Model M7009R
24VDC Regulated Buffer

Model M7009C
Ultracapacitor Storage Expansion Module

Customer Reference Manual

Bonitron, Inc.
Nashville, TN

An industry leader in providing solutions for AC drives.

ABOUT BONITRON

Bonitron designs and manufactures quality industrial electronics that improve the reliability of processes and variable frequency drives worldwide. With products in numerous industries, and an educated and experienced team of engineers, Bonitron has seen thousands of products engineered since 1962 and welcomes custom applications.

With engineering, production, and testing all in the same facility, Bonitron is able to ensure its products are of the utmost quality and ready to be applied to your application.

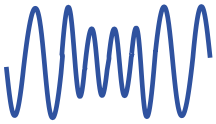
The Bonitron engineering team has the background and expertise necessary to design, develop, and manufacture the quality industrial electronic systems demanded in today's market. A strong academic background supported by continuing education is complemented by many years of hands-on field experience. A clear advantage Bonitron has over many competitors is combined on-site engineering labs and manufacturing facilities, which allows the engineering team to have immediate access to testing and manufacturing. This not only saves time during prototype development, but also is essential to providing only the highest quality products.

The sales and marketing teams work closely with engineering to provide up-to-date information and provide remarkable customer support to make sure you receive the best solution for your application. Thanks to this combination of quality products and superior customer support, Bonitron has products installed in critical applications worldwide.

AC Drive Options

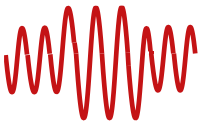
In 1975, Bonitron began working with AC inverter drive specialists at synthetic fiber plants to develop speed control systems that could be interfaced with their plant process computers. Ever since, Bonitron has developed AC drive options that solve application issues associated with modern AC variable frequency drives and aid in reducing drive faults. Below is a sampling of Bonitron's current product offering.

World Class Products



Undervoltage Solutions

Uninterruptible Power for Drives
(DC Bus Ride-Thru)
Voltage Regulators
Chargers and Dischargers
Energy Storage



Overvoltage Solutions

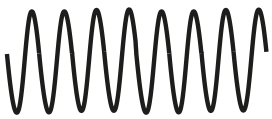
Braking Transistors
Braking Resistors
Transistor/Resistor Combo
Line Regeneration
Dynamic Braking for Servo Drives

Common Bus Solutions

Single Phase Power Supplies
3-Phase Power Supplies
Common Bus Diodes

Portable Maintenance Solutions

Capacitor Formers
Capacitor Testers



Power Quality Solutions

12 and 18 Pulse Kits

Green Solutions

Line Regeneration

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Tables

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1. INTRODUCTION

1.1. WHO SHOULD USE

This manual is intended for use by anyone who is responsible for integrating, installing, maintaining, troubleshooting, or using this equipment with any 24V control system.

Please keep this manual for future reference.

1.2. PURPOSE AND SCOPE

This manual is a user's guide for the model M7009R. It will provide the user with the necessary information to successfully connect and operate the M7009R.

In the event of any conflict between this document and any publication and/or documentation related to any associated hardware (capacitor bank, etc.), the latter shall have precedence.

1.3. MANUAL VERSION AND CHANGE RECORD

The initial release for this module is Rev 00a.

Updated section 2.1 in Rev 00b.

Figure 1-1: M7009C & M7009R

1.4. SYMBOL CONVENTIONS USED IN THIS MANUAL AND ON EQUIPMENT

	Earth Ground or Protective Earth
	AC Voltage
	DC Voltage
 DANGER!	DANGER: Electrical hazard - Identifies a statement that indicates a shock or electrocution hazard that must be avoided.
 DANGER!	DANGER: Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss.
 CAUTION!	CAUTION: Identifies information about practices or circumstances that can lead to property damage, or economic loss. Attentions help you identify a potential hazard, avoid a hazard, and recognize the consequences.
 CAUTION!	CAUTION: Heat or burn hazard - Identifies a statement regarding heat production or a burn hazard that should be avoided.

2. PRODUCT DESCRIPTION

Bonitron's M7009R is a DIN rail mounted 24VDC buffer intended to provide back-up power to typical 24VDC control systems, allowing operation to continue after a power disruption or in the case controls need to continue operation after the mains have been disconnected to a system. The buffer consists of a bi-directional regulator and integrated ultra-capacitor bank which can be extended with external M7009C capacitor module. While power is available, the buffer draws a small current to store energy, then, in the event the connected bus falls below a set-point, the buffer reverses power flow and holds up the bus, regulating the voltage just below nominal. Light loads can be supplied for several minutes, but the M7009R can also provide power in the hundreds of Watts for more demanding applications.

2.1. RELATED PRODUCTS

M5628 ULTRA CAPACITOR/ BATTERY CHARGER

The M5628 charger can charge strings of batteries or ultra capacitors to voltages required for industrial and commercial applications. AC or DC input is available, along with separate float and equalization charge levels. The charger is current limited, and designed for use in integrated storage and backup systems, but can also be used in bench or mobile systems.

KIT 3628T ULTRA CAPACITOR DISCHARGER

Large capacitor banks store huge amounts of energy, and can be a hazard when systems are shut down for system maintenance. The KIT 3628T system discharges capacitor banks to safe working levels quickly, allowing work on the system to begin in seconds, rather than hours.

M3460 SERIES RIDE-THRU MODULES

Voltage regulators used for sag or outage protection of higher power systems.

M3534 SERIES RIDE-THRU MODULES

Voltage regulators used for sag or outage protection of lower power systems.

S3460CR SERIES RIDE-THRU SYSTEMS

Complete systems that use electrolytic capacitor storage for short term power outages.

S3460UR SERIES RIDE-THRU SYSTEMS

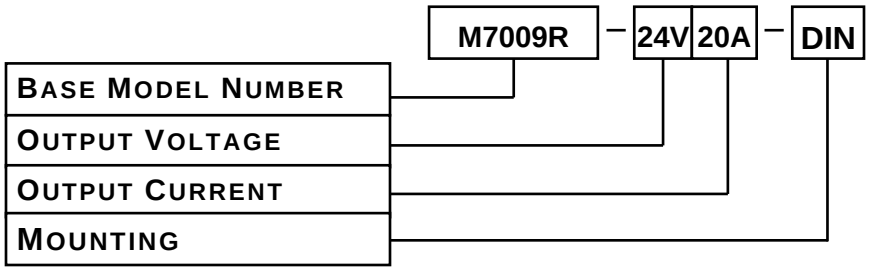
Complete systems that use ultracapacitor storage for short term power outages.

S3460BR SERIES RIDE-THRU SYSTEMS

Complete systems that use batteries for longer term power outages.

2.2. PART NUMBER BREAKDOWN

Figure 2-1: Example of Part Number Breakdown



BASE MODEL NUMBER

The base model number for the regulated buffer with ultra capacitor storage is M7009R. The base model number for additional ultra capacitor storage is M7009C.

OUTPUT VOLTAGE RATING

The Max Output Voltage rating indicates the DC output voltage the unit can supply, which is indicated by a code letter.

Table 2-1: Output Voltage

RATING CODE	VOLTAGES (DC VOLTAGE OUTPUT)
24V	24 VDC out

OUTPUT CURRENT RATING

The Max Output Current rating indicates the maximum DC current the unit can supply at its maximum voltage. (For the M7009C these digits are omitted as it does not have an output rating)

Table 2-2: Output Current

RATING CODE	AMPS (DC AMPS OUTPUT)
20A	20 ADC Out

MOUNTING

Both models are designed to be mounted on a standard DIN rail.

2.3. GENERAL SPECIFICATIONS

Table 2-3: M7009R General Specifications Table

PARAMETER	SPECIFICATION
Max DC Bus Voltage	27VDC
Max Charging Time*	6min
Max Hold-Up Current	20A
Internal Storage Capacitance	20F
Internal Storage Energy	5760J
Unit Size (H x W x D)	5.375" x 5" x 5.75"
Weight	3lbs
Storage Temp	-20°C to + 65°C
Operating Temp	-20°C to + 40°C
Humidity	Below 90% non-condensing
Atmosphere	Free of corrosive gas and conductive dust

*Using only the internal storage capacitance

Table 2-4: M7009C General Specifications Table

PARAMETER	SPECIFICATION
Internal Storage Capacitance	20F
Internal Storage Energy	5760J
Unit Size (H x W x D)	5.375" x 3.1" x 5.75"
Weight	2lbs
Storage Temp	-20°C to + 65°C
Operating Temp	-20°C to + 40°C
Humidity	Below 90% non-condensing
Atmosphere	Free of corrosive gas and conductive dust

GENERAL PRECAUTIONS AND SAFETY WARNINGS

ELECTROCUTION HAZARD!

- THIS UNIT PRODUCES CURRENTS CAPABLE OF CAUSING INJURY OR DEATH!
- FOR USE BY QUALIFIED AND TRAINED PERSONNEL ONLY!
- **IMPROPER OPERATION OF THE PRODUCT OR IGNORING THESE WARNINGS MAY RESULT IN SERIOUS BODILY INJURY OR DEATH!**
- NEVER OPERATE THIS PRODUCT WITH THE ENCLOSURE COVER REMOVED.

DANGER!

- NEVER ATTEMPT TO SERVICE THIS PRODUCT.
- CERTAIN PARTS INSIDE THIS PRODUCT MAY GET HOT DURING OPERATION.
- DO NOT CONNECT THE **M7009R** TO A LIVE **DC** BUS
- CONNECTING THE **M7009R**'S VOLTAGE OUTPUT TO A **DC** BUS OR CAPACITOR BANK WITH THE POLARITY REVERSED CAN CAUSE DAMAGE TO YOUR EQUIPMENT AND POTENTIALLY CREATE A FIRE OR EXPLOSION HAZARD, THREATENING LIVES. ENSURE THAT THE POSITIVE AND NEGATIVE TERMINALS ON ALL EQUIPMENT ARE POSITIVELY IDENTIFIED AND CORRECTLY CONNECTED BEFORE OPERATION.
- BEFORE CONNECTING THIS DEVICE TO ANY OTHER PRODUCT, BE SURE TO REVIEW ALL DOCUMENTATION OF THAT PRODUCT FOR PERTINENT SAFETY PRECAUTIONS.

ANY QUESTIONS AS TO APPLICATION, INSTALLATION, OR SERVICE SAFETY SHOULD BE DIRECTED TO THE EQUIPMENT SUPPLIER.

3. INSTALLATION INSTRUCTIONS

3.1. ENVIRONMENT

The M7009R and M7009C use passive airflow through gratings in the enclosures to maintain their internal temperatures within an acceptable range. The environment should be free of dust and liquids, and the ambient temperature should not exceed 40°C. Vibration should also be avoided as the weight of the internal storage creates a sizeable moment arm that could fatigue the plastic enclosure's mounting points.

3.2. UNPACKING

Upon receipt of this product, please verify that the product received matches the product that was ordered and that there is no obvious physical damage to the unit. If the wrong product was received or the product is damaged in any way, please contact the supplier from which the product was purchased.

3.3. MOUNTING

The M7009R and M7009C come with attached spring-loaded DIN rail clips on the back of the enclosure. To mount the module onto a DIN rail in the desired location, engage the bottom hooks with the DIN rail and lift the unit up compressing the spring on the mounting clip. Once the spring is compressed, tilt the unit up then lower the unit down engaging the upper hooks on the DIN rail.

3.4. WIRING AND CUSTOMER CONNECTIONS

3.4.1. POWER CONNECTIONS AND WIRING

Connections to the 24V DC bus and additional capacitor modules are made using the labeled screw terminals on the bottom of the enclosure. Wire connecting the module to the DC bus should be appropriate for the maximum expected load, while wire connecting to additional capacitance should be a minimum of 12AWG in free air, or 10AWG in conduit or raceways.

3.4.1.1. DC BUS (+) AND DC BUS (-)

These are the main connections to the 24V DC bus. They are used to both charge the capacitors when the main 24V power supply is operating, and supply 24V DC power when the main 24V power supply is not operating.

3.4.1.1.1. SOURCE CONSIDERATIONS

The connected DC bus should not exceed 27VDC or damage to the unit may result. Additionally, the charging current can reach 1.5A, which the bus source must be capable of supplying in addition to the normal operating load. Failure to meet the minimum current requirement may result in improper operation and the collapse of the DC bus.

3.4.1.1.2. LOAD CONSIDERATIONS

The M7009R will be responsible for powering all loads on its connected DC bus in the event the primary source is lost. The total draw of these loads should not exceed 20 amps. Exceeding this current limit may result in damage to the unit, and a collapse of the DC bus.

3.4.1.1. CAPACITOR (+) AND CAPACITOR (-)

These connections are used to connect the M7009C ultra-capacitor expander module. Only one expander module may be connected to lengthen the amount of time the M7009R unit will support a load. **When making these connects, ensure the polarity is correct, otherwise catastrophic damage and injury may occur.**

3.4.2. SIGNAL CONNECTIONS AND WIRING

Three solid-state relays provide feedback to the user about malfunctions in the unit, closing to report the respective malfunction. The relays are accessed through labeled screw terminals on top of the enclosure. Each relay is electrically isolated from the unit, DC bus, and the other relays, and should draw no more than 100mA.

3.4.2.1. FAULT

This relay closes when the unit senses a DC bus overvoltage or an overtemperature condition.

3.4.2.2. FUSE 1

This relay closes when the internal fuse for the first capacitor bank has blown. It is accompanied by the illumination of the red LED labeled Fuse 1.

3.4.2.3. FUSE 2

This relay closes when the internal fuse for the second capacitor bank has blown. It is accompanied by the illumination of the red LED labeled Fuse 2.

3.4.1. CONNECTIONS EXAMPLE

Figure 3-1: M7009R

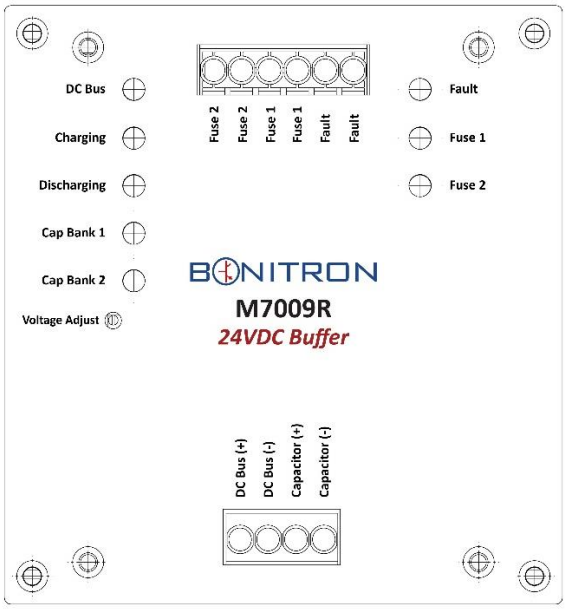


Figure 3-2: M7009

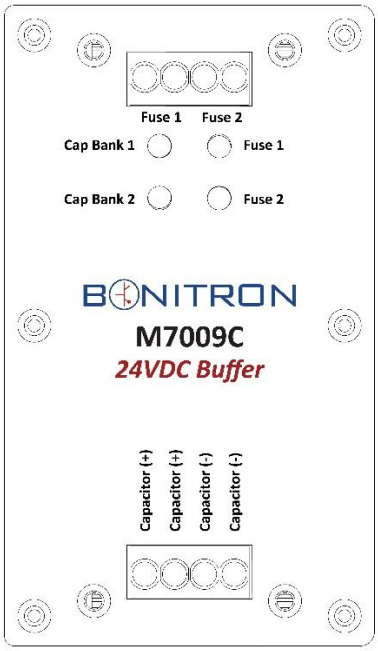
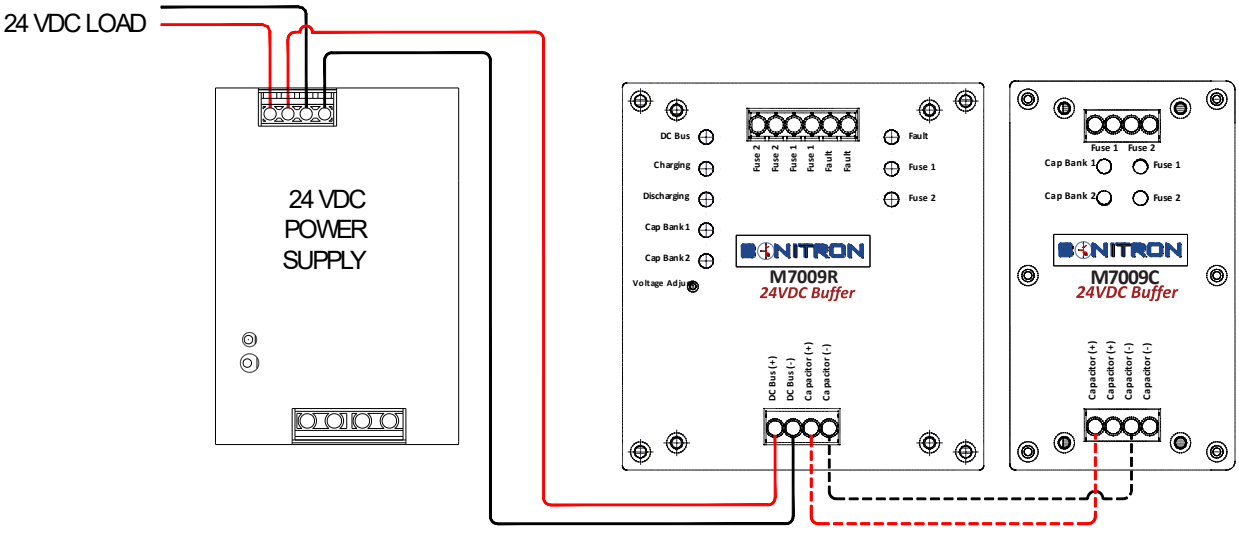


Figure 3-3: Example Connection of M7009R to M7009C and 24 VDC Power Supply



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4. OPERATION

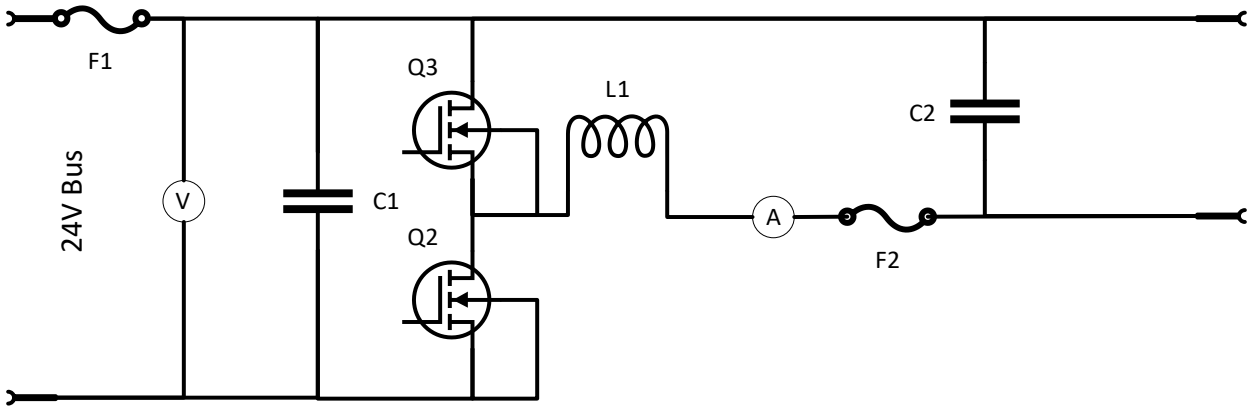
4.1. FUNCTIONAL DESCRIPTION

The M7009R belongs to the class of devices commonly referred to as uninterruptable power supplies or buffers, intended to continue supplying power in the event main power is lost. The M7009R automatically charges its internal and optional M7009C external energy storage as well as automatically holds up its connected DC bus. No commands are necessary to activate either of these functions, though signals are sent out from the unit that provide diagnostic information in the event of a malfunction.

4.2. ARCHITECTURE AND CIRCUIT SCHEMATIC

Electrically, the M7009R is a current and voltage regulated, bi-directional DC-DC converter with response times on the order of milliseconds. It also comes with significant integrated energy storage, which can be connected to an additional M7009C external capacitor bank. During charging, it acts as a current limited buck converter, bringing its energy storage up to the bus voltage and maintaining this voltage once complete. When the connected DC bus voltage drops below a setpoint, the regulator reverses power flow, becoming a voltage regulating boost converter. Current is provided as needed and only limited in the capacitor bank.

Figure 4-1: M7009R Schematic



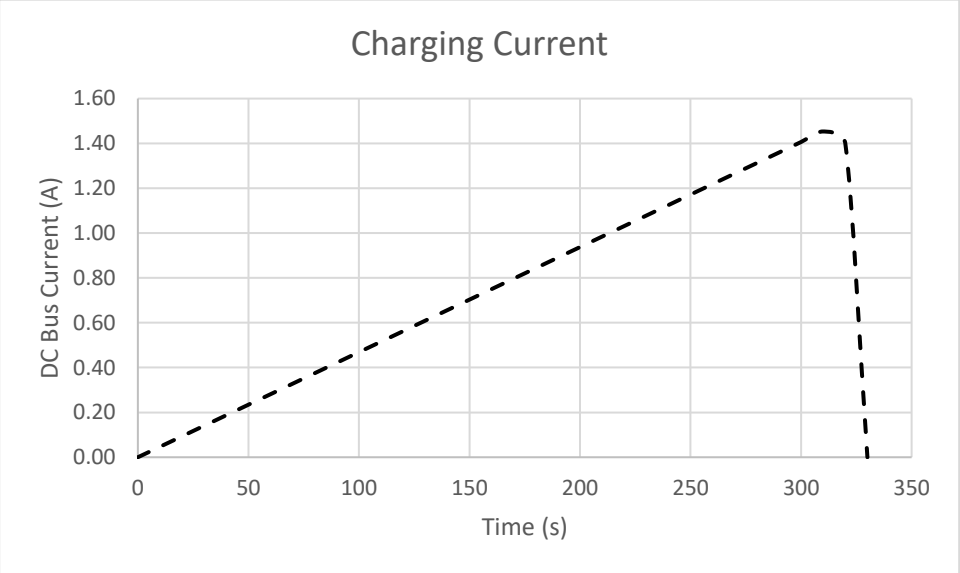
4.3. MODES OF OPERATION

Operation of the M7009R is relatively simple—so long as 24VDC is connected to the DC bus terminals, the unit will charge and maintain any connected ultra-capacitor banks; in the event the bus is lost but there is at least some charge on the capacitors, it will automatically try to hold up the bus voltage. No action is required from the user. In addition to the “Charging” and “Discharging” modes, there is also a “Faulted” state and an “Undervoltage” state which protect the unit.

4.3.1. CHARGING

While the M7009R is in “Charging” mode, it supplies a constant current to any connected capacitor storage, internal and external, until the bank reaches the bus voltage. Charging mode is activated any time the DC bus is above roughly 23.5V. This setpoint can be adjusted +/-0.25V by turning the “Voltage Adjust” trim pot. As capacitor voltage rises, the input current from the DC bus also rises, with a peak of 1.5A occurring roughly when the capacitor bank reaches the bus voltage. Below is a plot showing how the charging current drawn from the DC bus varies with time as the storage voltage rises.

Figure 4-2: M7009R Charging Current



4.3.2. DISCHARGING

While the M7009R is in “Discharging” mode, it regulates the connected capacitor storage to provide a constant voltage to the DC bus. Discharging mode is activated any time the bus voltage tries to fall below roughly 23.5V, which is also the voltage it will try to maintain. As with the charging threshold, this setpoint can be adjusted by turning the “Voltage Adjust” trim pot. While the unit is holding up the DC bus, it has no set current limit. Instead, a 30A current limit is imposed on the capacitor bank which for practical purposes

limits the DC bus current. As the M7009R supplies current to the loaded DC bus, the capacitor voltage drops while the capacitor current rises. Eventually, the capacitor current limit will be activated and the DC bus voltage will begin to decline. The duration that the M7009R can maintain a fixed voltage is a function of the load current and connected capacitance. Information on determining the capacitance necessary for an application and the hold-up time can be found in the Engineering Data and Appendix sections of this manual. The curves below illustrate this phenomenon, showing the storage current and voltage as functions of time for different loads.

Figure 4-3: Storage Voltage vs. Time for Selected Loads with 20F of Storage

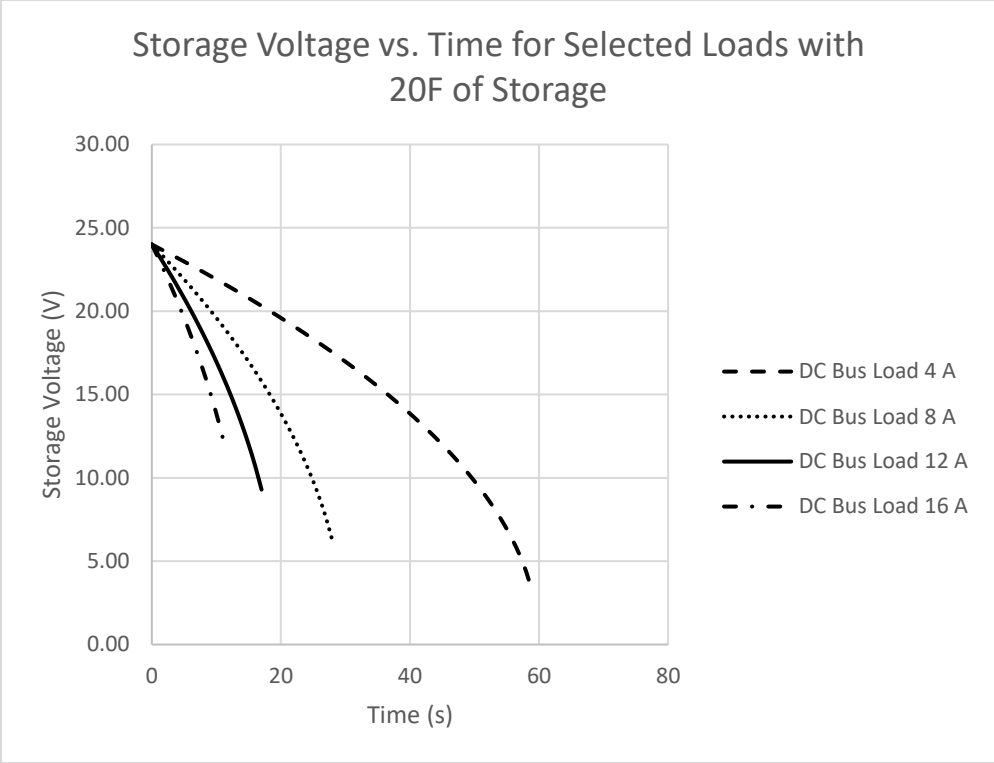


Figure 4-4: Storage Current vs. Time for Selected Loads with 20F of Storage

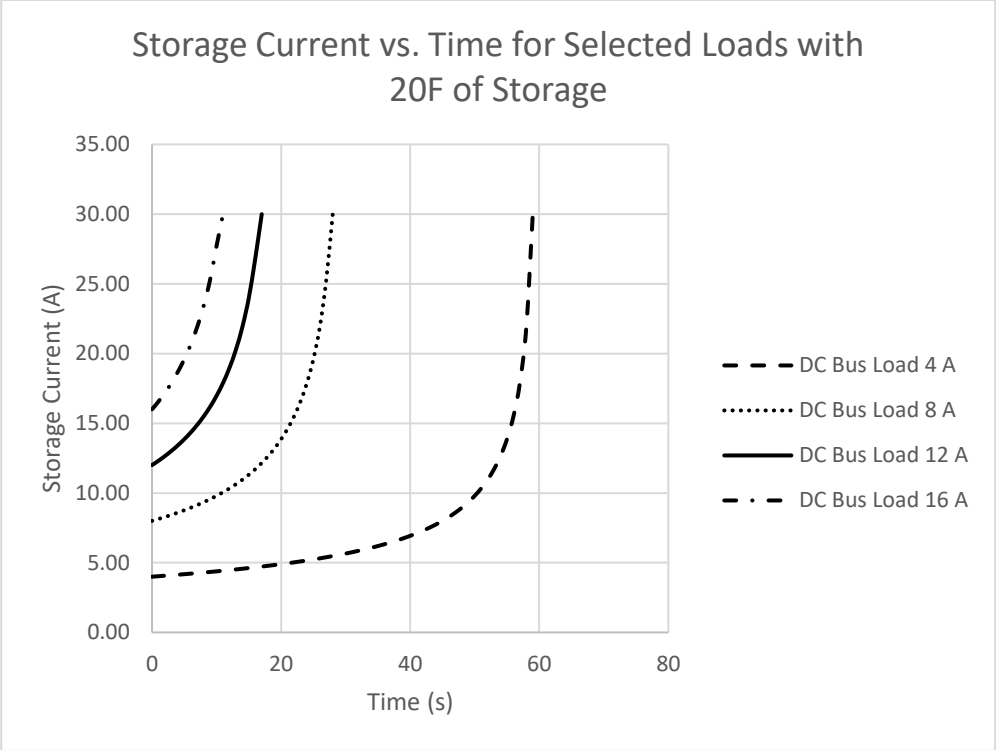


Table 4-1: Hold up Times for Selected Loads

Current (Amps)	20F Hold Up Time (Sec.)	40F Hold Up Time (Sec.)
20	4	8
18	5	11
16	6	13
14	8	17
12	10	21
10	13	27
8	17	35
6	23	49
4	37	73
2	73	149

4.3.3. FAULT

While faulted, the unit will not charge connected energy storage or attempt to hold up the DC bus. Faults are cleared once the condition has been resolved, requiring no additional action from the user. Overheating and DC bus over-voltage are the only fault conditions tested for and both produce the same response making them indistinguishable without further investigation. It is important to keep in mind that even though the regulator may be disabled while faulted, the capacitor bank will likely have a great deal of energy remaining.

4.3.4. UNDERVOLTAGE

In the event the DC bus voltage falls below 16V, the unit disconnects itself from the DC bus to prevent an unregulated discharge of its connected capacitance.

4.4. HARDWARE FEATURES

4.4.1. INTEGRATED FUSING AND HARDWARE PROTECTION

The M7009R has several built-in protections against destructively high currents. The first layer of protection is a 30A current limit imposed on the storage bank by the regulator. Outside of charging current, which is also regulated at the capacitor bank, there are no other current controls, and by extension there are no direct controls on the current the unit can supply to the DC bus. Limiting the capacitor current, however, does indirectly limit the current that can be supplied. At maximum charge, it is possible for the M7009R to deliver 30A, but as this would inevitably require increasing storage current as the capacitors discharge, the DC bus voltage would precipitously collapse. In general, this is the main implication of the storage current limit—the unit maintains DC bus regulation so long as the storage current is below 30A, but as the storage voltage drops, its current must also rise, eventually activating the current limit and causing a collapse of the DC bus. Information on estimating the available hold-up time for a given load and capacitance is given in section 6.

Aside from a regulated current limit, fuses are also integrated into different sections of the circuitry. First, there is a 30A fuse between the regulator and the DC bus connection terminals. Additionally, each internal and external capacitor bank (M7009C) is connected to the regulator through its own 40A fuse. All of these fuses primarily protect against unregulated currents flowing in or out of the super-capacitors following a transistor failure.

4.4.2. PANEL INDICATORS

There are eight LEDs in the front panel to indicate the operational status of the M7009R.

- DC Bus: Indicates that the unit is connected to the 24V DC bus
- Charging: Indicates that the unit is presently charging its energy storage. The brightness decreases as the unit approaches full charge.
- Discharging: Indicates that the unit is presently discharging its energy storage and holding up the DC bus. The brightness increases as the capacitors discharge.
- Cap Bank 1: Indicates the voltage across internal capacitor bank 1
- Cap Bank 2: Indicates the voltage across internal capacitor bank 2
- Fault: Indicates the unit is disabled and either too hot or the DC bus voltage is too high
- Fuse 1: Indicates that the fuse connecting Capacitor Bank 1 to the regulator has cleared
- Fuse 2: Indicates that the fuse connecting Capacitor Bank 2 to the regulator has cleared

There are four LEDs in the front panel to indicate the operational status of the M7009C.

- Cap Bank 1: Indicates the voltage across internal capacitor bank 1
- Cap Bank 2: Indicates the voltage across internal capacitor bank 2
- Fuse 1: Indicates that the fuse connecting Capacitor Bank 1 to the regulator has cleared
- Fuse 2: Indicates that the fuse connecting Capacitor Bank 2 to the regulator has cleared

4.4.3. FAULT RELAYS

The M7009R features three solid-state relays that close in the event of certain monitored malfunctions, as described in the “Faults” section of this manual. These SSRs are fully isolated and capable of carrying 100mA.

The M7009C features two solid-state relays that close in the event of certain monitored malfunctions, as described in the “Faults” section of this manual. These SSRs are fully isolated and capable of carrying 100mA.

4.5. INTERNAL FAULTS

Faults and the clearing of capacitor fuses in the M7009R and M7009C are indicated by red LEDs in the panel and each closes a solid-state relay accessible by the user through the screw terminal block on top of the unit.

4.5.1. OVER-VOLTAGE – M7009R

This fault occurs when the DC bus has exceeded 27V. During the fault, operation will be disabled, the “Fault” indicator will light up, and the “Fault” relay will close. Reducing the bus voltage below 27V will immediately restore

operation. If the fault will not clear, your unit is likely damaged. Contact Bonitron for service options.

4.5.2. OVER-TEMPERATURE – M7009R

This fault indicates that the regulator has overheated. During the fault, operation will be disabled, the "Fault" indicator will light up, and the "Fault" relay will close. Operation will be restored immediately if the temperature falls to an acceptable range. If the fault will not clear, your unit is likely damaged. Contact Bonitron for service options.

4.5.3. CAPACITOR FUSES – M7009R & M7009C

These faults indicate that the fuse connecting the respective internal capacitor bank has cleared. During this fault, the regulator will continue to function, but the capacitor bank will be permanently disconnected, reducing hold-up time. This fault is indicated by an LED in the front panel and will close its respective solid-state relay. Contact Bonitron for service options.

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5. START-UP, MAINTENANCE, AND TROUBLESHOOTING

5.1. POWERING UP

Applying 24V to the M7009R will immediately initiate charging of the internal and any external capacitance. The green "DC Bus" indicator and green "Charging" indicator should both light up, and the two green "Cap Bank" indicators should slowly light up after several seconds. If charging does not begin, the voltage set-point may need to be adjusted down by turning the "Voltage Adjust" trim-pot counter-clockwise. The range is adjustable from 23.25V to 23.75V. It is also recommended that once fully charged, operation of the unit be tested while connected to full load with the source disconnected.

5.2. MAINTENANCE

The M7009R and M7009C require no regular maintenance.

5.3. TROUBLESHOOTING

If a malfunction occurs on start-up or during normal operation, refer to the problems described below. If a problem persists after following the steps below, contact Bonitron Tech Support, the product supplier or your system integrator for assistance.

Repairs or modifications to this equipment are to be performed by Bonitron approved personnel only. Any repair or modification to this equipment by personnel not approved by Bonitron will void any warranty remaining on this unit.

Table 5-1: Troubleshooting

DC Bus indicator will not illuminate	• Ensure that the 24V DC bus is securely connected to the "DC Bus" screw terminals and that the polarity of the connections is correct. If the unit will still not power up, the internal circuitry may need service. Consult Bonitron for service options.
Unit will not charge	• Ensure that the connected bus voltage is above 23.25V. If it is, try adjusting the voltage set-point using the "Voltage Adjust" trim-pot in the panel. If the unit will still not charge, the internal circuitry may need service. Consult Bonitron for service options.
Fuse indicator is active	• This indicates that a capacitor bank is now effectively disconnected from the regulator. Consult Bonitron for service options.
Fault activated during operation	• Remove any obstructions blocking the vents • Ensure that the ambient temperature is less than 40°C • Ensure that the DC bus voltage is lower than 27V • If the system continues to show a fault, consult Bonitron for service options.
Capacitor bank indicator not illuminating	• This indicates that the respective capacitor bank is not charging and the internal circuitry may need service. Consult Bonitron for service options.

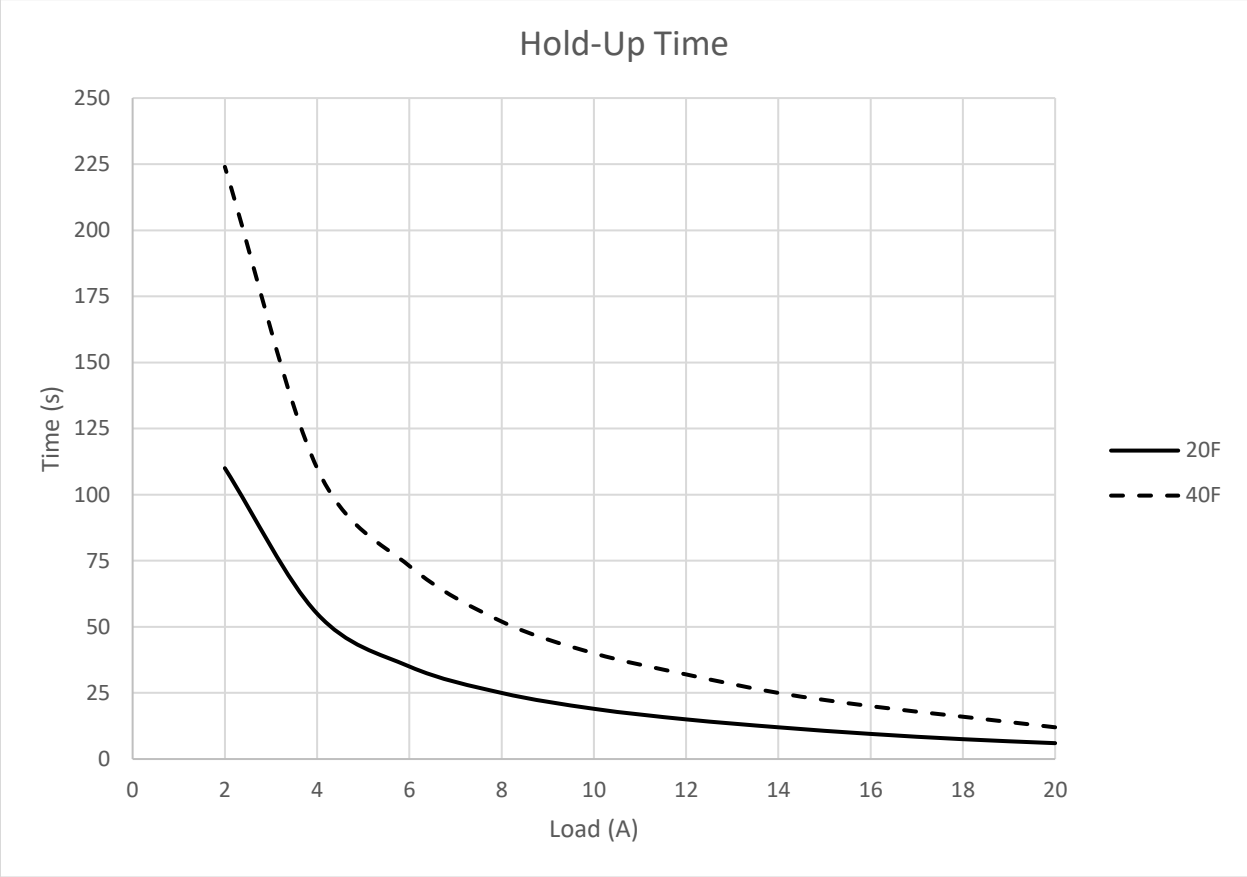
Hold-up time too short	• If using external capacitor banks, ensure that the connections to the buffer are tight and have the correct polarity. Verify that they fully charge • Verify that the load current is as expected and if not, reevaluate hold-up time • If the hold-up time remains shorter than expected, the internal circuitry may need service. Consult Bonitron for service options.

6. ENGINEERING DATA

6.1. OPERATION GRAPHS

Use the graph below to estimate hold-up time for your application and determine if additional storage capacitance is required. Alternatively, hold-up time can be calculated using the procedure given in the appendix.

Figure 6-1: Hold Up Time



6.2. RATINGS

Table 6-1: Ratings Chart

	Minimum	Nominal	Maximum	Unit
DC Bus Voltage	16	24	27	V
Hold-Up Voltage	23.25	23.5	23.75	V
Charging Current			1.5	A
Hold-Up Current			20	A
Charge Time*			360	s
Hold-Up Time*	4		1600	s
Internal Storage		20		F
Operating Temp	-20	25	40	°C

*Using only the internal storage capacitance

Table 6-2: M7009R Dimensions

Height	5.375 in.
Width	5 in.
Depth	5.75 in.

Table 6-3: M7009C Dimensions

Height	5.375 in.
Width	3.1 in.
Depth	5.75 in.

7. APPENDIX

7.1. CALCULATING HOLD-UP TIME

To calculate the hold-up time and determine if additional storage is required, the following calculations can be performed.

1) Calculate Load Power $P_L = I_L \times V_{DC}$
2) Calculate Stored Energy $E_o = \frac{1}{2} C \times V_{DC}^2$
3) Calculate Capacitor Cut-Out Voltage $V_{cf} = P_L \,/\, 30A$
4) Calculate Remaining Energy $E_f = \frac{1}{2} C \times V_{cf}^2$
5) Calculate Hold-Up Time $T_{hu} = \left(E_o - E_f\right) / P_L$

Or

$$T_{hu} = \frac{1}{2} \frac{C}{I_L V_{DC}} \left[V_{DC}^2 - \left(\frac{I_L V_{DC}}{30A} \right)^2 \right]$$

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