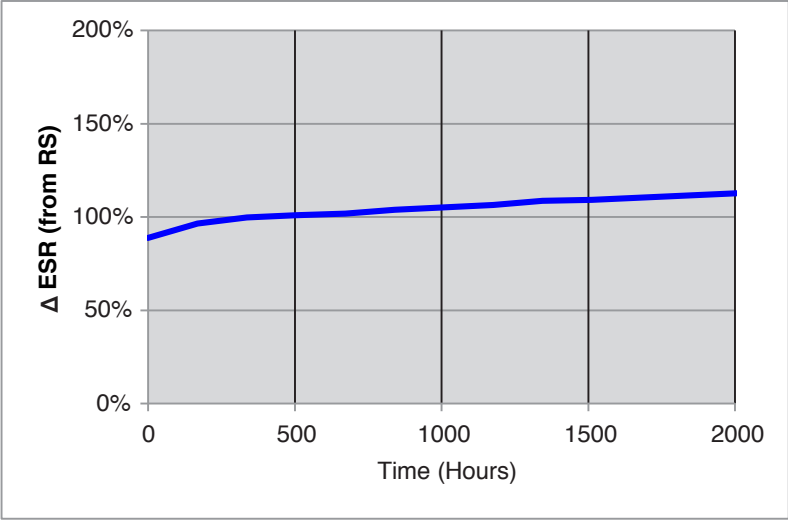


Figure 4: Accelerated Aging ESR Performance
 $V_R = 160V$, $T_A = 65^{\circ}C$

DETAILED PRODUCT DESCRIPTION

Introduction

The BMOD0006 E160 C02 energy storage module is built with sixty (60) ultracapacitor cells in series; these board mounted cells are passively balanced and the entire assembly is packaged into a rigid plastic enclosure.

Technology Overview

Electrochemical double layer capacitors (EDLCs) are also known as Electric double layer capacitor, supercapacitors or ultracapacitors deliver energy at relatively high rates (beyond those accessible with batteries) because the mechanism of energy storage is by charge-separation. Ultracapacitors store charge electrostatically (non-Faradaic) by reversible adsorption of the electrolyte onto electrochemically stable high surface area carbon electrodes. Charge separation occurs on polarization at the electrode/electrolyte interface, producing a double layer. This mechanism is highly reversible, allowing the ultracapacitor to be charged and discharged hundreds of thousands to even millions of times.*

Ultracapacitor Construction

An ultracapacitor is constructed with symmetric carbon positive and negative electrodes separated by an insulating ion-permeable separator, packaged into a container then filled with organic electrolyte (salt/solvent) designed to maximize ionic conductivity and electrode wetting. It is the combination of high surface-area activated carbon electrodes (typically >1500m²/g) with extremely small charge separation (Angstroms) that results in high capacitance.

Ultracapacitor Energy = $\frac{1}{2} CV^2$

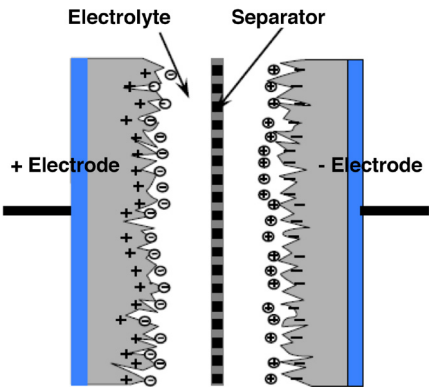


Figure 5: Ultracapacitor Structure Diagram

*Results may vary. Additional terms and conditions, including the limited warranty, apply at the time of purchase. See the warranty details for applicable operating and use requirements.

Ultracapacitors can be packaged in different mechanical packages: Prismatic Design, where the positive-separator-negative electroactive assembly can be wound on a paddle, stacked or Z-folded, then sealed in either a soft pouch cell or a hard shell prismatic can. For products with round or cylindrical packaging, the electrodes and separator are wound into a jellyroll configuration and sealed into cylindrical aluminum cans.

Ultracapacitor Cell Description

Rated at 2.7V 350F, the ultracapacitor cell in the module integrates Maxwell's most advanced electrode formulation in a compact and reliable cylindrical form factor, with outstanding electrical parameters and life performance. This ultracapacitor cell, with 4-axial, through-hole snap-in terminals is board mountable to achieve reliable and robust electrical and mechanical connectivity which maintains its integrity in high vibration applications.

Module Configuration

The BMOD0006 E160 C02 module integrates a total of sixty ultracapacitor cells rated at 2.7V 350F connected in series to achieve the desired electrical characteristics of the module. This can be calculated using the following formulas:

$$C_R = C_{CELL} \times \frac{\# \text{ parallel}}{\# \text{ series}}$$

$$R_S = R_{CELL} \times \frac{\# \text{ series}}{\# \text{ parallel}} + R_{ACCESS}$$

Where:

- C_R = module rated capacitance (F)
- C_{CELL} = cell capacitance
- R_S = module serial resistance (mΩ)
- R_{CELL} = cell equivalent series resistance
- R_{ACCESS} = module access resistance
- # parallel = number of parallel string = 1
- # series = number of cells in series = 60

Cell Balancing

To provide an equal voltage distribution across the sixty internal ultracapacitor cells, the BMOD0006 E160 C02 features an integrated passive balancing circuitry. Sized to accommodate the slight tolerance in capacitance and leakage current of each individual ultracapacitor cell in the design, the integrated passive balancing circuit ensures each cell will operate within normal operating conditions, ensuring the longest lifetime of the product.

The passive balancing circuit of the BMOD0006 E160 C02 is optimized for stationary, low duty cycle applications. Should there be an interest in higher cycling applications, please consult Maxwell Technologies Applications Engineering.

Mechanical Housing

The module packaging is a rigid plastic enclosure rated for the following stress and environmental conditions:

- Vibration per IEC60068-2-6
- Shock per IEC60068-2-27

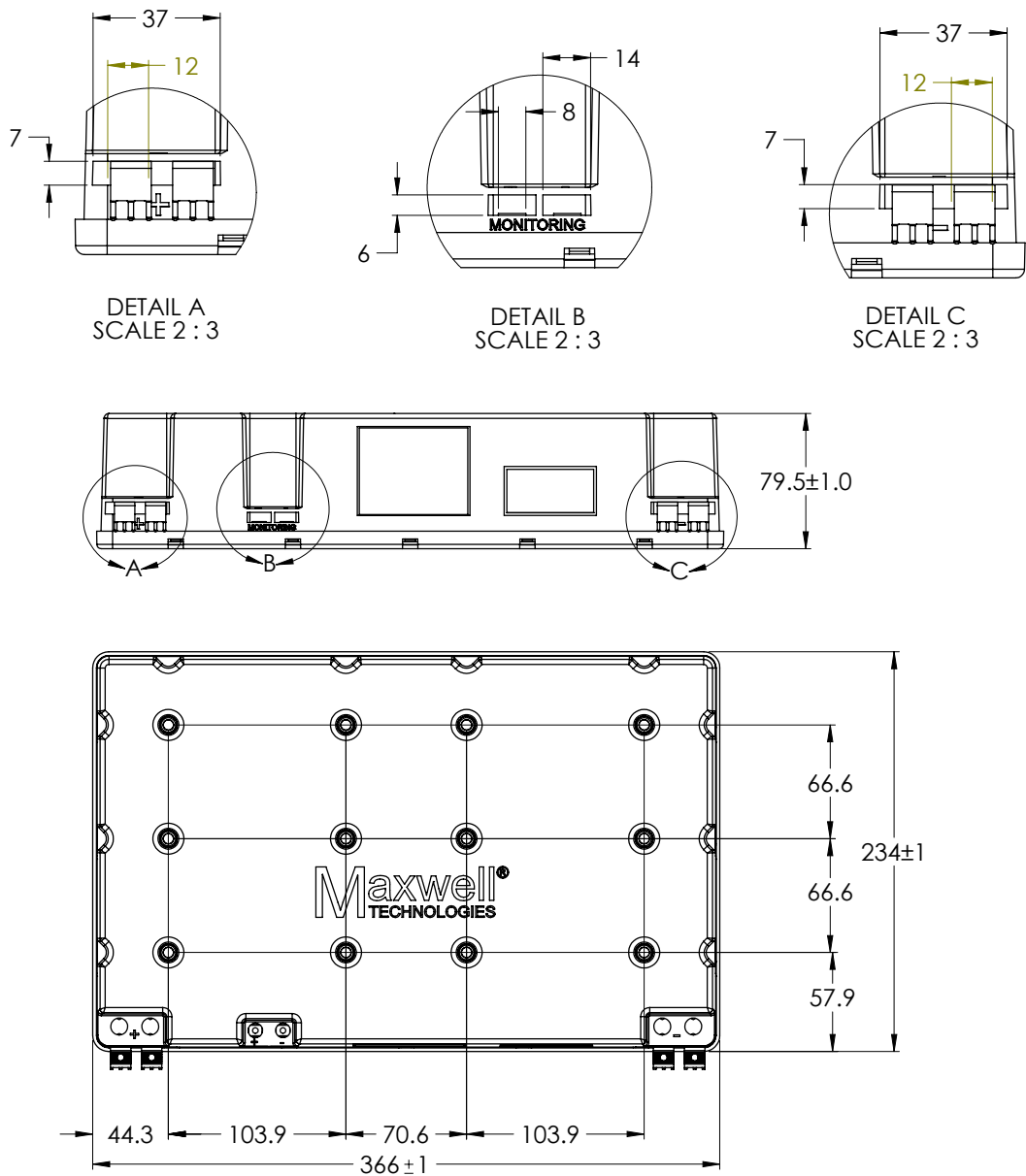
Electrical Terminals

The BMOD0006 E160 C02 module offers two power terminals (one positive, one negative) and one voltage center tap for monitoring purposes.

Mounting Points

The BMOD0006 E160 C02 module offers twelve mounting points for securing the module in the application.

MECHANICAL DRAWINGS



DIMENSIONS	MIN	TYP	MAX	UNIT
Length (L)	365.0	366.0	367.0	mm
Width (W)	233.0	234.0	235.0	mm
Height (H)	78.5	79.5	80.5	mm

INSTALLATION INSTRUCTIONS

Unpacking

Inspect the shipping carton for signs of damage prior to unpacking the module. Damage to the shipping carton or module should be reported to the carrier immediately. Remove the module from the shipping carton and retain the shipping materials until the unit has been inspected and is determined to be operational.

Note: The original shipping materials are approved for both air and ground shipment. The original shipping container should contain the following:

- 3x for BMOD0006 E160 C02. If a Maxwell business partner has repackaged the unit(s) for shipment the quantity may be different.
- 1x Product Information Sheet.

If the unit is found to be defective or any parts are missing, contact your supplier. A Return Material Authorization (RMA) number must be issued prior to returning the unit for repair or replacement.

Handling

Maxwell ultracapacitor modules are designed to provide years of trouble-free operation. Proper handling is required to avoid damage to the module. In particular, the following handling precautions should be observed:

- Do not stack modules once they have been removed from the shipping containers.
- Do not drop modules. Internal damage may occur that will not be visible from the exterior.
- Do not step on modules.

Mechanical Installation

The BMOD0006 E160 C02 module has 12 clearance holes for mounting screw locations. The modules can be mounted in any orientation as shown by Figure 6.

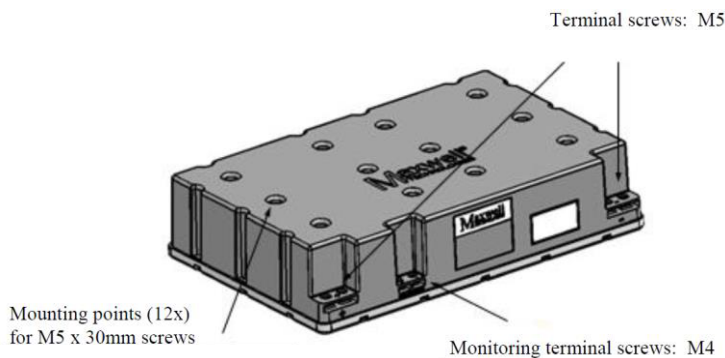


Figure 6: Module Mechanical Configuration

For best results the modules should not be mounted in locations where they are directly exposed to the environment. In particular, areas of direct splash should always be avoided. In systems that operate at voltages in excess of 60V, appropriate protection and sealing should be used on module terminals to avoid shock hazards and corrosion. Note that the terminals are fully exposed to the environment.

Dimensional spacing of the mounting holes for the modules is shown in Figure 7. It is recommended to leave at least 1 cm of spacing between modules along the vertical axis.

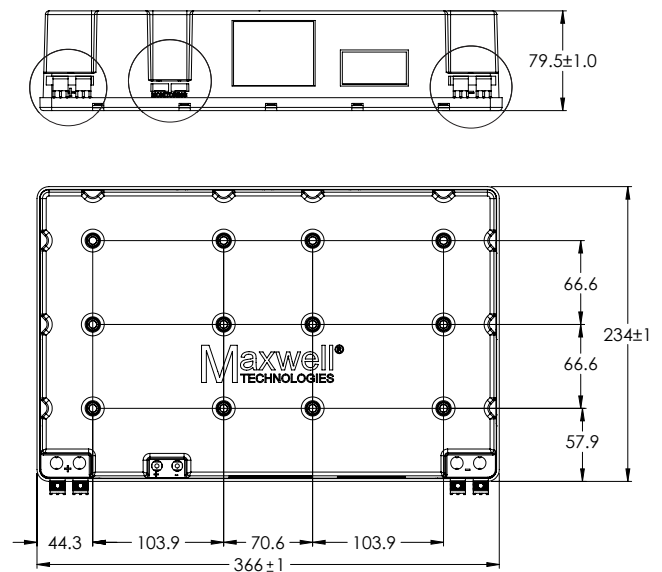


Figure 7: Module Mounting Hole Locations

A proper installation should not exert any bending or twisting torque to the module enclosure. Ensure that the module's mounting points are co-planar within ± 1 mm. If the actual mounting location is out-of-plane, use spacers to bring all four mounting locations within plane to within ± 1 mm.

The BMOD0006 E160 C02 module has been qualified to IEC60068-2-6 for vibration performance. Ensure that this is adequate for the end-use environment. To ensure meeting specified vibration performance, all mounting points should be used. If more severe vibration performance is required, consider the use of isolators to provide damping. Contact Maxwell Application Engineering for assistance in these cases.

Electrical Installation

WARNING



CAUTION

To avoid arcing, the energy storage module should be in a discharged state and the system power disconnected during installation. The module is shipped discharged and with a shorting wire. The shorting wire should be removed prior to installation of electrical connections.

WARNING



CAUTION

To provide the lowest possible ESR, the energy storage modules are not fused. Care should be taken within the application to prevent excessive current flow. Excessive current and/or duty cycle will result in overheating the module and cause irreparable damage. Please consult the specific data sheet for each module for current and duty cycle capabilities.

The power output terminals of the modules consist of M5 screw terminals intended to mate with spade or ring terminals. Ensure that interconnect wire is of sufficient gauge to carry the system current. The modules may be connected in series for higher voltages. As mentioned earlier, the maximum torque is 4 Nm.

The BMOD0006 E160 C02 module has a center-tap terminal that can be used to compare the voltage of the upper half of the ultracapacitor array with that of the lower half as a diagnostic for imbalance. This mid-point voltage is accessible through the M4 monitoring terminals as illustrated in Figure 6.

The current drawn from the center tap should not exceed 10 µA. Drawing currents in excess of this amount can create imbalance within the module. The maximum torque for this M4 terminal is 3.5 Nm.

The energy storage module has low Equivalent Series Resistance (ESR). As a result, the resistance of the wires connecting the energy storage module to the application can easily exceed the ESR of the module. Connection of modules in series or parallel should utilize the same gauge wire as determined for final output connections. When connecting in series connect the positive output terminal of one module to the negative output terminal of the next module. Two possible series orientations are illustrated in Figure 8 and two possible parallel orientations in Figure 9.

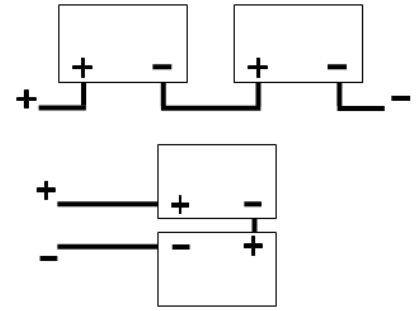


Figure 8: Possible Series Connection Arrangements

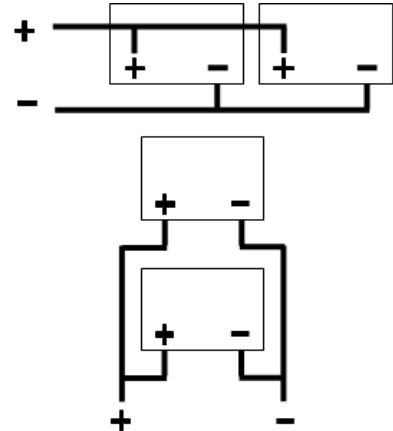


Figure 9: Possible Parallel Connection Arrangements

The maximum allowable operating voltage for a series string is 750 VDC. When several modules are connected in series for operating at higher system voltages, care must be taken to ensure proper creepage and clearance distances in compliance with appropriate national and local safety standards for electrical equipment.

Thermal Performance

The module should operate within the temperature limits indicated in this specification. Operating the module above its maximum operating temperature is not recommended and can cause accelerated aging of the ultracapacitor cells. The maximum temperature in the cells T_{CELL} can be calculated by the following equation:

$$T_{CELL} = T_A + I^2 R_S R_{th} d_f, \text{ where}$$

- T_A = Maximum ambient temperature (°C)
- I = Maximum application RMS current (A)
- R_S = Equivalent series resistance (ohms)
- R_{th} = Module thermal resistance (°C/W)
- d_f = Application duty cycle fraction

This module is not designed for high cycling applications. Should there be an interest in higher cycling applications, please consult Maxwell Technologies Applications Engineering.

Operation

The module should only be operated within specified voltage and temperature ratings. Determine whether current limiting is necessary based on the current ratings of attached components. Observe polarity indicated on module. Do not reverse polarity.

Safety

WARNING



DANGER – HIGH VOLTAGE HAZARD!

Never touch the power terminals as the module can be charged and cause fatal electrical shocks. Always check that the module is fully discharged before manipulating the module. Please refer to the step by step instructions below for the manual discharge procedure.

- Do not operate unit above the specified voltage.
- Do not operate unit above the specified temperature rating.
- Do not touch terminals with conductors while charged. Serious burns, shock, or arcing may occur.
- Protect surrounding electrical components from incidental contact.
- Provide sufficient electrical isolation when working above 50 VDC.
- Prior to installation on or removal from the system, it is mandatory to fully discharge the module to guarantee the safety of personnel.

WARNING



A fully discharged module may “bounce back” if it is stored without a shorting wire connected to the + and – terminals. This bounce back can be as much as 2V for the BMOD0058 and 20V with the BMOD0006. When used in series strings this has the potential to cause dangerous electrical shocks.

General Maintenance

Prior to removal from the system, cable removal, or any other handling ensure that the energy storage module is completely discharged in a safe manner. The stored energy and the voltage levels may be lethal if mishandling occurs.

Maintenance should only be conducted by trained personnel on the discharge procedure.

Discharge Procedure

Proceed as follows to discharge the module:

1. Using a voltmeter, measure the voltage between the 2 terminals.
2. If the voltage is above 2V, a resistor pack (not supplied with the module) will need to be connected between the terminals. Proper care needs to be taken in the design and construction of such a dissipative pack. The resistor pack will need to be sized and provided with suitable cooling to handle the resulting power dissipation. Additionally, proper isolation and packaging are necessary to ensure safety.
3. If the voltage is under 2V, connect a shorting wire to the + and – connectors.
4. The module is now safe for handling. However, leave the shorting wire connected at all times until the module is installed and the power cables are connected again.

Routine Maintenance

1. Clean exterior surface of dirt/grime
 - Reason – Improve power dissipation performance.
 - Use a cleaning cloth dampened with water. Avoid use of any chemical substances. Do not use high-pressure sprays or immersion. Keep excess amounts of water away from all surfaces.
 - Frequency – annually
2. Check mounting fasteners for proper torque
 - Reason – Avoid mechanical damage
 - Frequency: high vibration environments (6 months), low vibration environments (12 months)
3. Inspect housing for signs of damage
 - Reason – identify potential internal damage
 - Frequency – Annually
4. Check electrical connections for proper torque
 - Reason – avoid false signals, shock hazards, and high-resistance connections
 - Frequency: high vibration environments (6 months), low vibration environments (12 months)

Storage

The discharged module can be stored in the original package in a dry place. Discharge a used module prior to storage or shipment. A shorting wire across the terminals is strongly recommended to maintain a short circuit after having discharged the module.

Disposal

Do not dispose of module in trash. Dispose of according to local regulations.

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