



Model M3628PUT Portable Ultracapacitor Tester

Customer Reference Manual

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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.

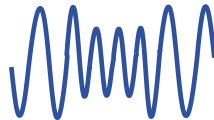
The Bonitron engineering team has the background and expertise necessary to design, develop, and manufacture the quality industrial electronic systems demanded in today's market. A strong academic background supported by continuing education is complemented by many years of hands-on field experience. 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.

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AC DRIVE OPTIONS

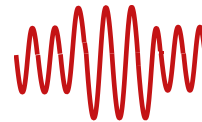
In 1975, Bonitron began working with AC inverter drive specialists at synthetic fiber plants to develop speed control systems that could be interfaced with their plant process computers. Ever since, Bonitron has developed AC drive options that solve application issues associated with modern AC variable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

WORLD CLASS PRODUCTS



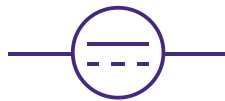
Undervoltage Solutions

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
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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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1. INTRODUCTION

1.1. WHO SHOULD USE

This manual is intended for use by trained personnel responsible for maintaining or testing Ultracapacitors.

Please keep this manual for future reference.

1.2. PURPOSE AND SCOPE

This manual is a user's guide for the Model M3628PUT. It will provide the user with the necessary information to successfully connect and operate the M3628PUT.

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

Rev 00 is the original printing of the M3628PUT manual.

The Example of the Part Number Breakdown was changed in Rev 00a.








Input Voltage options were added in Rev 01.

The manual template was updated in Rev01a.

Figure 1-1: M3628PUT



1.4. SYMBOL CONVENTIONS USED IN THIS MANUAL AND ON EQUIPMENT

	Earth Ground or Protective Earth
	AC Voltage
	DC Voltage
 <p>DANGER!</p>	Electrical Hazard - Identifies a statement that indicates a shock or electrocution hazard that must be avoided.
 <p>DANGER!</p>	DANGER: Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss.
 <p>CAUTION!</p>	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.
 <p>CAUTION!</p>	Heat or burn hazard - Identifies a statement regarding heat production or a burn hazard that should be avoided.

2. PRODUCT DESCRIPTION / FEATURES

The M3628PUT is designed for testing of ultracapacitors. As ultracapacitors age and wear, their capacitance decreases, and their ESR increases. This can result in decreased system performance, and ultimately, process failure. Measurement of an ultracapacitor's capacitance and ESR can help avoid expensive preemptive replacement.

The M3628PUT is a portable digitally-controlled capacitor tester. The digital interface allows the user to charge an attached ultracapacitor to a specified voltage, and then discharge the capacitor. After discharge is complete, the display will show the capacitance and ESR of the ultracapacitor.

2.1. RELATED PRODUCTS

M3528 ULTRACAPACITOR/ BATTERY CHARGER

The M3528 Charger can charge strings of batteries or ultracapacitors 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.

M3628 ULTRACAPACITOR DISCHARGE CONTROLLER

Large capacitor banks store huge amounts of energy, and can be a hazard when systems are shut down for system maintenance. The M3628 system discharges capacitor banks to safe working levels quickly, allowing work on the system to begin in seconds, rather than hours.

M3628PCF PORTABLE CAPACITOR FORMER

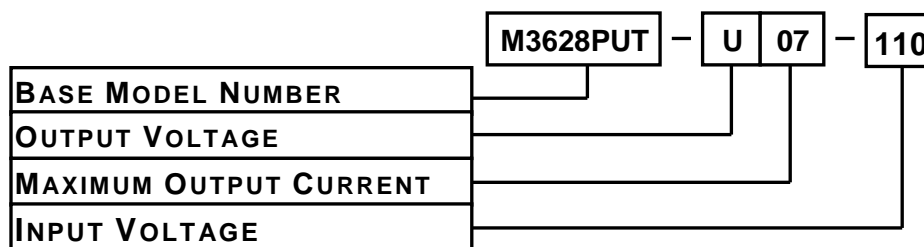
The M3628 Portable Capacitor Former can be used to charge or discharge capacitor banks as large as 50 kJ. The output voltage is manually variable between 0 and 900 VDC, and the system is capable of supplying 1 ADC continuously. The unit can be used for reforming disused capacitors.

M3628PCT PORTABLE CAPACITOR TESTER

The M3628 Portable Capacitor Tester can be used to charge, discharge and measure capacitor banks as large as 300 kJ. The output voltage can be set by digital control to between 0 and 800 VDC, and the system is capable of supplying 1 ADC up to 450 VDC. When discharging, the unit times the discharge and gives a capacitance value for capacitor banks between 2200 uF and 1F. The unit can also be used for automatic reforming of disused capacitors.

2.2. PART NUMBER BREAKDOWN

Figure 2-1: Example of Part Number Breakdown



BASE MODEL NUMBER

The Base Model Number for all Portable Ultracapacitor Testers is M3628PUT.

OUTPUT VOLTAGE RATING

The Maximum Output Voltage Rating indicates the DC output voltage the unit can supply. At present there is only a U model.

MAX OUTPUT CURRENT RATING

The Maximum Output Current rating indicates the maximum DC current the unit can supply at its maximum voltage.

INPUT VOLTAGE RATING

This indicates the input voltage for the unit.

2.3. GENERAL SPECIFICATIONS

Table 2-1: General Specifications Table

PARAMETER	SPECIFICATION
Input Voltage	110-120VAC, 220-240VAC, 1 \emptyset
Output Voltage	0-130VDC
Output Current	1-7ADC
Minimum Load Capacitance	1 Farad
Maximum Load Energy	500 kJ
Minimum Cycle Voltage	5V
Controls	Six display soft keys Abort button
Display	Four line, eighty character LCD (4x20)
Unit Size (H x W x D)	18.00" x 22.00" x 10.50"
Weight	50 lbs.
Storage Temp	-20°C to +65°C
Humidity	Below 90% non-condensing
Atmosphere	Free of corrosive gas and dust

2.4. GENERAL PRECAUTIONS AND SAFETY WARNINGS



**ELECTROCUTION
HAZARD!**

- THIS UNIT PRODUCES VOLTAGES 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!
- BEFORE CONNECTING THE M3628PUT TO A CAPACITOR BANK, ENSURE THAT THE BANK IS FULLY DISCHARGED BY CHECKING WITH A VOLTMETER.
- CONNECTING THE M3628PUT'S VOLTAGE OUTPUT TO A LOAD 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 BOTH THE SOURCE AND LOAD ARE POSITIVELY IDENTIFIED AND CORRECTLY CONNECTED BEFORE OPERATION.
- 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.
- 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.

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3. INSTALLATION INSTRUCTIONS

3.1. ENVIRONMENT

While closed, the M3628PUT is water, dust, and crush resistant. When open and in operation, the unit should be used only in dry, clean areas. Ensure that the interior of the unit casing is kept dry.

3.2. WIRING AND CUSTOMER CONNECTIONS

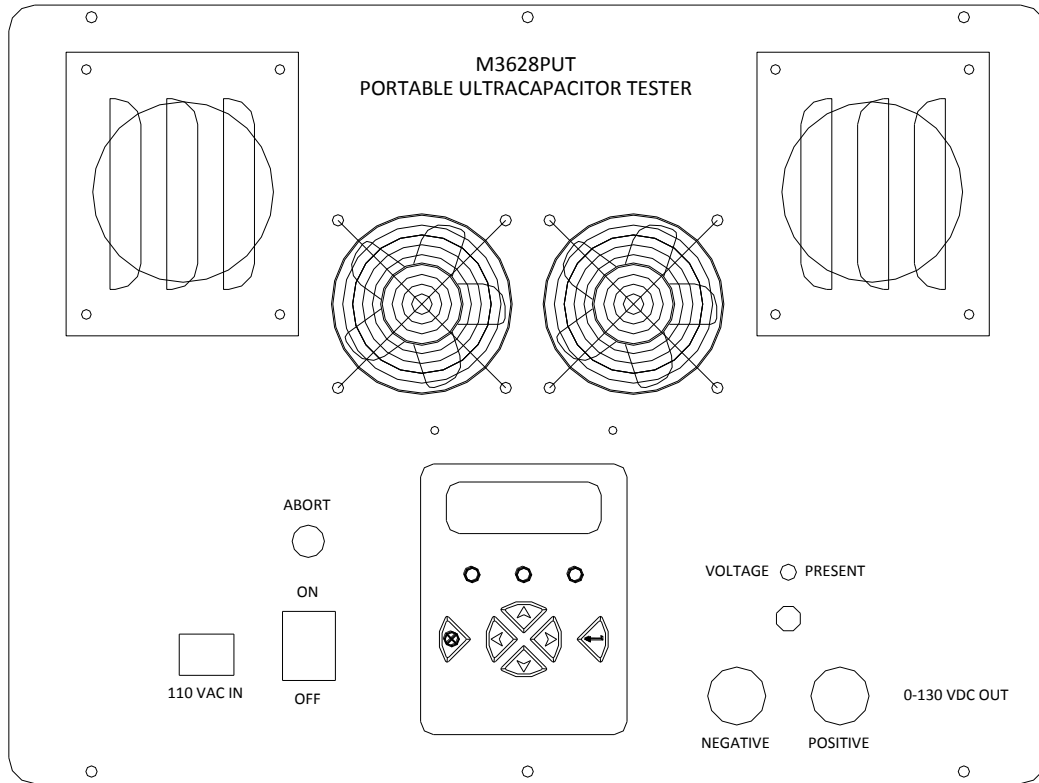
3.2.1. POWER WIRING

The Power Input connector accepts 50-60Hz AC from the included standard C13 power cable. The DC Output connectors supply DC voltage at the user-selected level via a pair of high-current connectors. Output leads can be constructed as needed. The unit should be powered ON before connecting to a load, as the unit is in discharge mode when powered off.



Attaching the unit to an AC input voltage other than that specified for your unit may cause improper operation or damage!

Figure 3-1: M3628PUT Faceplate



3.2.2. SOURCE CONSIDERATIONS

It is important to only connect this unit to a source that meets the specified voltage and current requirements.

The source must be capable of supplying 14A @110VAC or 7A @ 220VAC under normal operating conditions.

Failure to meet the minimum current requirement may result in improper operation.

Connecting the unit to an input voltage other than that specified on the unit faceplate may also result in improper operation or damage to the unit.

3.2.3. LOAD CONSIDERATIONS

To ensure the most accurate possible measurements, the capacitor under test should be charged to its full rated voltage. Note that the M3628PUT will discharge the attached load capacitor to 2VDC. This unit is thus not recommended for use on ultracapacitors rated at less than 5VDC.

Before charging or discharging an attached capacitor, ensure that the capacitor is capable of safely sourcing the current which will be drawn by the .6 ohm discharge resistor at the desired charge voltage. $I=V/R$.



Drawing current from a capacitor in excess of its maximum rated current can cause the capacitor to overheat and explode! Confirm the maximum current rating of the capacitor before charging or discharging.

4. OPERATION

4.1. FUNCTIONAL DESCRIPTION

The M3628PUT is a digitally controlled DC supply capable of sourcing between 1 and 7 amps at between 0 and 130VDC. The unit is powered by standard 50-60 Hz AC. The output voltage is controlled by the digital interface panel on the front of the unit. The unit is capable of safely charging and discharging connected capacitors. It is also capable of executing a pre-programmed charging profile, with defined step voltages and hold times. When a capacitor is discharged, the unit will calculate and display the capacitance and ESR of the capacitor. An *Abort* button is present in case of user error when selecting charge voltage. The unit automatically enters discharge mode when powered off.

4.2. FEATURES

4.2.1. AC POWER INPUT CONNECTOR

The M3628PUT is equipped with a standard IEC C14 connector for input power. This connector mates with a standard C13 cable, commonly used with desktop computers, to provide power to the unit.

4.2.2. DC OUTPUT CONNECTORS

Two high-current jacks provide the user with DC output voltage between 0 and 130VDC, and provide a discharge path for the current from the capacitor being tested. Cables are included, and can be constructed as desired.

4.2.3. DISPLAY

The digital display presents the user with information about the present status of the system, including the output voltage and current. The display also presents the user with options to control system operation, including charging and discharging attached capacitors.

4.2.4. INTERFACE BUTTONS

The function of each button depends on the active screen. For menu screens, *enter* selects a menu option, while *cancel* moves back to the previous screen. *Up* and *down* move the menu cursor. On screens where numbers are input by the user, the *left* and *right* buttons move the cursor, while the *up* and *down* buttons change the selected digit. *Enter* stores the present value, while *cancel* undoes any changes. On some screens, certain buttons may perform no function.

4.2.5. LEDs

Three LEDs indicate the present status of the PUT. Red indicates a fault condition. Yellow indicates that the unit is presently charging or discharging. Green indicates that the unit has power.

4.2.6. ABORT BUTTON

There is a red Abort button on the face of the unit. This button will cause the system to immediately switch to discharge mode, regardless of the

present system activity. In the event the unit is accidentally set to charge to a higher voltage than is safe for one load, this button should be pressed immediately.

4.2.7. VOLTAGE PRESENT INDICATOR



Do not use this light as an indication that the output is safe to work on! Always check the output with a working voltmeter before servicing equipment, as the lamp may be malfunctioning!

ELECTROCUTION HAZARD! *This unit produces dangerous levels of voltage that can cause injury or death. Always follow safety protocols when working with high voltages!*

A red light indicates that there is an unsafe voltage on the DC output of the unit. Do not touch the output connectors or the attached equipment while this light is on, as electric shock will result.

4.2.8. FUSE

This fuse is in the charging output of the PUT. If the fuse fails, power down the unit, and replace it with the same fuse. (see Section 5) Do not replace the fuse while the system is live!

4.2.9. POWER SWITCH / CIRCUIT BREAKER

The Power Switch also acts as a circuit breaker to protect from overload conditions. If the breaker is tripped, you can reset it by simply turning the switch back on.

NOTE: When switched OFF, the unit is in Discharge mode.

4.3. SCREENS & MENU NAVIGATION

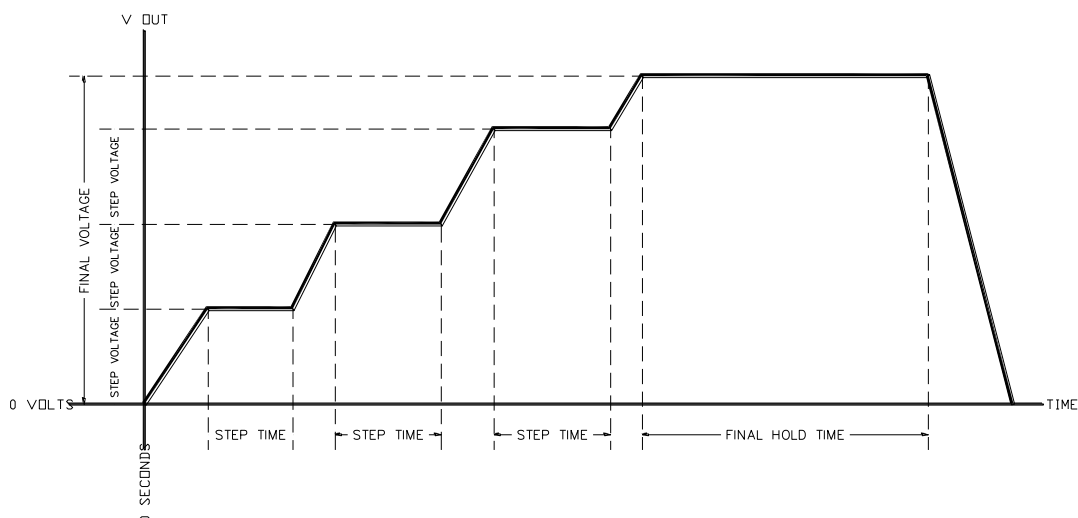
Many screens are menus allowing access to other screens, or lists presenting a number of options. The presently selected item on the menu is indicated by a '>' character. This selection indicator is moved using the *up* and *down* buttons. If a line on the menu represents another screen, that screen may be accessed with the *enter* key. The *cancel* button will typically return the display to the parent screen.

4.3.1. MAIN MENU

The Charging Profile, Single Charge, Discharge, and Previous Results screens may be accessed from the Main Menu.

4.3.1.1. CHARGING PROFILE

From this selection, the user may input the variables necessary to execute an automatic Charging Profile. A charging profile charges the capacitor in steps, each step a specified voltage apart. When each step voltage is reached, the load is held at that voltage for a specified number of seconds before charging to the next step voltage. When the final voltage is reached, the load is held at that voltage for a specified number of seconds before discharging. See Figure 4-2.

Figure 4-1: M3628PUT Charging Profile**4.3.1.1.1. SET PROFILE FINAL VOLTAGE**

From this screen the user may set the final charge voltage. The *right* and *left* buttons control which digit is being edited, and the *up* and *down* buttons increment or decrement that digit. Enter will save changes. Cancel will abort changes.

4.3.1.1.2. SET PROFILE STEP VOLTAGE

From this screen the user may set the voltage step by which the load will approach the final voltage. The *right* and *left* buttons control which digit is being edited, and the *up* and *down* buttons increment or decrement that digit. Enter will save changes. Cancel will abort changes.

4.3.1.1.3. SET PROFILE CURRENT

From this screen the user may set the maximum charge current. The *right* and *left* buttons control which digit is being edited, and the *up* and *down* buttons increment or decrement that digit. Enter will save changes. Cancel will abort changes.

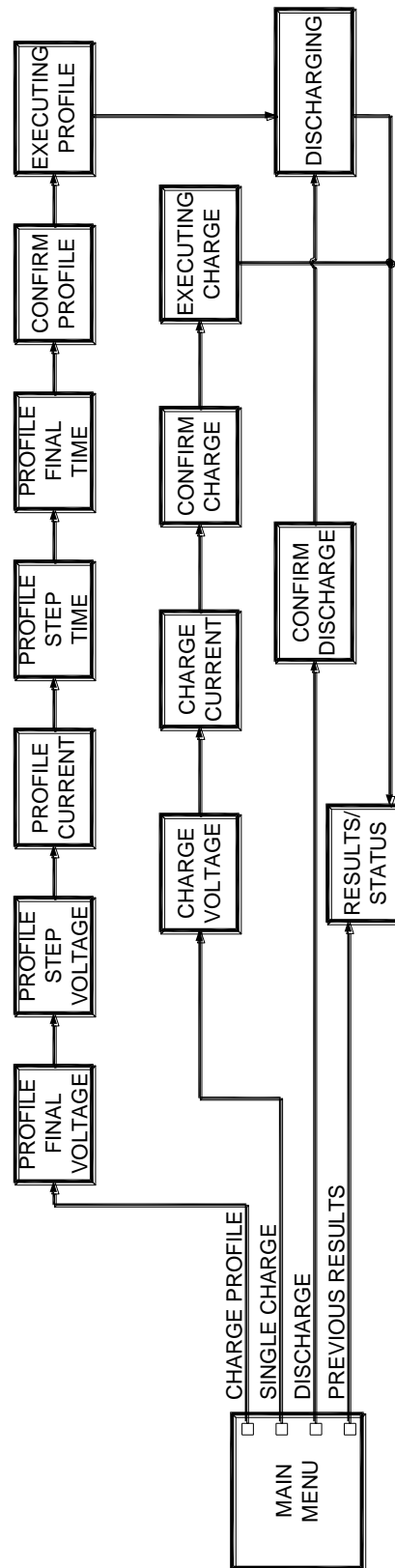
4.3.1.1.4. SET PROFILE STEP HOLD TIME

From this screen the user may set the number of seconds each step voltage will be held. The *right* and *left* buttons control which digit is being edited, and the *up* and *down* buttons increment or decrement that digit. Enter will save changes. Cancel will abort changes.

4.3.1.1.5. SET PROFILE FINAL HOLD TIME

From this screen the user may set the number of seconds the final voltage will be held. The *right* and *left* buttons control which digit is being edited, and the *up* and *down* buttons increment or decrement that digit. Enter will save changes. Cancel will abort changes.

Figure 4-2: M3628PUT Interface Screen Tree



4.3.1.1.6. CHARGE PROFILE CONFIRM

At this screen the user is asked to confirm the Profile settings. Enter will start charging. Cancel will abort charging.

4.3.1.1.7. EXECUTING PROFILE

This screen displays the present output voltage and current and seconds left for each step. It transitions to the "Discharging" screen (4.3.1.2.6.) when the output voltage reaches the set point and is held for the specified number of seconds. Charging may be aborted by pressing cancel. This will not initiate discharging; if charging is aborted via the cancel button, the load will remain at voltage until discharging is manually initiated or the unit is turned off.

4.3.1.2. SINGLE CHARGE MENU

The user may set the charge voltage and current, and initiate charging from here.

4.3.1.2.1. SET CHARGE VOLTAGE

From this screen the user may set the charge voltage. The *right* and *left* buttons control which digit is being edited, and the *up* and *down* buttons increment or decrement that digit. Enter will save changes. Cancel will abort changes.

4.3.1.2.2. SET CHARGE CURRENT

From this screen the user may set the maximum charge current. The *right* and *left* buttons control which digit is being edited, and the *up* and *down* buttons increment or decrement that digit. Enter will save changes. Cancel will abort changes.

4.3.1.2.3. CHARGE CONFIRM

At this screen, the user is asked to confirm the charge voltage and current. Enter will start charging. Cancel will abort charging.

4.3.1.2.4. CHARGING

This screen displays the present output voltage and current. It transitions to the Results screen (4.3.1.2.7) when the output voltage reaches the set point. Charging may be aborted by pressing any of the four directional buttons. This does not initiate discharging. Caps will remain at voltage until discharging is manually initiated or the unit is turned off.

4.3.1.3. DISCHARGE CONFIRM

At this screen the user is asked to confirm their intent to discharge the capacitor bank. If the user confirms, the capacitor starts discharging, until the load voltage reaches 2VDC. The time the capacitor takes to discharge is measured, and from this value the load capacitance is calculated.

4.3.1.4. DISCHARGING

This screen displays the present output voltage and discharge current. It transitions to the "Results" screen when the output voltage reaches 2VDC.

4.3.1.5. RESULTS

This screen presents the user with the present output voltage and the results of the previous capacitor discharge and measurement, including capacitance and ESR. The system transitions to this screen after a period of inactivity.

4.4. FAULTS

If a fault condition occurs, the red LED will illuminate, and the display will indicate the nature of the fault. Once a fault state has cleared, the red LED will turn off; and the description of the fault will remain. Press the *cancel* button to return to the main menu.

4.4.1. OVERTEMP

This fault indicates that the unit has exceeded its safe operating temperature range. Leave the unit connected to power and load, and allow the unit to cool. The fault should clear within 60 minutes.

4.4.2. COMMUNICATION LOSS

This fault indicates that a serial connection has been lost within the M3628PUT. This is not user-serviceable. Contact Bonitron for service options (Section 5.3).

4.4.3. REVERSE BIAS

This fault indicates that the voltage on the output terminals of the M3628PUT is of the incorrect polarity; the negative terminal is higher than the positive terminal. Check the polarity of the leads attached to the ultracapacitor under test.

4.4.4. FUSE LOSS

This fault indicates that the fuse in the charging link of the M3628PUT has failed. Power down the unit and replace the fuse with one of comparable specifications (Section 5.1).

4.4.5. RELAY FAILURE

This fault indicates that the relay driving the output of the M3628PUT is open. If the fault will not clear, your unit is damaged. Contact Bonitron for service options (Section 5.3).

4.4.6. SHORT IGBT

This fault indicates that the discharge control transistor has shorted. If this fault will not clear, your unit is damaged. Contact Bonitron for service options (Section 5.3).

5. MAINTENANCE AND TROUBLESHOOTING

5.1. MAINTENANCE ITEMS

The fuse on the front panel of the unit must be rated to break the short circuit DC current of the attached ultracapacitor. Recommended replacements are Littelfuse 505 series or equivalent, 20ADC.

5.2. TROUBLESHOOTING

If a problem occurs on start-up or during normal operation, refer to the problems described below. If a problem persists after following the steps below, contact 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

Output fuse failed	<ul style="list-style-type: none"> • Power down the unit and wait for the load to discharge. • Replace the fuse with another of the same current rating.
Display never comes on	<ul style="list-style-type: none"> • Ensure that the input power cable is connected firmly to the unit and to a functioning power source of appropriate voltage. • If both connections and the power supply are good, make sure the input circuit breaker has not tripped.
Output voltage never rises above zero while charging	<ul style="list-style-type: none"> • Check the connections between the unit and the load, making sure that the connection is solid and that the polarity is correct. • Check the fuse on the faceplate of the unit. • Check the output voltage with a separate voltage meter; if voltage is present, the internal circuitry may need service. Consult Bonitron for service options.
Display shows no output current while charging	<ul style="list-style-type: none"> • Check the output connections to make sure there is good contact. • Make sure there is voltage at the output terminals and on the load.
Load capacitor takes a long time to charge/discharge	<ul style="list-style-type: none"> • Make sure the charging current is not set to a very low value. • Check the connections between the unit and the load, making sure that the connection is solid and that the polarity is correct. • Large loads may take a long time to charge or discharge such as a load in excess of 500 Farads. • Excessively leaky loads may not be able to reach the full 130V range.
Red voltage present light is ON	<ul style="list-style-type: none"> • The voltage present light indicates that there is voltage between the output terminals of the unit. If the display indicates that no voltage is present, contact Bonitron.
Red voltage present light never turns on regardless of output voltage	<ul style="list-style-type: none"> • Check the output voltage with a separate voltmeter. If the voltage is above 50VDC, your unit may require service. Contact Bonitron.



Always monitor the output voltage while operating the unit. Ensure that the attached loads do not exceed their rated voltage, as catastrophic damage, injury, or death may occur.

5.3. TECHNICAL HELP

If technical help is required, please have the following information available when contacting Bonitron (615-244-2825 or email:info@bonitron.com):

- Model number of unit
- Serial number of unit
- Name of original equipment supplier (if available)
- Brief description of the application
- Nameplate information of capacitor under test
- AC line voltage

6. ENGINEERING DATA

6.1. RATINGS CHART

Table 6-1: Ratings Chart

Input Voltage	110-120VAC
Output Voltage	0-130VDC
Output Current	0-7.0A
Discharge Resistor	.6 Ohm

6.2. DIMENSIONAL DRAWING

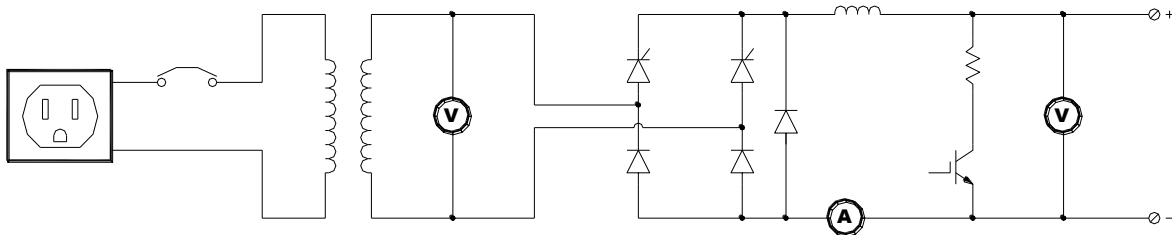
Figure 6-1: M3628PUT Dimensions



Note: Handle is not included in dimensions and retracts flush with the unit when not needed.

6.3. BLOCK DIAGRAM

Figure 6-2: Block Diagram



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7. APPENDIX

7.1. APPLICATION NOTES

7.1.1. TYPICAL CAPACITOR BANK FORMING / TESTING PROCEDURE

Capacitors may undergo physical changes when stored for long periods. Depending on the ambient conditions of the storage, this can be from six months to two years. If the capacitors are rapidly taken to their rated voltage, excessive leakage current may cause them to overheat and fail.

Capacitors also undergo physical and chemical changes after long periods of use. If wear continues, these capacitors can fail, potentially causing catastrophic damage. Capacitor lifetime is heavily dependent on use and ambient conditions, and thus impossible to predict. Periodically measuring the capacitance of a bank can help quantify the wear on and remaining lifetime of the capacitors, helping avoid catastrophic failure without periodically replacing the entire bank.

If the capacitor bank is part of a larger system, as a Variable Frequency Drive, check with the drive manufacturer for specific instructions on how to reform the capacitor bank.

A short description is below.

1. Ensure the capacitor bank is fully discharged and floated.
2. Apply power to the M3628PUT.
3. Attach the output leads to the capacitor bank directly. If you are forming the capacitors in a drive, ensure that you are directly across the DC bus, not attached through the braking circuit.
4. Select "Charging Profile" from the main menu.
5. Set the final voltage to the rated voltage of the capacitor bank.
6. Set the step voltage to approximately 10% of the rated voltage of the capacitor.
7. Set the charging current to its maximum setting, unless counter-indicated by the capacitor manufacturer.
8. Set the step hold time to at least 600 seconds.
9. Set the final hold time to at least 900 seconds, or consult the equipment manufacturer for a suitable reforming time.
10. Begin charging the capacitor, listening for abnormal sounds or other indications in the capacitors or attached equipment. Monitor the current indicator to make sure there is not excessive leakage current, and the voltage indicator to see that the voltage is rising. Continually monitor the capacitor banks or attached equipment for abnormal signs, such as noise, heating, or smell. Internal bleeder resistors on the capacitor bank may require current during the process. Consult the equipment manufacturer for more information.

IF AT ANY TIME ABNORMAL SIGNS ARE DETECTED, OR THE LOAD CAPACITORS ARE OVERVOLTAGED, PRESS AND HOLD THE IMMEDIATE DISCHARGE BUTTON TO END THE PROCEDURE.

11. After the final hold time, the unit will discharge the load and calculate its capacitance. Wait until discharging is complete before dis-

connecting the load. Record the calculated capacitance and ESR somewhere safe, along with the designation of the capacitor being tested. Multiple tests may be performed if desired, to ensure repeatability.

12. Once the procedure is completed successfully, the capacitor bank or equipment can be returned to storage or put into use, as appropriate. If the storage bank is put into storage, a ground strap should be placed across the + and – of the ultracapacitor.
13. If the bank is put into service, test the capacitor bank periodically, on a schedule recommended by the capacitor manufacturer. Ensure that all tests are performed in a similar ambient temperature, otherwise comparison between results may not be valid. If, over time, the bank capacitance falls below the manufacturer-recommended percentage of the original recorded capacitance, discard and replace the capacitor.

NOTES



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