BONITRON

Solutions for AC Drives

Model M3452

Heavy Duty Braking Transistor with EtherNet / IP® or PROFIBUS®DP Communications

K6, K9, K10, M14, T10 Chassis R8EIP, R8PDP Options

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

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 AC drive system.

Please keep this manual for future reference.

1.2. PURPOSE AND SCOPE

This manual is a user's guide for the Model M3452 dynamic braking transistor module. It will provide the user with the necessary information to successfully install, integrate, and use the M3452 dynamic braking transistor Module in a variable frequency AC drive system.

In the event of any conflict between this document and any publication and/or documentation related to the AC drive system, the latter shall have precedence.

1.3. MANUAL VERSION AND CHANGE RECORD

Application notes and indicator information were updated in Rev 01h.

Dimensional outlines and connection drawings were updated in Rev 02.

Link Length limits were updated in Rev 02a.

A correction was made in the Node Address Switches section in Rev 02b.

The T10 Chassis was added in Rev 02c.

Figure 3-5 was updated in Rev 02d.

Manual template was updated in Rev 02e.

Figure 6-5 was updated in Rev 02f.

Update to Section 4.2.6.1.4 in Rev 02g.

Update to Section 3.4 was made in Rev 02h.

Added Altitude to table 2-6 in Rev 02i.

Updated Table 3-1 in Rev 02j.

Figure 1-1: Typical M3452 – R8

K9 CHASSIS

M14 CHASSIS

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 M3452 heavy duty braking transistors are used with AC drives to allow full power braking and eliminate overvoltage faults. This permits controlled braking and dramatically shortens motor stopping time.

The M3452 works with variable frequency drives (with DC bus connections) to monitor the DC bus. If overvoltage occurs, the M3452 shunts the excess energy through an external braking resistor to prevent overvoltage faults.

During motor braking or deceleration, the frequency of an AC motor is higher than the connected variable frequency drive. In this case, the motor acts as a generator. This power returns to the DC bus of the drive, causing the voltage to rise. If this energy is not controlled, the motor may run with high peak voltages, the energy may be dissipated as heat in the motor, or the drive may trip on an over-voltage condition.

The R8 option allows for braking kit monitoring and control over a remote I/O network or with discrete I/O. Extensive fault monitoring and chopper operation can be controlled over the network, and critical functions can be controlled or monitored discretely. Master/Slave operation can be changed on the fly for multiple-module systems to allow for redundancy in the power sections for critical applications or quick reconfiguration. Remote temperature monitoring can be used to allow for maximum production. Remote discharge can also be used to bring the DC bus of a system down during shutdowns for quick maintenance. Remote setpoint adjustment can be used to tailor braking thresholds for energy efficiency and process control. Other parameters can also be monitored, including bus voltage and duty cycle, along with a history of faults.

2.1. RELATED PRODUCTS

The M3452 series is one of several overvoltage solutions offered by Bonitron. Below are a few related products, including braking resistors that are used in conjunction with the M3452 series.

BRAKING TRANSISTORS

- Like the M3452 heavy duty braking transistors, Bonitron M3575T and M3675T standard duty braking transistors work with variable frequency drives (with DC bus connections) to monitor the DC bus. If overvoltage occurs, the M3575T or M3675T shunts the excess energy through an external braking resistor to prevent overvoltage faults. The M3575T series is rated up to 600A peak / 20% duty, while the M3675T series is rated up to 10A peak / 20% duty.

BRAKING RESISTORS

- Bonitron offers resistor solutions to complement its braking transistor selection. The M3575R series is rated up to 32 A peak / 20% duty, while the M3775R series is rated up to 1600 A / 100% duty. Custom resistors are also available.

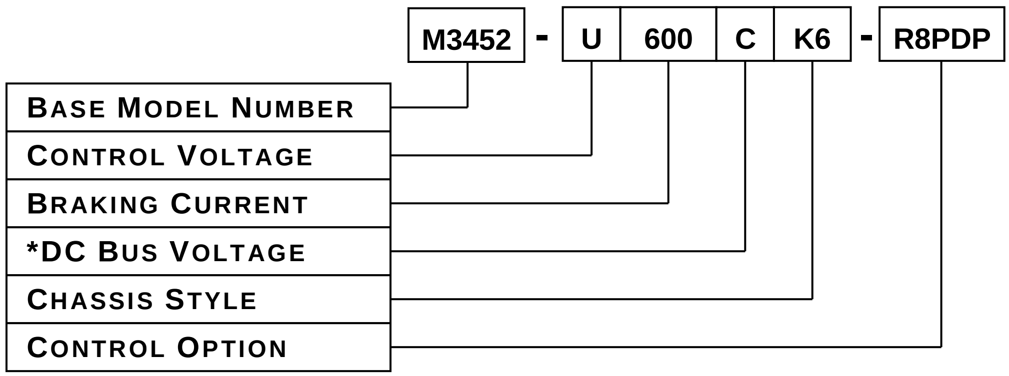
LINE REGENERATION

- Bonitron is famous for its industry-leading line regeneration solutions. The Bonitron M3645 line regen returns regenerative energy back onto the AC line instead of dissipating the energy as heat in a resistor, and is ideal for applications with high duty cycles, frequent deceleration, or where heat from a resistor may be an issue. The M3645 line regen features an interactive digital display with event logging.

Please contact your AC drive distributor or visit our website at www.bonitron.com for more information on these additional products.

2.2. Part Number Breakdown

Figure 2-1: M3452 Part Number Breakdown



Base Model Number

The base model number for all dynamic braking transistor modules is **M3452**.

Control Voltage Rating

The control voltage rating indicates the control voltage to the unit. This can be the drive system AC line voltage or a different input voltage. This is indicated by a code letter.

Note: Not all system voltages are available as control voltages.

Table 2-1: Control Voltage Rating

Control Voltage Rating Code	Voltages
U	115 - 120VAC
L	230 - 240VAC
E	380 - 415VAC
H	460 - 480VAC
C	575 - 600VAC

Braking Current Rating

The braking current rating indicates the maximum current level that can safely be handled by the M3452 dynamic braking transistor module.

The braking current rating is indicated by a 3 or 4-digit number. For example, **300** indicates a braking current rating of 300 Amps maximum.

Table 2-2: Available Braking Current Ratings

Available Current Ratings (ADC)
200, 300, 600, 800, 1200, 1600

*DC BUS VOLTAGE

*This code is used **only** if different from the control voltage rating.*

Omit this position if control voltage is the same as nominal AC line voltage.

The DC bus voltage indicates the voltage regulation level of the DC bus if the control voltage input does not correspond to the actual drive bus being controlled.

The DC bus voltage uses the codes L, E, H, C, and Y as shown in Table 2-3.

Table 2-3: DC Bus Voltage Rating

VOLTAGE RATING CODE	VOLTAGES (NOMINAL AC LINE / DC BUS TRIGGER LEVEL)
L	230 – 240 VAC Line / 375 VDC
E	380 – 415 VAC Line / 620 VDC
H	460 – 480 VAC Line / 750 VDC
C	575 – 600 VAC Line / 940 VDC
Y	690 VAC Line / 1090 VDC"
Nxxxx	Special (xxxx VDC)

Nxxxx is used only for custom trigger levels. Contact Bonitron before specifying Nxxxx.

CHASSIS

The chassis code represents the chassis type and size of the dynamic braking transistor module.

Table 2-4: Chassis Codes

CHASSIS CODE	CURRENT (AMPS)	TYPE	DIMENSIONS (H" x W" x D")
K6	200-600	Open Chassis	20.00 x 7.12 x 10.50
K9	800	Open Chassis	20.00 x 9.05 x 10.25
K10	1200	Open Chassis	20.00 x 10.00 x 10.50
M14	1600	Open Chassis	28.00 x 13.90 x 14.60
T10	1600	Open Chassis	30.60 x 10.12 x 19.20

CONTROL AND NETWORK OPTION

This code indicates the network protocol selected. See Table 2-5 below for a list of available R8 options. Please contact Bonitron if you have any other special requirements.

Table 2-5: Control Option Codes

CONTROL OPTION CODE	DESCRIPTION
R8PDP	R8 unit with PROFIBUS comm module
R8EIP	R8 unit with EtherNet/IP comm module

2.3. General Specifications

Table 2-6: General Specifications

PARAMETER	SPECIFICATION	
DC Bus Voltage	325 – 1090 VDC	
DC Braking Current	200 – 1600 ADC	
Control Voltage	Single Phase, 115, 230, 380, 460, 575 VAC ±10% 50/60 Hz 70 VA	
Indicators	DC Bus Control Power Active Braking	
Network I/O	Inputs	Outputs
	Enable DC Bus Discharge Fault Reset Master/Slave Select Setpoint Adjust	Heat Sink Temperature Bus Voltage Fault State Master/Slave Status Fault Records
Logic I/O	Inputs – 24V	Outputs – Max 140 VAC / 200 VDC at 100mA
	Enable Fault Reset DC Bus Discharge	Ready Status
Control I/O	Sharing Control Signal	
Operating Temp	0° to 40°C	
Storage Temp	-20° to 65°C	
Humidity	Below 90%, non-condensing	
Atmosphere	Free of corrosive gas or conductive dust	
Altitude	• Up to 1000 Meters (3000 feet) above sea level*	

*Units must be derated by 2% for every 300 meters (1000 feet) above 1000 meters (3000 feet) sea level.

2.4. GENERAL PRECAUTIONS AND SAFETY WARNINGS

DANGER!

- HIGH VOLTAGES MAY BE PRESENT!
- NEVER ATTEMPT TO SERVICE THIS PRODUCT WITHOUT FIRST DISCONNECTING FROM THE INCOMING AC POWER AND DC BUS.
- ALWAYS ALLOW ADEQUATE TIME FOR RESIDUAL VOLTAGES TO DRAIN BEFORE ATTEMPTING SERVICE.
- BEFORE ATTEMPTING INSTALLATION OR REMOVAL OF THIS PRODUCT, BE SURE TO REVIEW ALL AC DRIVE DOCUMENTATION FOR RELATED SAFETY PRECAUTIONS.
- INSTALLATION AND/OR REMOVAL OF THIS PRODUCT SHOULD ONLY BE DONE BY A QUALIFIED ELECTRICIAN IN ACCORDANCE WITH NATIONAL ELECTRICAL CODE OR EQUIVALENT REGULATIONS.
- **FAILURE TO HEED THESE WARNINGS MAY RESULT IN SERIOUS BODILY INJURY OR DEATH.**

CAUTION!

- THIS PRODUCT WILL GENERATE HEAT DURING OPERATION.
- THIS PRODUCT SHOULD BE INSTALLED ACCORDINGLY ON NON-FLAMMABLE SURFACES WITH CLEARANCES OF AT LEAST TWO INCHES IN ALL DIRECTIONS.
- ALWAYS ALLOW AMPLE TIME FOR THE UNIT TO COOL BEFORE ATTEMPTING SERVICE ON THIS PRODUCT.
- ALWAYS BE SURE THE BRAKING CAPACITY OF THE CHOPPER AND LOAD BANK DOES NOT EXCEED THE CAPACITY OF THE CONNECTED DRIVE!
- REVIEW THE APPLICATION NOTE IN SECTION 7 OF THIS MANUAL FOR INFORMATION ABUT COMMON DC BUS SYSTEMS.

<u>Important Notice about Drives with DC Link Chokes!</u>

- DURING BRAKING SITUATIONS, ENERGY STORED IN A DRIVE'S DC LINK CHOKES CAN CREATE EXTREME OVER-VOLTAGE CONDITIONS FOR DYNAMIC BRAKING CONTROL MODULES. TO AVOID THESE CONDITIONS, DC CONNECTIONS FROM RESISTIVE BRAKING CONTROL MODULES TO THE DRIVE SYSTEM MUST ALWAYS BE MADE DIRECTLY IN PARALLEL WITH THE DRIVE'S FILTER CAPACITORS. THESE MODULES SHOULD NEVER BE CONNECTED IN SERIES WITH A DRIVE'S DC LINK CHOKES.
- BE SURE TO REVIEW THE RELEVENT AC DRIVE DOCUMENTATION TO ENSURE THAT THE PROPER CONNECTIONS ARE USED.
- CONTACT THE DRIVE MANUFACTURER OR EQUIPMENT SUPPLIER FOR ASSISTANCE WITH DRIVE CONNECTIONS.

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

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3. INSTALLATION INSTRUCTIONS

DANGER!

Installation and/or removal of this product should only be performed by a qualified electrician in accordance with National Electrical Code or local codes and regulations.

Proper installation of the model M3452 dynamic brake module should be done following the steps outlined below. Be sure to refer to all other relevant system documentation as these steps are performed. Please direct all installation inquiries that may arise during the installation and start-up of this product to the equipment supplier or system integrator.

3.1. PRODUCT INSPECTION

Upon receipt of this product, please verify that the product received matches the product that was ordered and that there is no 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.

3.2. SITE SELECTION

The installation site for the module should be chosen with several considerations in mind:

- All units require adequate protection from the elements.
- Adequate clearance should be allowed for easy access to terminals and adjustments. This will facilitate inspection and maintenance.
- Sufficient circulation of clean, dry air should be provided. Ambient temperatures should not exceed +40°C (+104°F) nor be less than 0°C (+32°F) and non-condensing. Ambient air should not be contaminated with harmful chemical vapors or excessive dust, dirt, or moisture.
- The unit will require a minimum clearance of six (6) inches above and below it to allow for proper airflow for cooling. Avoid mounting the unit with its air intake near heat sources.

3.3. MOUNTING

Once the installation site has been selected as outlined above, and the mounting holes drilled and mounting studs or anchors installed, the dynamic brake module is ready to be hung in position. Be sure all mounting hardware is tightened securely.

Refer to Section 6.4 of this manual to determine the correct mounting dimensions and provisions for the unit.

3.4. WIRING AND CUSTOMER CONNECTIONS

3.4.1. POWER WIRING

DANGER!

Only qualified electricians should perform and maintain the interconnection wiring of this product. All wiring should be done in accordance with local codes.

Wire size should be selected in accordance with local codes, according to the current rating of the braking transistor. Use copper conductors rated 75°C. In general, the wire type should be selected by the nominal system AC voltage and the continuous current rating of the module.

Table 3-1: Power Wiring Specifications

CHASSIS	TERMINAL	CONNECTION	TORQUE
K6	DC+, DC-, RES+, RES-	3/8” stud	192 lb-in
K9	DC+, DC-, RES+, RES-	1/2" stud	300 lb-in
K10	DC+, DC-, RES+, RES-	1/2" stud	300 lb-in
M14	DC+, DC-, RES+, RES-	Bus Bar	N/A
T10	DC+, DC-, RES+, RES-	Bus Bar	N/A

3.4.1.1. DC BUS CONNECTION

As a general rule of thumb, 30 feet (10m) is the maximum total buswork or cable that the chopper should be mounted from the drive. This means that the actual installation distance should be 15 feet (5m), as the cable must go out and back. If you must connect the choppers farther away, see Section 6.6.

The braking transistor must be connected directly to the DC bus filter capacitors of the drive.

Figure 3-10 is an example of the terminals that may be available in your installation. Not all of the terminals may be on your drive. Refer to the drive manufacturer's manual or technical documents to locate the proper terminals. Your drive will have different terminal markings depending on manufacturer and drive series.

Ensure that the polarity of the connection is correct. Incorrect polarity will effectively short the DC bus of the drive, and can cause severe damage to the drive, load resistor, and the Bonitron braking transistor.

The proper terminals to attach the braking transistor are marked + and - on Figure 3-10.

The terminals marked BR+ and BR- are intended for the internal braking transistor. If the Bonitron external braking transistor is hooked to the terminals, the braking transistor will not operate properly. In some cases, it may cause drive failure.

The terminals marked X and Y are intended for connection of a DC link choke. If the Bonitron braking transistor is connected to the terminals marked "X" and "-" in Figure 3-10, switching resonances caused by the DC link choke will destroy the braking transistor. If the Bonitron braking transistor is connected between X and Y, the drive will not operate.

If the braking transistor is connected to the terminals marked "A" and "B" in Figure 3-10, switching resonances caused by the lack of filter capacitance during precharge will destroy the braking transistor.

3.4.1.2. Resistor Connection

The polarity of the resistor connections is not important; however, it is critical that the resistor be connected to the proper terminals. Improper hookup can lead to the resistor being connected directly across the DC bus, which will cause severe overheating and drive stress.

3.4.1.3. Grounding Requirements

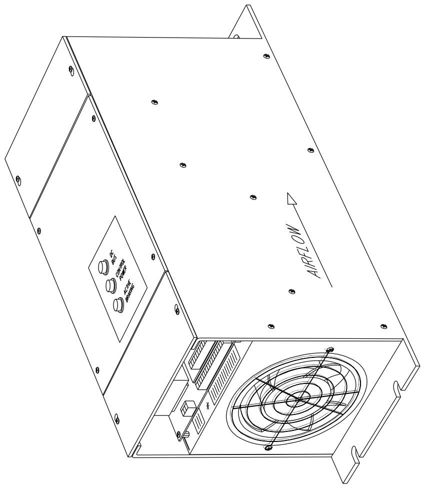
All units come equipped with either a ground terminal or ground stud that is connected to the module chassis. Ground the chassis in accordance with local codes. Typically, the wire gauge will be the same as is used to ground the attached drive.

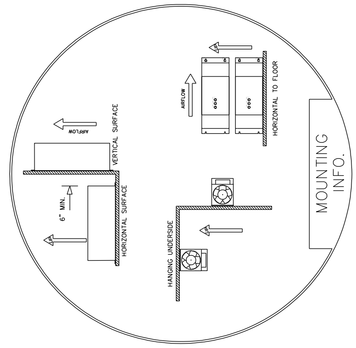
3.4.2. I/O Wiring

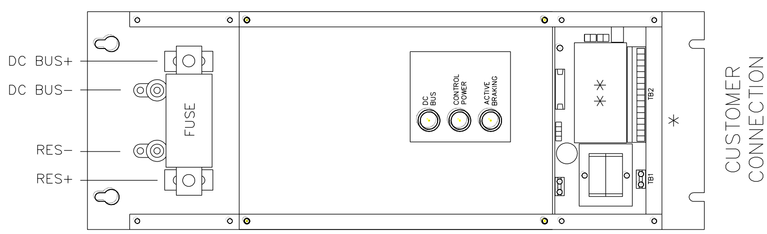
Table 3-2: I/O Terminal Block Specifications: R8 Control Board

Terminal	Function	Electrical Specifications	Min Wire AWG	Max Wire AWG	Torque
TB1-1	Control Voltage L1	120 VAC – 0.6 A 230 VAC – 0.3 A 460 VAC – 0.16 A 575 V – 0.15 A	16	10	4.5 lb-in
TB1-2	Control Voltage L2	120 VAC – 0.6 A 230 VAC – 0.3 A 460 VAC – 0.16 A 575 VAC – 0.15 A	16	10	4.5 lb-in
TB2-1	V+ Input Supply	Max 50mA 24V supply for inputs	18	12	4.5 lb-in
TB2-2	Enable Input	24 V, 10 mA	18	12	4.5 lb-in
TB2-3	Discharge Bus Input	24 V, 10 mA	18	12	4.5 lb-in
TB2-4	Reset	24 V, 10 mA	18	12	4.5 lb-in
TB2-5	Input Common Return	Max 100 mA, 24 VDC	18	12	4.5 lb-in
TB2-6&7	Status Output	110 VAC, 100 mA Max	18	12	4.5 lb-in
TB3-1&2	Master/Slave control signal	<50 VDC, 500 mA	18	12	4.5 lb-in

Figure 3-1: Customer Connections in K6 Chassis







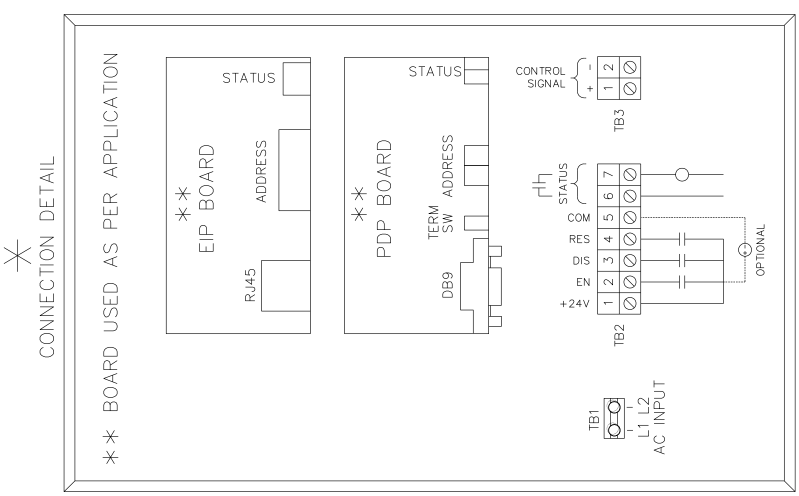


Figure 3-2: Customer Connections in K9 Chassis

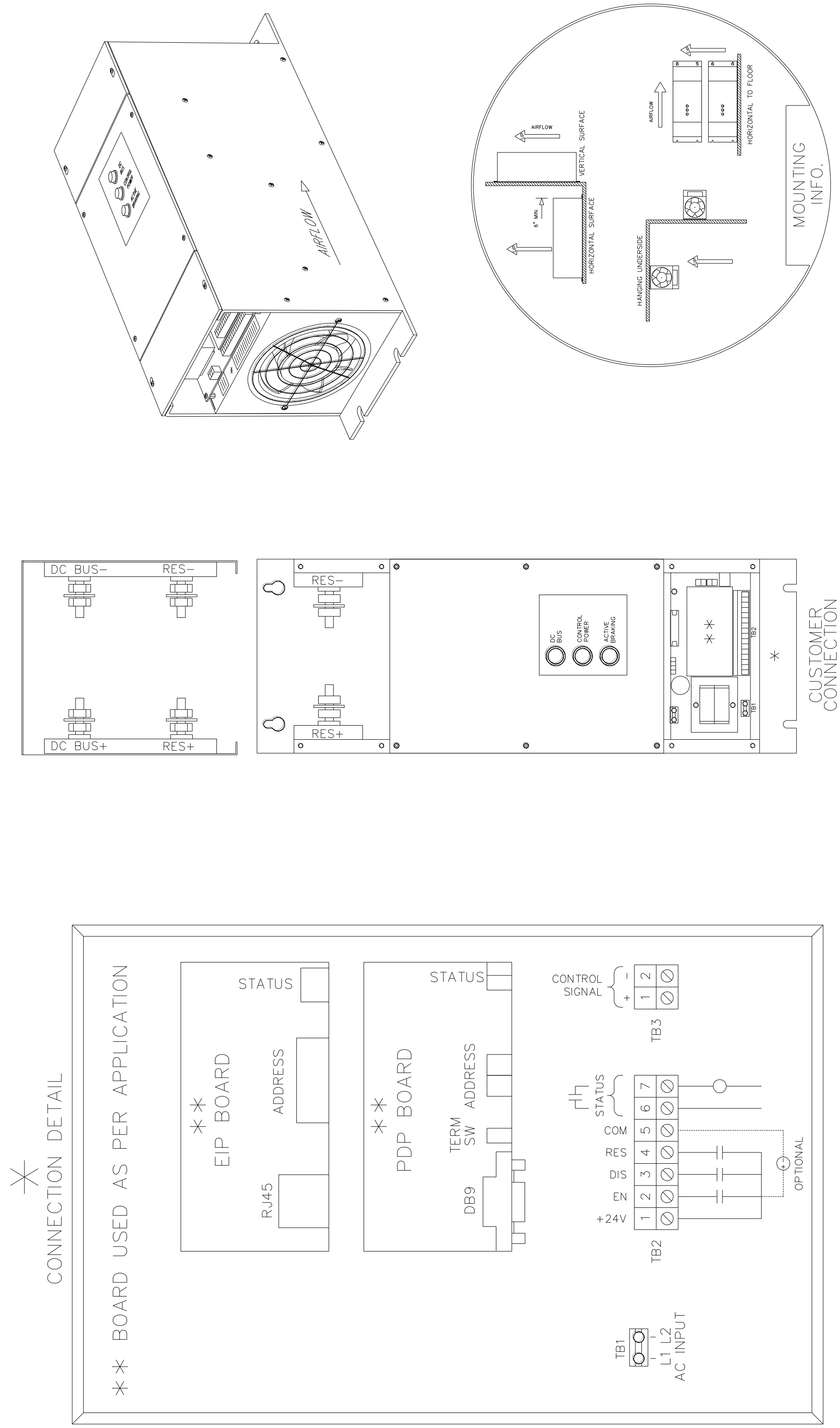


Figure 3-3: Customer Connections in K10 Chassis

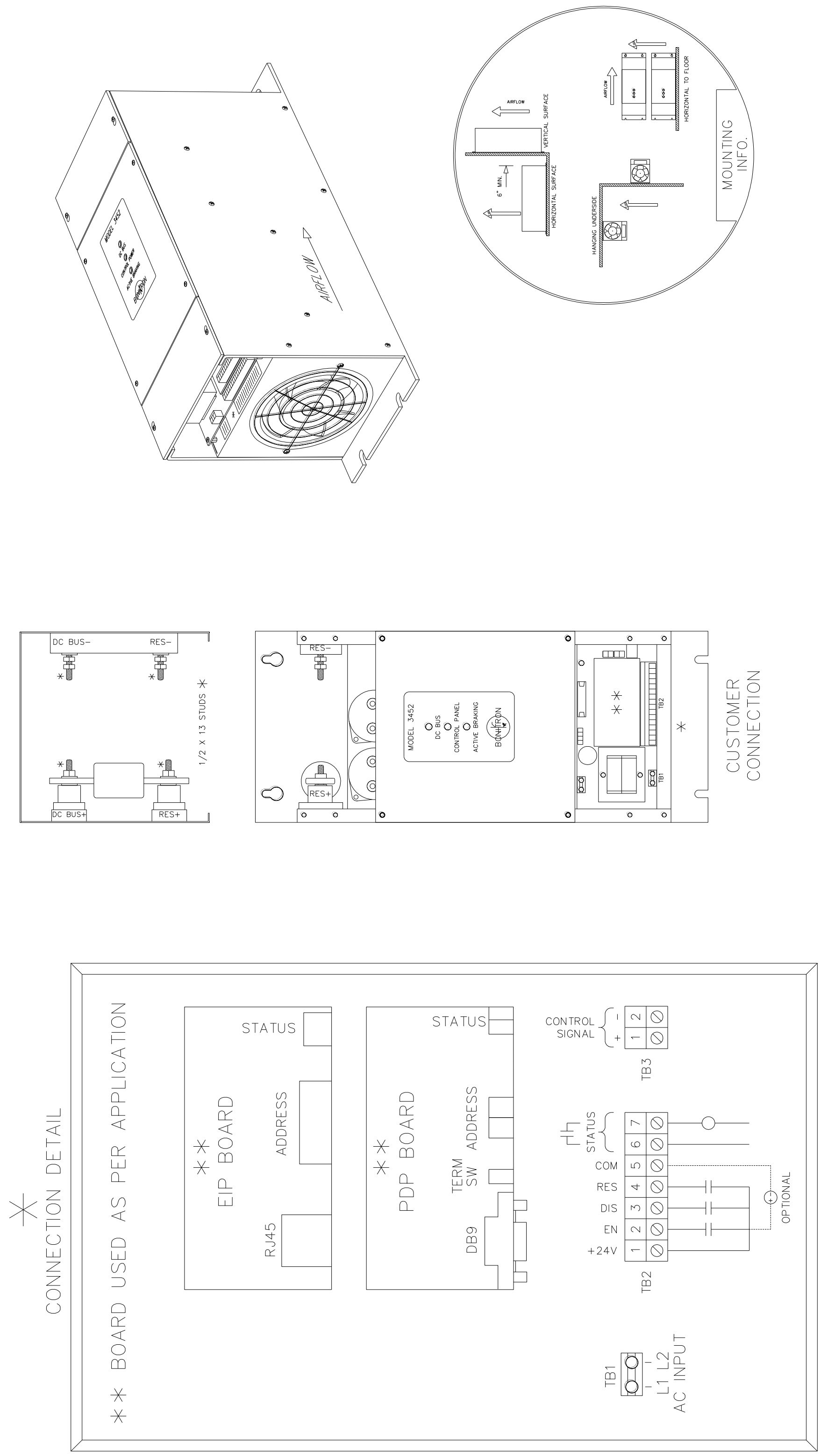


Figure 3-4: Customer Connections in M14 Chassis

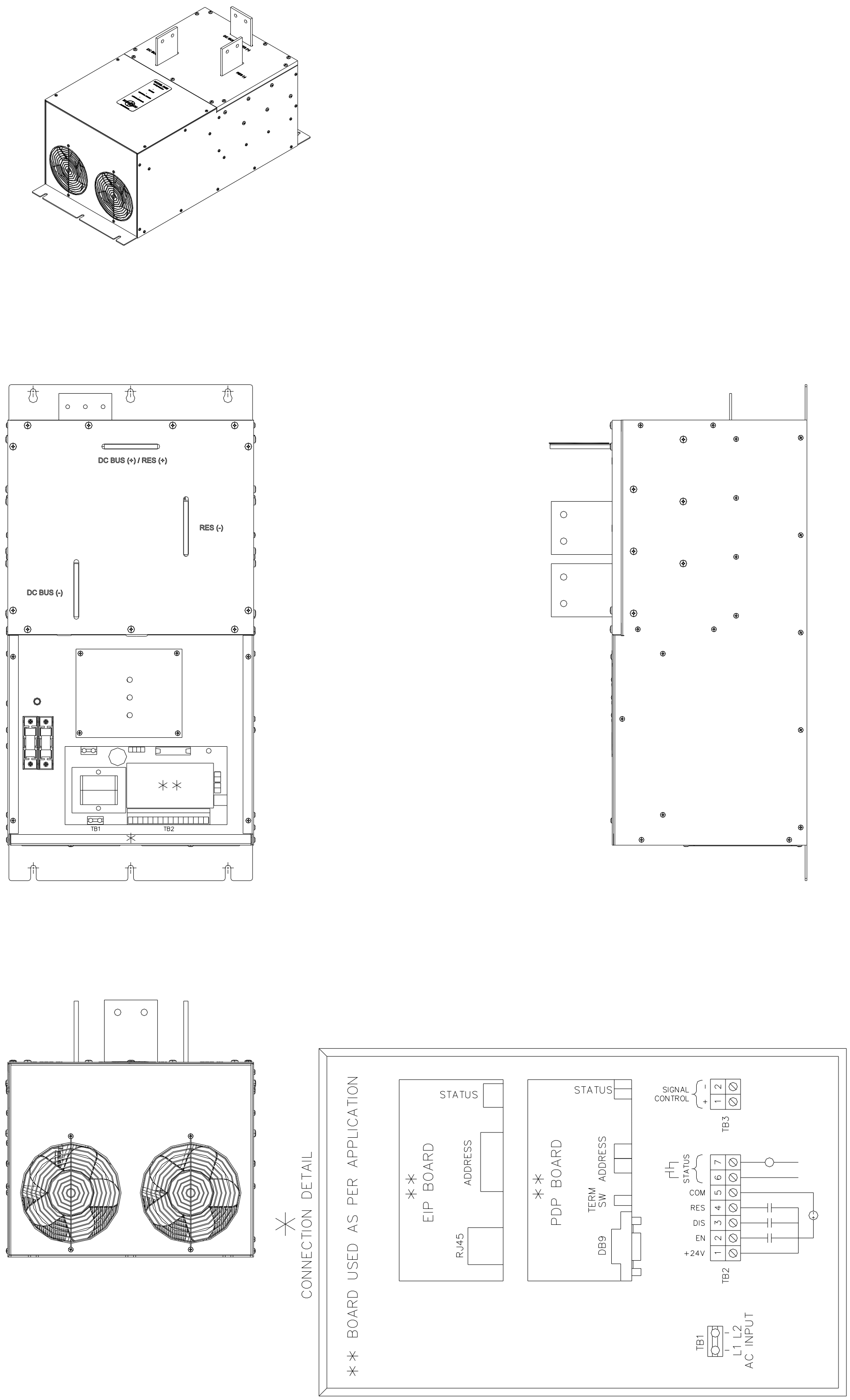
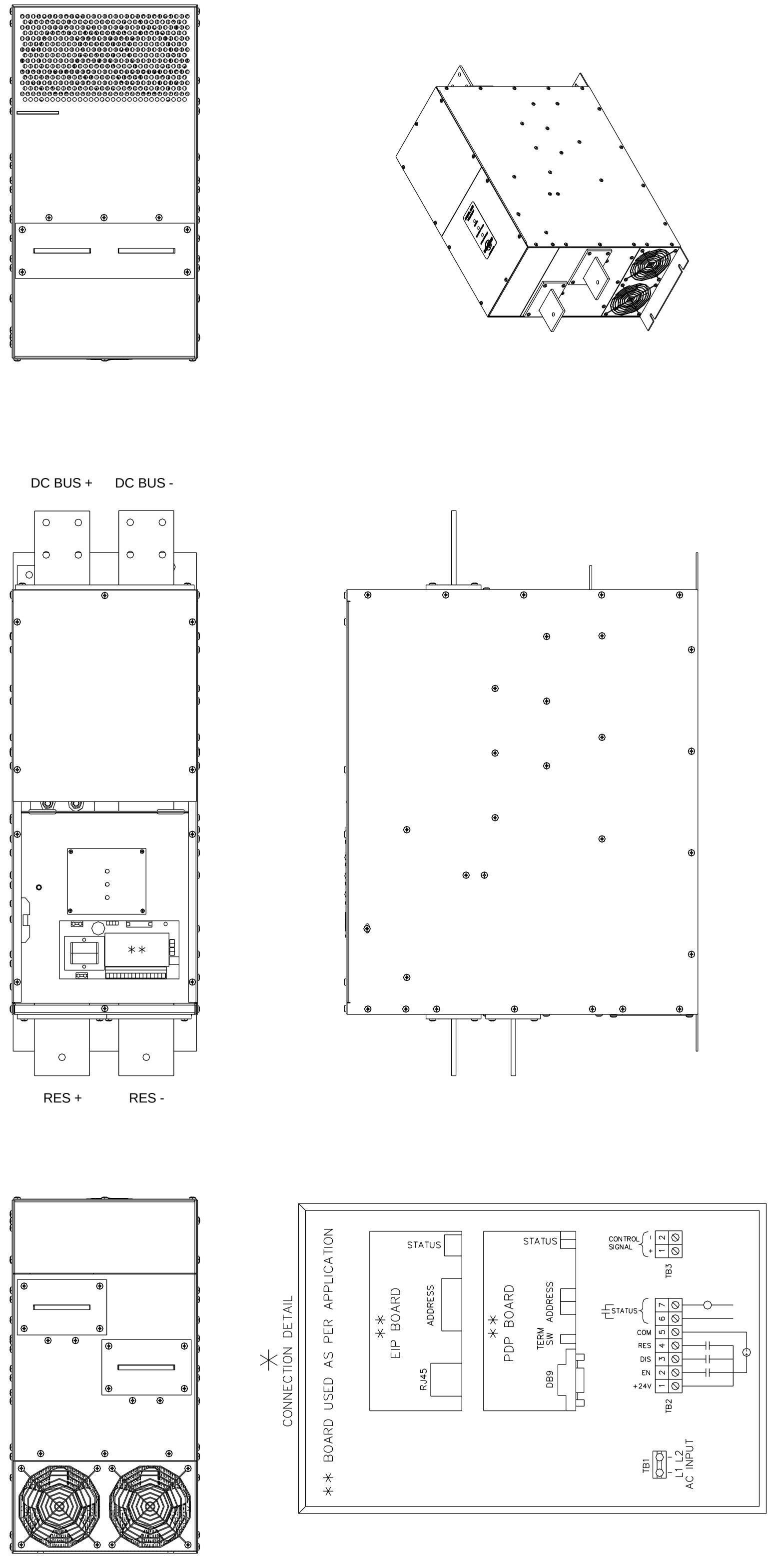


Figure 3-5: Customer Connections in T10 Chassis



3.5. TYPICAL CONFIGURATIONS

Figure 3-6: Master Stand-Alone Hookup

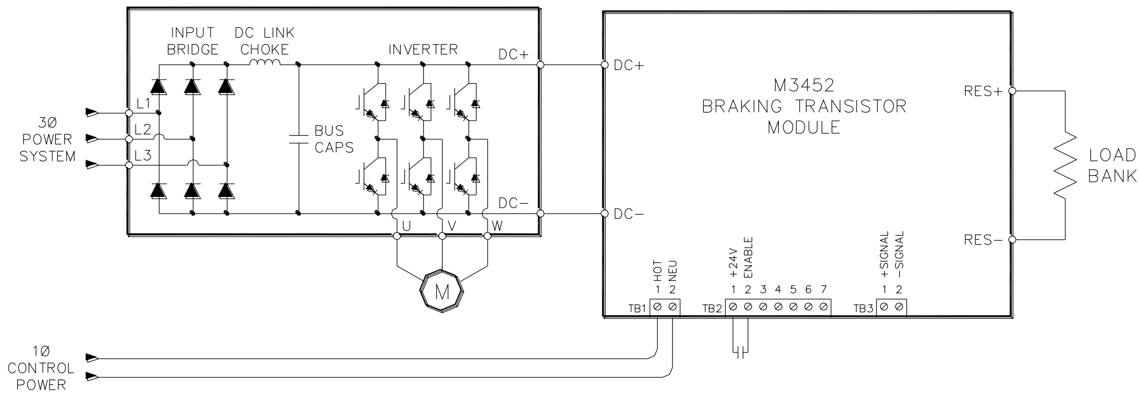


Figure 3-7: Master with Slave(s) Hookup

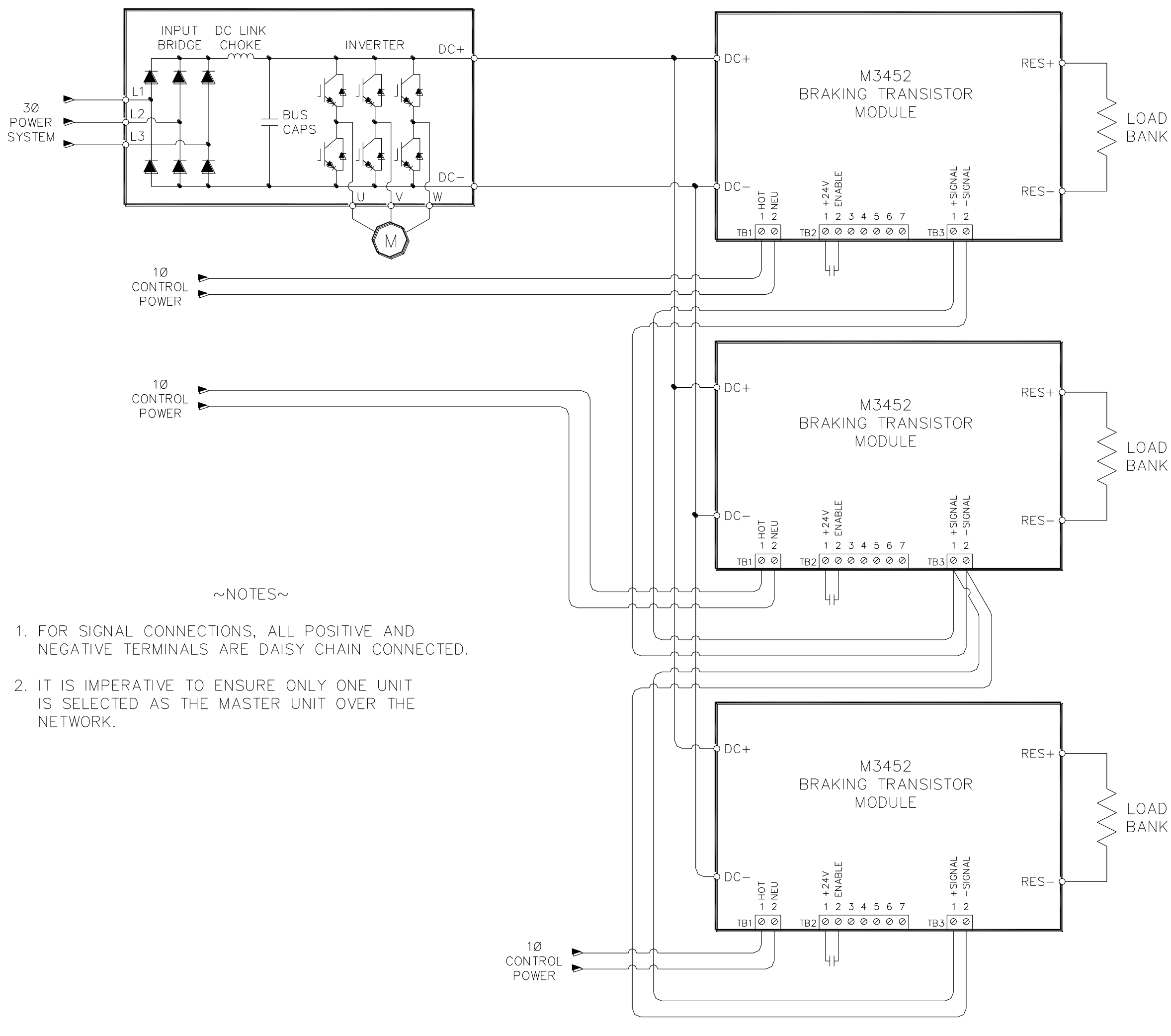


Figure 3-8: I/O Hookup

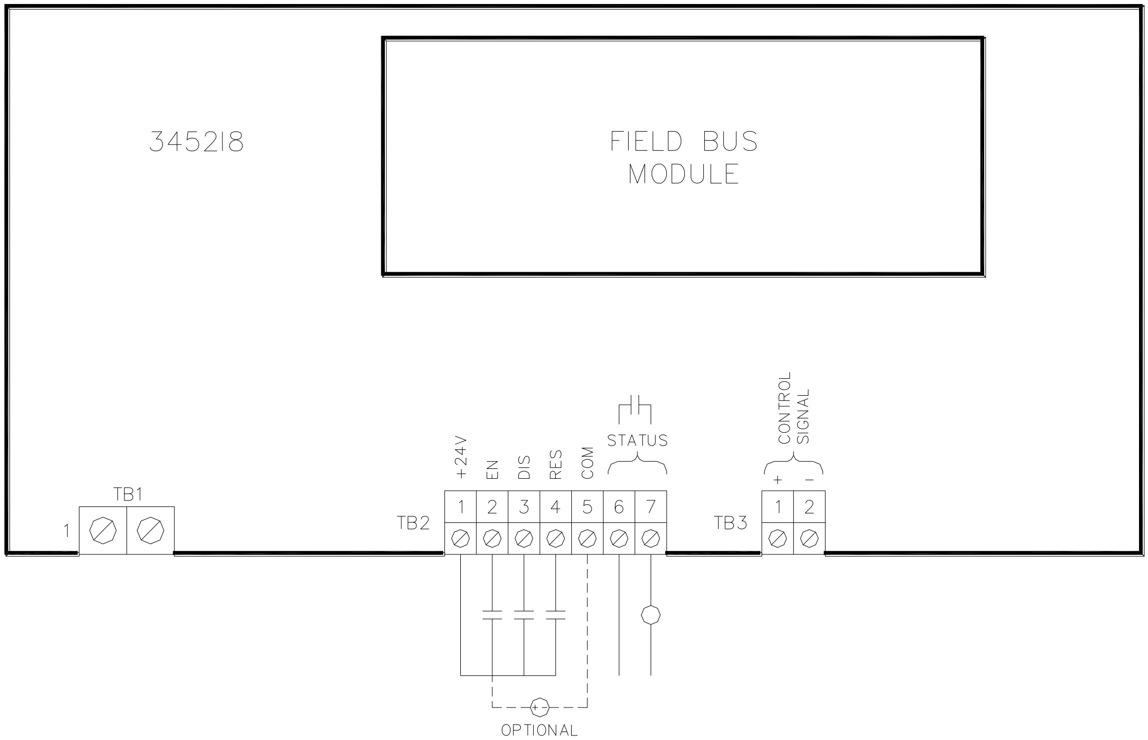


Figure 3-9: Equivalent Input/Output Diagrams

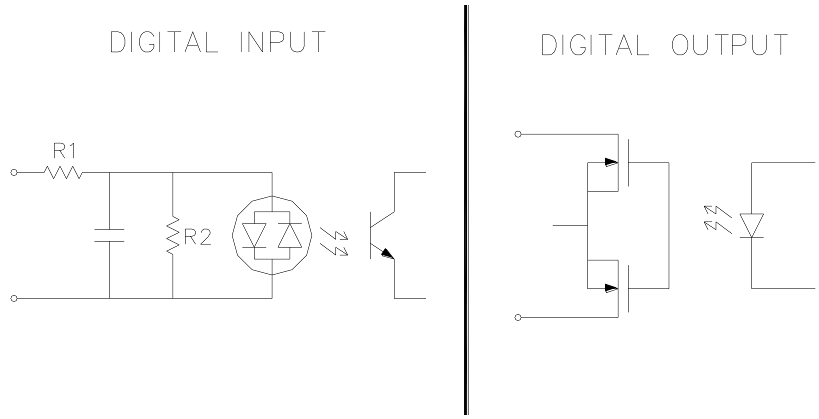
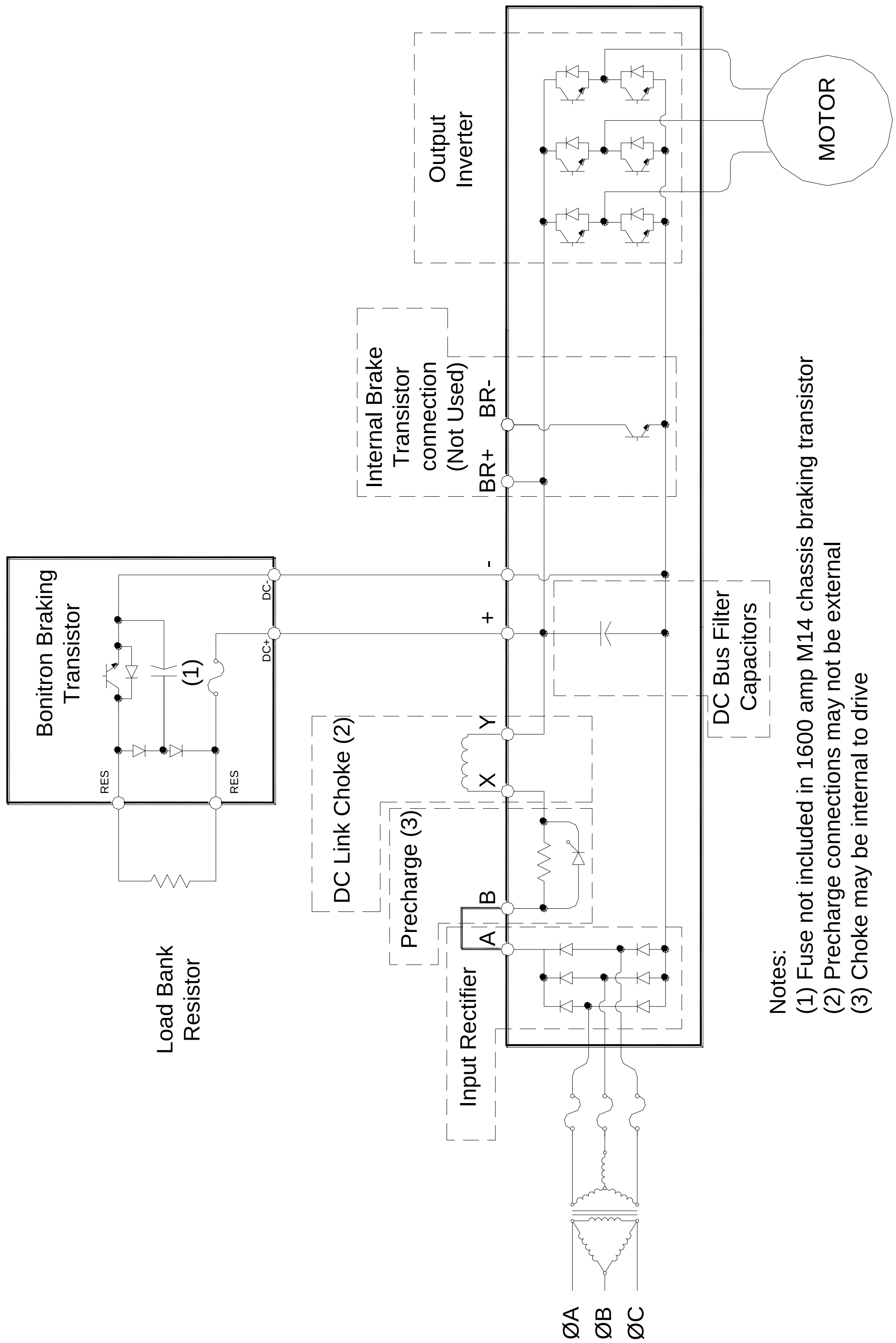


Figure 3-10: Braking Transistor Customer Connections



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4. OPERATION

4.1. FUNCTIONAL DESCRIPTION

The M3452 module controls the bus voltage of a variable frequency drive by transferring energy to a resistor.

When the drive's DC bus voltage exceeds a fixed setpoint, the dynamic braking transistor module's control electronics turns on an IGBT transistor connecting a resistive load across the DC bus. When the DC bus drops below another threshold, the IGBT turns off. The setpoints are listed in Section 6.

The R8 version adds control and monitoring over a network connection.

4.2. FEATURES

4.2.1. INDICATORS

4.2.1.1. DC BUS

The amber DC bus indicator illuminates when the voltage between the DC+ and DC- terminals is greater than 50VDC.

CAUTION! *Do not use this light as an indication that the DC bus is safe to work on! Always check the DC bus with a working voltmeter before servicing equipment, as the DC bus light may be broken!*

4.2.1.2. CONTROL POWER / FAULT

This green indicator illuminates when control power is applied to the unit. A solid light indicates that no faults are present and the control circuit is functioning. A flashing light indicates a fault, with the pattern of flashing lights indicating the type of fault (see Table 4-1 in Section 4.2.5). All faults (except Overtemp and Open Thermistor) latch until a reset signal is applied. Overtemp and Open Thermistor will clear automatically when the unit temperature falls to a safe level. See Section 4.2.2.4 for more information about the reset input. The short IGBT blown fuse faults will not reset until power-down.

Note: See Section 5 for specific faults and troubleshooting.

4.2.1.3. ACTIVE BRAKING

This red indicator illuminates when the chopper IGBT is on. When the drive is idle, this light should <u>not</u> be on. During braking, this light will be on or flashing, depending on the amount of braking energy.

This light will also be on if the Bus Discharge input is active.

4.2.2. TERMINAL STRIP I/O

4.2.2.1. V+ INPUT SUPPLY – TB2-1

This unregulated 24VDC supply can be used to drive the inputs. It is rated at 50 mA. It should only be used for this purpose.

4.2.2.2. ENABLE INPUT – TB2-2

These terminals must be connected for the module to regulate the DC bus.

Modules are enabled by closing a dry contact between the terminals. This is an active high (sinking) 24V signal common to TB2-5. Both this input and the network “Enable” bit must be set for the module to operate. See Section 4.2.4 for network information.

4.2.2.3. DISCHARGE INPUT – TB2-3

This input can be used to quickly drain the drive system’s DC bus down for maintenance. This is an active high (sinking) 24V signal common to TB2-5. This input will set the braking IGBT to go full on and stay until the input is removed.

WARNING! *The discharge input causes the IGBT to go on full until the input is removed. This can cause severe overheating in the load resistor if input power is not removed from the DC bus!*

In order to use this feature, the unit must be enabled, the network “Discharge” input must be high, and the unit must be selected as Master for the input to have an effect.

See Section 4.2.4 for network information.

4.2.2.4. RESET FAULT INPUT – TB2-4

This input will reset any latched faults that have occurred, provided the fault condition has been removed. This is an active high (sinking) 24V signal common to TB2-5. Once the faults have been cleared, the module will return to normal operation. This input operates on a rising edge.

This has the same effect as setting the reset bit in the control word. (Section 4.2.4.2.1.3)

Either the reset input or the reset bit will reset faults.

4.2.2.5. INPUT COMMON – TB2-5

This terminal is common for the digital I/O, and must be connected to the return if an external supply is used. If the internal 24V+ is used, this terminal has no connection.

4.2.2.6. STATUS READY OUTPUT – TB2-6&7

This normally open contact indicates the status of the module. When this contact is closed, the module has no faults and is regulating the DC bus.

If there is a fault, the fault is indicated with either the flash code on the front indicators (Section 4.2.5) or with the status bits (Section 4.2.5.1).

4.2.2.7. CONTROL SIGNAL – TB3-1&2

These terminals are used for the Master/Slave communication port used in multiple unit configurations. The signals of all modules are connected in a “daisy chain” (+ to +, - to -).

The port is bidirectional, serving as an output for modules operating in the Master mode, inputs for modules operating in the Slave mode.

The signal is a complex waveform that is not reproducible as an analog input or output. See Section 4.2.3 for further information on Master/ Slave configurations.

WARNING! *Do not attempt to use these signals for any purpose other than interconnecting Bonitron M3452 with R7, R7E, or R8 units! Damage may occur to the M3452 as well as to the connected equipment! If monitoring of these signals is desired, see Bonitron model M3452ON.*

4.2.3. MASTER / SLAVE CONTROL (200 AMP TO 1600 AMP)

Several braking modules can be connected in parallel for current ratings higher than possible with a single module. This method requires that one module be in control of all other modules. This module is considered the Master and the others are slaved to it.

WARNING!

Each module must have its own dedicated load bank!

If the output of modules is wired in parallel, severe current imbalances will damage the units.

Parallel modules do not have to have the same current rating; however, each module must have a load resistor appropriate for the individual module's current rating.

Up to 10 additional modules can be driven from a Master module if all Slave modules are within close proximity of the Master module.

In this configuration, any module can be selected as the Master module, and can be changed "on the fly" remotely.

WARNING!

AT NO TIME *should more than one Master be selected simultaneously. If multiple masters are selected, all but one will detect the condition and cease operation. This fault can only be cleared by powering down the system and powering back up with only one master module. Ensure that the logic control will select only one Master at any given time.*

4.2.3.1. WIRING FOR MASTER / SLAVE OPERATION

The control signal for parallel systems should be wired in a "daisy chain" configuration, with all (+) signals connected and (-) signals connected. Use twisted/shielded pair cable for interconnection. See and Section 3.5 for typical configurations.

Do not exceed 15 feet of total cable length to connect the Master pulse to the farthest Slave module.

Excessive distance can lead to unacceptable noise in the signal lines, and can cause false triggering, poor operation, or catastrophic system failure.

4.2.3.2. CONFIGURATION

Master mode is selected by setting the Master Bit in the input word.

All modules have a status output indicating that the module's bus regulation and power switching circuitry are functioning properly.

If a Master module faults it will continue to control slave modules as long as it is enabled and there is no logic voltage fault. The Master module with the fault will not switch its own power stage. This allows the braking system to operate at reduced capacity in the event of a Master module power stage failure.

If a Master module experiences a logic voltage fault, or is disabled no bus regulation will occur.

For modules selected as Slaves, the unit must have no faults for that module to switch and regulate the DC bus. The operation of other modules is not affected.

The Master/Slave Status bit (4.2.4.3.1.1) indicates the operation mode of a module.

4.2.3.2.1. STATIC MASTER

Static Master systems have a single module that will always function as the master. For systems that have a static Master module, set the Master bit in the network interface (4.2.4.2.1.4).

4.2.3.2.2. DYNAMIC MASTER

For large systems that require more flexibility or redundancy, the mode can be switched remotely. Modules selected as Slaves will follow the signal on the Control Signal port from the single module selected as a Master.

The dynamic master switching sequence should follow these steps:

- Disable all modules by clearing the “Enable” input. Bus regulation stops.
- Set the Master Control flag (4.2.4.2.1.4) on the Master module.
- Ensure that only one Master/Slave Bit is active in the system, indicating that only one module is master.
- Enable all modules. Bus regulation resumes.

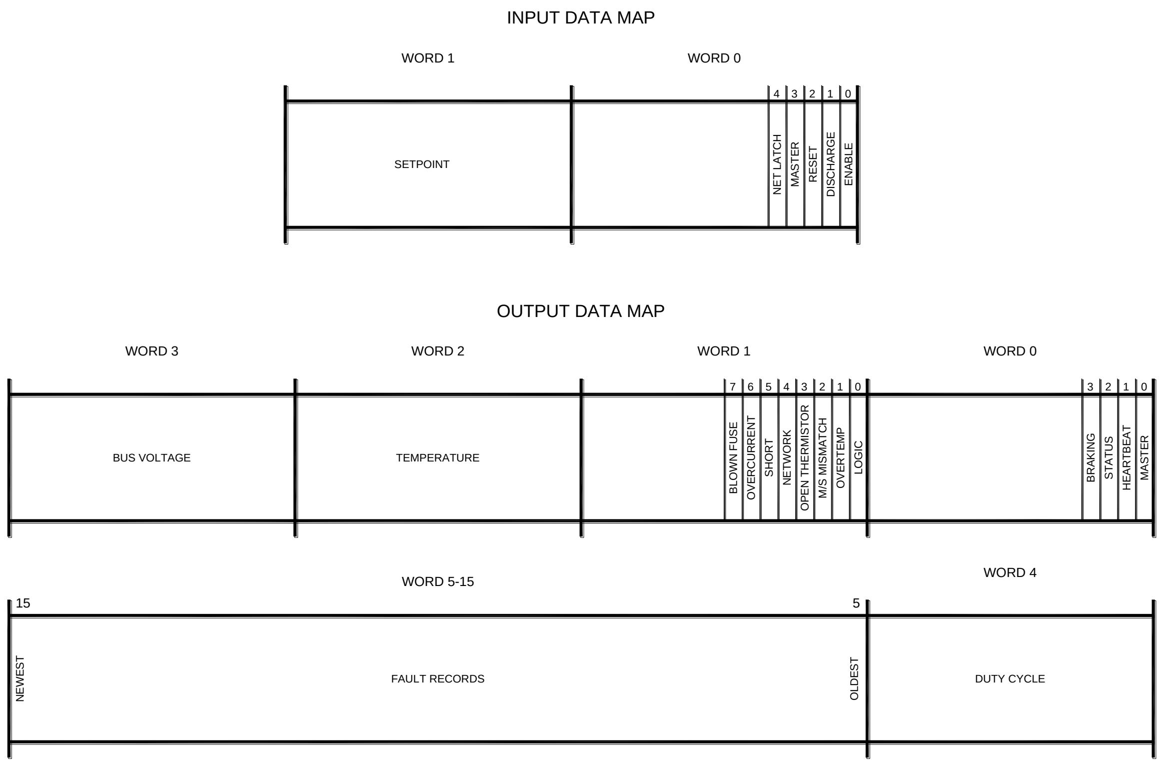
4.2.4. FIELDBUS I/O

4.2.4.1. MEMORY MAP

The memory map shows the position of the control and status words in relation to the base address on the network. Detailed descriptions of each bit and register are in the next sections.

The memory map is word based, each word using 16 bits.

Figure 4-1: 3452R8 Memory Map



4.2.4.2. INPUTS

Words 0-1 of input data are control registers for the braking module. Word 0 is the least significant word.

4.2.4.2.1. CONTROL BITS

The bits of word 0 of input data represent the controllable status flags for the braking unit. Bit 0 is the least significant bit.

4.2.4.2.1.1. ENABLE – BIT 0

Setting bit 0 enables the braking unit. The hardware enable terminal (4.2.2.2) must also be closed for the unit to be active.

4.2.4.2.1.2. DISCHARGE - BIT 1

Setting bit 1 sends a discharge command to the braking unit. The hardware discharge terminal (4.2.2.3) must also be closed to initialize a discharge.

WARNING! *The discharge input causes the IGBT to go on full until the input is removed. This can cause severe overheating in the load resistor if input power is not removed from the DC bus!*

4.2.4.2.1.3. RESET - BIT 2

Setting bit 2 sends a reset command to the braking unit. The hardware reset terminal (4.2.2.4) does **not** need to be closed for the unit to reset the braking unit.

When the braking unit resets, it clears the faults that are no longer active.
This signal operates on a rising edge.

4.2.4.2.1.4. MASTER - BIT 3

Setting bit 3 makes the braking unit operate as a master, while clearing the bit represents setting the unit to be a slave. See Section 4.2.3 for more information.

4.2.4.2.1.5. NET LATCH - BIT 4

Setting bit 4 will allow the braking unit to continue operating in the event of a network loss fault. See Section 4.2.5.1.5 for more information.

4.2.4.2.2. SETPOINT ADJUST – WORD 1

Word 1 of input data adjusts the setpoint that the braking kit from the nominal value. This is a signed eight bit integer.

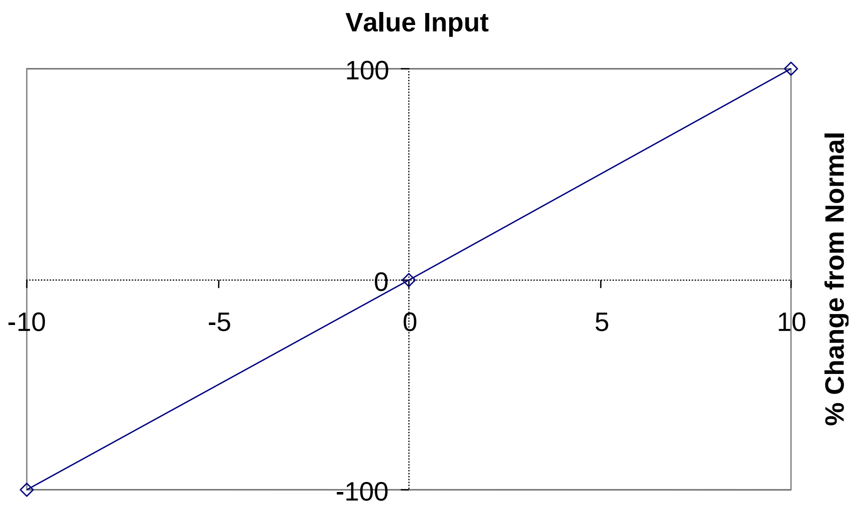
The setpoint can be adjusted ±10% of the nominal value.

The adjustment range for the register is -100 to 100.

For the braking kit to operate at its standard value, this should be set to 0.

For the standard braking voltages refer to Table 2-3 (Bus Voltage Rating).

Figure 4-2 Setpoint Adjustment Range



4.2.4.3. OUTPUTS

Words 0-7 of output data describe the status of the braking module. Word 0 is the least significant word.

4.2.4.3.1. STATUS WORD – WORD 0

Word 0 has status flags in it that indicate operation of the module.

4.2.4.3.1.1. MASTER STATUS – BIT 0

This is set if the braking module is set to operate as a master, and cleared if set to operate as a slave.

4.2.4.3.1.2. Heartbeat – Bit 1

This bit changes states every 500ms. There is a rising edge every 1 second, and can be used to indicate that the system is still functional and communicating.

4.2.4.3.1.3. Fault Status – Bit 2

This indicates that there are no faults, and that the module is operating properly.

4.2.4.3.1.4. Active Braking – Bit 3

This indicates that the unit is actively braking, and follows the red front panel indicator. (Section 4.2.1.3)

4.2.4.3.2. Fault Word – Word 1

This holds the current fault bits. The Fault states are listed in Section 4.2.5.

4.2.4.3.3. Temperature – Word 2

This indicates the temperature of the braking module heat sink in degrees. This is a 16 bit unsigned integer that represents degrees Fahrenheit. The resolution is to one degree, for example: 93 = 93°F.

The temperature feedback is valid when the heatsink temperature is above 30°F. Below 30°F, the value will be zero. The value will also be zero if there is an open thermocouple fault.

4.2.4.3.4. Bus Voltage – Word 3

This indicates the present bus voltage in volts. This is a 16 bit unsigned integer. The resolution is to one volt, for example, 675 = 675V.

4.2.4.3.5. Duty Cycle – Word 4

Word 4 indicates the present braking duty cycle of the module, with 0 representing fully off (0%) and 100 representing fully on (100%). This is an 8 bit unsigned integer.

The duty cycle of the braking module is a 1 second average of the high frequency pulse width during a braking cycle. This can give an idea of the system loading during braking.

4.2.4.3.6. Fault Records – Words 5 - 15

These words hold the last 10 fault states, oldest in the lowest address.

The value stored is the fault state, as listed in Section 4.2.5.

4.2.5. FAULT MODES

Faults are indicated in two ways. The green Control Power LED on the front of the module will flash, and a fault bit will be set in the Fault Word on the network. When there is any unrecoverable fault, the Status output will open. (Section 4.2.2.6)

Table 4-1: Fault Conditions Table

FLASHES	FAULT WORD - BIT	FAULT	DESCRIPTION
1 Fast	6 - 0	Logic Voltage	Logic Voltage has failed.
2 Fast	6 - 1	Overtemp	Unit has overheated.
3 Fast	6 - 2	Master / Slave Mismatch	More than one master detected on Control Signal network.
4 Fast	6 - 3	Open Thermistor	Temperature feedback has been lost.
5 Fast	6 - 4	Network Fault	Network communication fault.
1 Slow	6 - 5	Short IGBT	Main IGBT has shorted.
2 Slow	6 - 6	Overcurrent	Instantaneous overcurrent.
3 Slow	6 - 7	Blown Fuse	Main input fuse has blown.

Note: See Section 5 for Troubleshooting.

4.2.5.1. FAULT FLAGS

Word 1 of output data represents flags for each individual system fault. Bit 0 is the least significant bit.

4.2.5.1.1. LOGIC VOLTAGE – BIT 0

This indicates that the onboard control power is not operating properly. One of the power supplies on the control board has failed, and the braking module cannot regulate the DC bus.

If the supply voltage returns to normal, this fault can be reset with the reset bit (Section 4.2.4.2.1.3) or the reset input (Section 4.2.2.4).

4.2.5.1.2. OVERTEMP – BIT 1

This contact indicates that the module's heatsink is outside operating temperature. If the heatsink gets too hot to safely operate, the module will stop braking control and this bit will go high. Once the temperature of the heatsink falls to a safe operation temperature, the module will begin braking action again, and this bit will go low.

For 1600 amp modules, the shutdown temperature is 180°F, for all others the shutdown temperature is 160°F.

4.2.5.1.3. MASTER/SLAVE MISMATCH – BIT 2

If more than one master is configured on a system, the braking modules configured as masters will sense extra pulses on the control signal lines and stop operating. This bit will go high.

Reconfigure the system to have only one master. (Section 4.2.3)

This fault can be reset with the reset bit (Section 4.2.4.2.1.3) or the reset input (Section 4.2.2.4).

4.2.5.1.4. OPEN THERMISTOR – BIT 3

This bit goes high if there is a thermistor open. This fault indicates that the temperature feedback is invalid. This can also occur if the temperature of the module is below 30°F (0°C).

Once the thermistor is reconnected, the unit will resume normal operation.

4.2.5.1.5. NETWORK FAULT – BIT 4

This indicates that there is a fault in the network communications. When this happens, the module stops regulating the bus until the module is reset, either with the external input or the reset bit. If communications have not returned, the module will fault again.

Use the network diagnostic lights listed below for the type of network module installed.

If there is a network fault, the braking module will not regulate the bus unless the Net Latch input bit is set. (4.2.4.2.1.5)

4.2.5.1.6. SHORT IGBT – BIT 5

This bit indicates that the braking power transistor has failed. The bit is low if the IGBT is operating properly.

If the IGBT shorts during operation, this bit will go high. When this bit goes high, it will stay high until power is cycled.

When this bit goes high, the IGBT is damaged and the unit needs repair. Contact Bonitron for assistance.

4.2.5.1.7. INSTANTANEOUS OVERCURRENT – BIT 6

This bit goes high when there is a high transient current through the main chopper. This can be due to a short or arcing fault.

This fault can be reset with the reset bit (Section 4.2.4.2.1.3) or the reset input (Section 4.2.2.4), although Bonitron highly recommends checking the power system before continuing operation, as there could be an electrical hazard.

4.2.5.1.8. BLOWN FUSE – BIT 7

This bit goes high if the fuse is blown on the unit. This bit has no function on units above 1200 amps, as there is no internal main power fuse. This bit is reset at power up.

4.2.6. NETWORK CONFIGURATION

The network configuration depends on the type of network purchased. The M3452-R8 uses the Anybus-S embedded interface controller from HMS networks.

Support files for the different networks can be found at www.bonitron.com.

Extensive information on setup and operation can be found at www.anybus.com.

4.2.6.1. ETHERNET / IP

The EtherNet I/P interface can be configured in several different ways. The module can be set using hardware switches, a PC utility or directly through a web browser. The default address is 0.0.0.0.

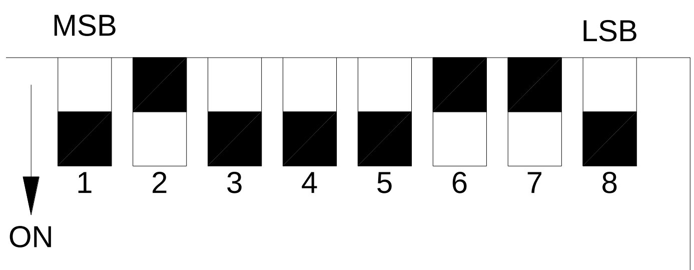
4.2.6.1.1. EtherNet / IP Addressing Switches

The DIP switches on the EtherNet interface card can be used to set a static IP address. These switches are to the right of the EtherNet connector.

If the switches are set to a non-zero value, the module will use the following settings:

IP Address:	192.168.0.x (x = binary switch value)
Gateway	255.255.255.0
Subnet	255.255.255.0
DHCP	Off

The switches specify the binary value of the last byte of the IP address as illustrated by the following example, where the IP address is set to 192.168.0.185



Please note that the switches are numbered backwards from the bit numbers, the least significant bit is the rightmost switch.

If these switches are set to zero, the address used is the one set in the online configuration screen, described below.

4.2.6.1.2. Online Module Configuration with Anybus IPconfig

At first power-on, the module has no pre-configured static IP address, and DHCP is off. To assign an IP address to the network module, perform the following steps.

1. Power on the braking kit.
2. Connect the network module to a network with a Windows PC.
3. From the Windows PC, run the Anybus IPconfig software, which may be found on the Bonitron website. The program should list any braking kits on the network. Unconfigured modules will have an IP address of 0.0.0.0. This utility will scan the network for HMS braking units and list them regardless of the current IP address setting.
4. Double-click the list entry which matches the MAC address labeled on the network module.
5. Configure the module with the desired IP address, subnet mask, gateway, DNS servers, and DHCP configuration. A password may also be set if desired. Click "Set" to confirm changes. The IP address changes immediately, there is no need to cycle power.

6. Click "Scan" to confirm that the changes you made were accepted.

Multiple modules can be configured from the same PC at the same time.

4.2.6.1.3. ONLINE MODULE CONFIGURATION THROUGH A WEB BROWSER

The IP address can be changed using a standard web browser. Perform the following steps.

1. Power on the braking kit.
2. If you don't know the IP address of the module, you can use the hardware switches to temporarily force it to a standard address and make the stored IP address change as below.
3. Use a standard web browser to connect to the braking module. The web page configuration is compatible with Internet Explorer and Firefox. Others should work as well. To connect, put the IP address directly in the address bar of the browser.
4. This webpage can be used to drive the inputs and observe the outputs of the braking module. Use care, as bits set here will affect the actual operation of the chopper.
5. Configure the module with the desired IP address, subnet mask, gateway, DNS servers, and DHCP configuration. There is not SMTP configuration available, this can be left blank.
6. Press "Store Configuration" to change the settings. This change is not immediate; power must be cycled before the change takes place. If you had hard set the IP address with the configuration switches, make sure you turn all the switches off.

4.2.6.1.4. PLC CONFIGURATION

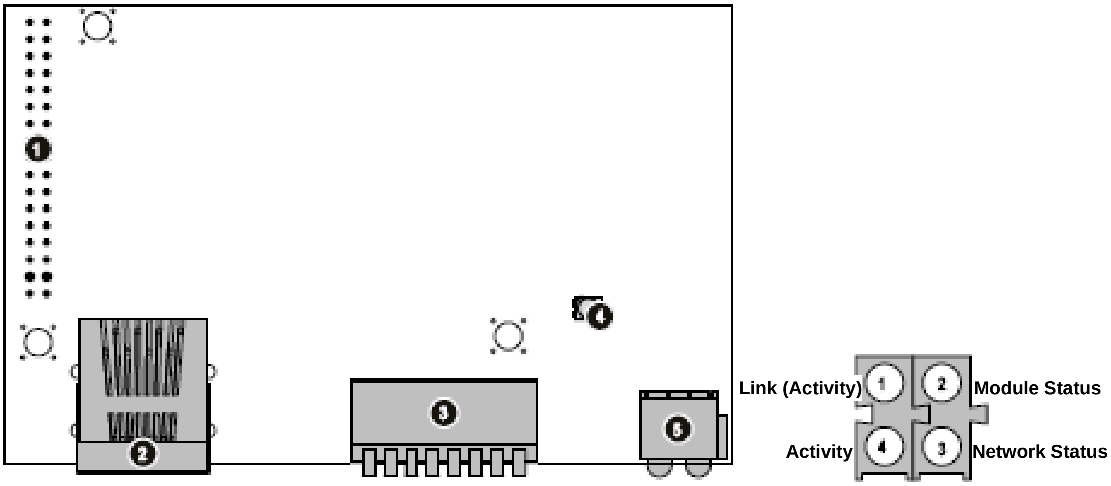
The EDS file for the network module may be found by visiting the Bonitron website. Load the EDS file onto your PLC according to your PLC manufacturer's instructions. Configure both the input and output data ranges to a size of **128 bytes**, and the RPI time to **100 mS**.

If instructed by the PLC for the Assembly Instance, such as the RSLogix 5000, use any non-zero value.

4.2.6.1.5. ETHERNET / IP STATUS INDICATORS

These LEDs indicate run time status and errors to the user. During power up, a LED test sequence is performed according to the EtherNet / IP specification.

Figure 4-3: EtherNet / IP Module Features



Legend:
1 Application Connector
2 Ethernet Connector
3 Configuration Switch
4 Anybus Watchdog
5 Status indicators

Table 4-2: Ethernet Status Indicators

1 LINK (ACTIVITY)

STATE	DESCRIPTION
Off	Link not sensed
Green	Link sensed

2 MODULE STATUS

STATE	DESCRIPTION
Off	No power
Green	Controlled by a scanner in Run state
Green, flashing	Not configured, or scanner in idle state
Red, flashing	A minor recoverable fault has been detected
Red	A major unrecoverable fault has been detected
Alternating Green / Red	Self-test in progress

3 NETWORK STATUS

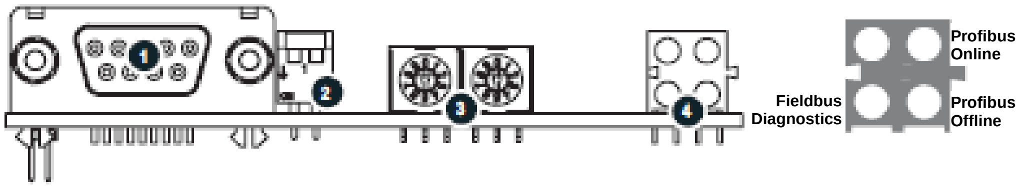
STATE	DESCRIPTION
Off	No power or no IP address
Green	On-line, one or more connections established (CIP Class 1 or 3)
Green, flashing	On-line, no connections established
Red	Duplicate IP address, fatal error
Red, flashing	One or more connections timed out (CIP Class 1 or 3)
Alternating Green / Red	Self-test in progress

4 ACTIVITY

LED blinks when packets are transmitted or received.

4.2.6.2. PROFIBUS DP

Figure 4-4: PROFIBUS Module Features



LEGEND:

1 PROFIBUS Connector
2 Termination Switch
3 Node Address Switches
4 Status indicators

4.2.6.2.1. PROFIBUS STATUS INDICATORS

These LEDs indicate run time status and errors to the user. During power up, a LED test sequence is performed according to the EtherNet / IP specification.

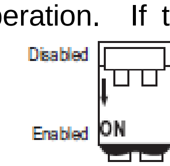
Table 4-3: PROFIBUS Status Indicators

LED	STATE	DESCRIPTION
Profibus Online	Green	Bus online, data exchange possible
	Off	Bus not online (or no power)
Profibus Offline	Red	Bus offline
	Off	Bus not offline (or no power)
Fieldbus Diagnostics	Off	No diagnostics present (or no power)
	Red, flashing (1 Hz)	Error in Configuration Data
	Red, flashing (2 Hz)	Error in Parameter Data
	Red, flashing (4 Hz)	Error in initialization of the PROFIBUS communication ASIC
	Red, flashing (8 Hz)	Watchdog timeout (internal error)

4.2.6.2.2. PROFIBUS CONFIGURATION SWITCHES

4.2.6.2.2.1. TERMINATION SWITCH

Each bus segment in a PROFIBUS network must be terminated properly to ensure error-free operation. If the module is used as the first or last node in a network segment, the termination switch must to be in ON position. If the module is in the middle of a network, the switch has to be in OFF position.



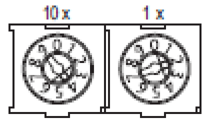
Note: If an external termination connector is used, the switch must be in OFF position

4.2.6.2.2.2. NODE ADDRESS SWITCHES

These rotary switches can be used to set the node address of the module in the range 0...99. The switches are read only during startup. If the setting is changed, the module will have to cycle power for the change to have effect.

4.2.6.2.3. MODULE CONFIGURATION

The module's network address is configured by the two rotary switches on the front of the network module. The module can be assigned any address between 0 and 99, with the left switch representing the most significant digit. *The module's address cannot be changed while the module is active. If the address is changed, the unit must be powered off and back on for the changes to take effect.*



Example: When the left switch is set to 4 and the right one is set to 2, the final value will be 42.

4.2.6.2.4. PLC CONFIGURATION

The GSD file for the network module may be found by visiting the Bonitron website. Load the GSD file onto your PLC according to your PLC manufacturer's instructions. Configure both the input and the output data ranges to a size of **128 bytes**, and the RPI time to **100 mS**.

4.3. STARTUP

WARNING!

Bonitron dynamic braking transistor modules are designed to be used with stand-alone or common DC bus drive/inverter systems with bus capacitors. When using the Bonitron modules on common bus systems, special considerations may apply. Review the Application Notes in Section 7 prior to start-up!

4.3.1. PRE-POWER CHECKS

Ensure that all connections are tight, DC bus polarity is correct, and that all field wiring is of the proper size for operational requirements. Check for exposed conductors that may lead to inadvertent contact. Verify the load bank is properly sized for the application. The ohms value and wattage rating of the load bank are important for proper and reliable system operation! ***Remember*: do not operate the module with less than its minimum ohms value rating!** Verify that the Master / Slave jumpers are in their proper position for intended use.

MASTER/SLAVE

All modules come from the factory set in Slave mode. If the module is the only module used in the system, it should be set as Master. Place a jumper between TB2-7&8 for stand-alone systems or systems that have a static Master. In systems that have multiple units, refer to Section 4.2.3 for more information on setting up systems with multiple units.

4.3.2. STARTUP PROCEDURE AND CHECKS

Apply AC power to the drive system and the dynamic braking transistor module. Do not start the motors on the system.

On the dynamic braking transistor module, verify the following:

- AC control voltage is within tolerance. Refer to Table 2-6: General Specifications for voltages and tolerances.
- Green **Control Power** indicator is **ON**.
- Amber **DC Bus** indicator is **ON**.
- Red **Active Braking** indicator is **<u>OFF</u>**! **Immediately** turn off all power if the indicator is **ON** to avoid possible load bank overheating and/or other equipment damage!
- Verify the drive system DC bus voltage, and make sure it is within tolerance for the drive system.
- Verify the DC current flow through the load bank is zero amps. Even though the Red **Active Braking** indicator is **OFF**, any significant current flow could indicate incorrect connections or damaged equipment. ***Immediately*** *turn off all power to avoid possible load bank overheating and/or other equipment damage!*
    - <u>Note</u>: Depending on the type of measuring equipment used, small currents could just be noise pickup and could be ignored.
- Check status contact to ensure it is closed. This indicates that the module is ready for operation.

If any of the above conditions are not as indicated, turn off all power and allow ample time for all system energy sources to discharge. **Verify that all voltages are zero and have discharged with a suitable meter!** Check all wiring connections and jumper configurations. Refer to the Troubleshooting Section of this manual for more information. For further assistance, contact Bonitron technical support.

Once the pre-checks are complete, the drive system can be enabled. Once the drive system is operational, run the motors with light deceleration, and decrease the braking time until the red **Active Braking** indicator lights.

4.4. OPERATIONAL ADJUSTMENTS

No adjustments are necessary for this module. All regulation pots are factory adjusted, and should not be changed in the field. See Section 4.2.4.2.1.5 for information on adjusting the braking setpoints over the Fieldbus interface. If your module is not functioning properly, refer to the Troubleshooting Section of this manual, or contact Bonitron for assistance.

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5. MAINTENANCE AND TROUBLESHOOTING

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.

5.1. PERIODIC TESTING

At least every other month, visually inspect the front panel indicator lights to be sure they are operating correctly. With control power applied, the green **Control Power** indicator should be illuminated. The amber **DC Bus** indicator will be on if the drive bus is above 50VDC. The red **Active Braking** indicator will only be on or flashing if the module is switching energy from the DC bus. There are no operational tests to be performed.

5.2. MAINTENANCE ITEMS

Monthly, check the module for buildup of dust, debris, or moisture. Dangerous voltages exist within the module and the buildup of dust, debris, and moisture can contribute to unwanted arcing and equipment damage. Take whatever corrective or maintenance actions are necessary to keep the module clean and moisture free.

Monthly, check the cooling fan and heatsink for any buildup of debris. If they require cleaning **power down the drive system** and blow the debris out with clean dry air as necessary to maintain proper cooling performance. **Note:** After blowing out the fan and/or heatsink, blow off any dust or debris that may have gotten on any of the circuit boards.

5.3. TROUBLESHOOTING

WARNING!	*Lethal voltages exist in these systems! Before attempting checks or repair, follow all precautions to ensure safe working conditions, including lockout / tagout procedures, and verifying safe working voltages with proper meters. Do not rely on the DC Bus indicator to ensure a safe condition.*
ATTENTION!	*Only qualified personnel familiar with variable frequency AC drives and associated machinery should plan or implement the installation, start-up, and subsequent maintenance of the system. Failure to comply may result in personal injury, death, and / or equipment damage!*

Feel free to call Bonitron any time the equipment appears to be having problems.

5.3.1. GREEN CONTROL POWER LIGHT NOT ILLUMINATED

- Check control voltage input level on customer terminal TB1-1&2. Refer to *Table 2-1: Control Voltage Rating* and be sure it is within the specified range. The modules can be ordered with various control voltages, and the proper voltage must be used for the module’s configuration.
- Check if the status of the Logic Voltage bit is set. This would indicate insufficient logic voltage. This can be caused by a failure in the control circuit. The module will need repair.
- If the control voltage is correct and status contacts are closed, the indicator may be burned out, and need replacement.

5.3.2. AMBER DC BUS LIGHT NOT ON

This can be a normal condition in systems where DC bus power and logic control power is applied. This indicates that there is less than 50 VDC on the inverter bus.

CAUTION!

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

- Use a DC voltmeter to check the bus voltage at the module terminals DC bus + and DC bus -.
- If the DC bus is above 50VDC, and the light is not on, the light or control circuit may be damaged, and the unit should be returned for repair.
- The main DC bus fuse may be blown. See next section.

5.3.3. BLOWN DC BUS FUSE

CAUTION!

Do NOT replace a blown DC bus fuse and reapply power to the system without determining the cause.

This usually indicates serious problems exist and reenergizing the system can cause significant or catastrophic failure! In most cases, the module will need to be returned for repair. Contact Bonitron before changing the fuse.

Possible causes for a blown fuse are:

- Shorted heatsink IGBT power transistor.
- Shorted heatsink commutation diode.
- Load bank in use below minimum ohms value.
- Shorted load bank.
- Shorted resistor cabling and or ground fault in cable.
- Operating braking module on a DC bus without inverters present. This is typically encountered in common bus systems when drives are removed from service. See Section 7 for more information.

5.3.4. FAN RUNS CONSTANTLY

The fan only runs when the braking module heatsink is hot. If the heatsink is above 110°F, then the fan runs until the heatsink cools to 80°F. If the ambient temperature is above 80°F, the fan may run continuously. A constantly running fan does not indicate a problem with the module. If the heatsink temperature is below 80°F, the thermostat may be damaged. This will not affect DC bus regulation.

5.3.5. FAN DOESN'T RUN

The fan only runs when the braking module heatsink is hot. If the heatsink is above 110°F, then the fan runs until the heatsink cools to 80°F.

If the fan never runs, even when the heatsink is hot or during heavy braking operation, the module may shutdown on heatsink over-temperature. This occurs at a heatsink temperature of 160°F. If for any reason the fan does not appear to be working properly, check the following:

- Input and output fuses on the fan transformer. These will be located on or around the fan transformer itself.

- Check fan for blockage. Clean if necessary.
- Check fan transformer primary voltage and ensure it is within tolerance for the control voltage input for that module.
- Replace fan.
- If fan still doesn't operate, the heatsink temperature switch may be faulty. Contact Bonitron for return for repair.

5.3.6. STATUS CONTACT WON'T CLOSE

If the status contacts will not close, this indicates either a fault, or that the unit is not enabled. Check the network I/O or the green Control Power LED to determine the fault state of the system. Ensure the unit is enabled both at the contact and over the network interface.

- Loss of Control Power
- Failure in control circuit
- Over-temperature in module
- Shorted IGBT (power transistor)
- IOC fault

If the over-temperature contacts will not close, check the temperature of the module see Section 5.3.7 for overheating troubleshooting. If the module is hot, wait for the module to cool and see if it begins to function properly.

If shorted IGBT or IOC faults are reported and will not clear, the module has a fault that needs to be repaired by Bonitron. Contact Bonitron for assistance.

If the module is cool and still will not operate, contact Bonitron for assistance or repair.

5.3.7. MODULE OVER-TEMP, OR MODULE SEEMS TOO HOT

It is normal for this module to produce heat. Temperatures of 150°F are not uncommon. If the modules fan is running, and the module is operating properly, it is within normal tolerances.

Check the network interface to determine the heat sink temperature. If the contacts are open, then the module is inhibited due to over-temperature. If the fan is not running, see Section 5.3.5 above for assistance.

If the fan is running, check to make sure the airflow through and around the module is unobstructed.

If the ambient temperature is high in the cabinet or installation area, the module may overheat. Make sure the environment is within the operating temperature requirements listed in the General Specifications (Table 2-6).

5.3.8. DRIVE TRIPS ON OVERVOLTAGE

CAUTION!

> *Make sure the DC+ and DC- connections are made directly to the drive system bus. They should not be connected to terminals dedicated to an internal transistor circuit on the inverter*.

If the drive trips on overvoltage, confirm that the green control power light is on (5.3.1), the status contact is closed (5.3.6), and the amber DC bus light is on (5.3.2). Watch the red "Active Braking" light on the front of the module during a braking cycle. If it never illuminates, ensure that the module is either configured as a master, or correctly wired to a properly configured master (4.2.3). There must be exactly one master in the system. Check the DC bus voltage and make sure the bus voltage at the braking module exceeds the trip point of the module, i.e. 750VDC for a 460VAC nominal system. See Table 2-3: DC Bus Voltage Rating.

If the red "Active Braking" light comes on, check the wiring to the load bank, and check the current to the load bank with a clamp on current meter. If the wiring to the load bank is good, make sure the DC bus fuse is good.

If the red "Active Braking" light comes on, and current is flowing to the load bank, check to make sure that the module is sized properly for the system. If the resistance of the load bank is too large, not enough current will flow to allow for the braking energy to be dissipated. Check the system design to make sure the braking requirements are matched with the braking module capacity.

MASTER/SLAVE SYSTEMS

Master/Slave systems must be properly configured and operating to share the load.

Check your system layout and make sure there is only one selected and operating Master and that all the Slaves are properly wired to that Master.

Make sure that all the modules have the DC bus and control power lights on.

When the system is braking, watch the **Active Braking** lights on all modules. They should all go on and off at the same time. If they do not, there may be a wiring or module configuration issue.

If the lights all go on at the same time, check the current going to each load bank as above and correct problems found with the wiring.

5.3.9. BRAKING LIGHT FLICKERS

During motor deceleration, the red braking LED may flicker if the braking cycle energy is low. This is normal.

If the red braking light flickers when the inverter is idle, this may indicate high voltage, excessive noise, or harmonics on the main system rectifier input AC voltage. Check the incoming AC line for these problems. Consult the project engineer for the appropriate corrective action.

In rare instances, the module is installed on a system that has very little capacitance, or the inverters have been removed from the bus. This configuration can cause damage to the braking module. See Section 7 in this manual for more information.

5.3.10. RED BRAKING LIGHT STAYS ON ALL THE TIME

- Make sure the Bus Discharge input is not activated. This causes the braking module to go full on. Extended operation with this input can cause load bank overheating and improper operation.
- System voltage is too high or high harmonic content is present. Check main system rectifier input AC voltage. Refer to the DC Bus Trigger Level found in Table 2-3. The undistorted main system rectifier AC input voltage should always be less than

$$DC_{BusTriggerLevel} / 1.414$$

  - Note: If the measured DC bus (in standby) is greater than the

$$RMS_{LineVoltage} * 1.414$$

  then harmonic distortion may exist. Consult the project engineer for the appropriate corrective action.
- Setpoint too low. The DC Bus Setpoint pot on the main control board may have been tampered with. If this is a possibility, then the module needs to be sent in for recalibration.
- Wrong braking module installed. Check the module chassis sticker for the part number. Refer to Section 2.2 of this manual and verify the sticker information represents the correct part number for your application and voltage levels. Remove and replace as required.
- Main control board has gone bad and the module needs to be sent in for repair.

5.3.11. MASTER UNIT APPEARS TO FUNCTION PROPERLY, BUT SLAVE UNITS DO NOT SEEM TO FOLLOW THE MASTER

Slave(s) may have missing or insufficient control voltage. Refer to Section 5.3.1 and correct as required.

Check the signal wiring between modules. The terminals should be daisy chained as described in Section 4.2.3.1.

Make sure that only one module is selected as Master on a network. More than one master can cause improper triggering and system damage.

5.3.12. ETHERNET/IP LINK SENSED LIGHT DOES NOT TURN ON

Check the cable running between the module and network hub. Check the network hub port for functionality. Try another port or another cable.

5.3.13. ETHERNET/IP MODULE STATUS LED IS SOLID RED, FLASHING RED, OR FLASHING GREEN

Make sure your EtherNet/IP scanner is active and connected to the network, and is programmed with the appropriate EDS file and configuration for this module.

5.3.14. ETHERNET/IP NETWORK STATUS LED IS SOLID RED

The module has detected a duplicate IP address on the network. Make sure the address configuration switches are all in the "OFF" position, and assign the module a new IP address using the IPconfig software.

5.3.15. PROFIBUS FIELDBUS OFFLINE LIGHT IS RED

Make sure there are no duplicate addresses on your PROFIBUS network.
Make sure your termination switch is set correctly.

5.3.16. PROFIBUS FIELDBUS DIAGNOSTICS LIGHT IS BLINKING

Contact Bonitron.

5.3.17. ATTACHED DRIVE WILL NOT PRECHARGE

Verify the polarity of the connection to the DC filter capacitors of the drive. If this connection is reversed, the commutation diode effectively shorts the DC bus and will not allow the drive to go through precharge.

5.4. TECHNICAL HELP – BEFORE YOU CALL

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

- Serial number of unit
- Name of original equipment supplier
- Brief description of the application
- Drive and motor hp or kW
- The line to line voltage on all 3 phases
- The DC Bus voltage
- KVA rating of power source
- Source configuration Wye/Delta and grounding

6. ENGINEERING DATA

6.1. RATINGS CHARTS

Table 6-1: Module Ratings: 230 – 240 VAC Drives (375 VDC Setpoint)

BASE MODEL NUMBER	CONTROL VOLTAGE	BRAKING POWER (PEAK)	BRAKING CURRENT (PEAK)	BRAKING CURRENT (RMS)	DUTY CYCLE	MINIMUM RESISTANCE	FUSING
M3452-U200LK6	115-120 VAC	100 HP	200 A	200 A	100%	1.90 Ω	FWP-200
M3452-L200K6	230-240 VAC						
M3452-U300LK6	115-120 VAC	150 HP	300 A	300 A	100%	1.25 Ω	FWP-300
M3452-L300K6	230-240 VAC						
M3452-U600LK6	115-120 VAC	300 HP	600 A	300 A	50%	0.63 Ω	A70QS600
M3452-L600K6	230-240 VAC						
M3452-U800LK9	115-120 VAC	400 HP	800 A	400 A	50%	0.47 Ω	A70QS800
M3452-L800K9	230-240 VAC						
M3452-U1200LK10	115-120 VAC	600 HP	1200 A	600 A	50%	0.32 Ω	A70QS800
M3452-L1200K10	230-240 VAC						

Table 6-2: Module Ratings: 380 – 415 VAC Drives (620 VDC Setpoint)

Base Model Number	Control Voltage	Braking Power (Peak)	Braking Current (Peak)	Braking Current (RMS)	Duty Cycle	Minimum Resistance	Fusing
M3452-U200EK6	115-120 VAC	160 HP	200 A	200 A	100%	3.10 Ω	FWP-200
M3452-E200K6	380-415 VAC						
M3452-U300EK6	115-120 VAC	240 HP	300 A	300 A	100%	2.07 Ω	FWP-300
M3452-E300K6	380-415 VAC						
M3452-U600EK6	115-120 VAC	490 HP	600 A	300 A	50%	1.04 Ω	A70QS600
M3452-E600K6	380-415 VAC						
M3452-U800EK9	115-120 VAC	660 HP	800 A	400 A	50%	0.78 Ω	A70QS800
M3452-E800K9	380-415 VAC						
M3452-U1200EK10	115-120 VAC	1000 HP	1200 A	600 A	50%	0.52 Ω	A70QS800
M3452-E1200K10	380-415 VAC						
M3452-U1600EM14	115-120 VAC	1330 HP	1600 A	1200 A	75%	0.39 Ω	N/A
M3452-E1600M14	380-415 VAC						
M3452-U1600ET10	115-120 VAC	1330 HP	1600 A	1200 A	75%	0.39 Ω	A100P1200
M3452-E1600T10	380-415 VAC						

Table 6-3: Module Ratings: 460 – 480 VAC Drives (750 VDC Setpoint)

Base Model Number	Control Voltage	Braking Power (Peak)	Braking Current (Peak)	Braking Current (RMS)	Duty Cycle	Minimum Resistance	Fusing
M3452-U200HK6	115-120 VAC	200 HP	200 A	200 A	100%	3.80 Ω	FWP-200
M3452-H200K6	460-480 VAC						
M3452-U300HK6	115-120 VAC	300 HP	300 A	300 A	100%	2.50 Ω	FWP-300
M3452-H300K6	460-480 VAC						
M3452-U600HK6	115-120 VAC	600 HP	600 A	300 A	50%	1.25 Ω	A70QS600
M3452-H600K6	460-480 VAC						
M3452-U800HK9	115-120 VAC	800 HP	800 A	400 A	50%	0.93 Ω	A70QS800
M3452-H800K9	460-480 VAC						
M3452-U1200HK10	115-120 VAC	1200 HP	1200 A	600 A	50%	0.63 Ω	A70QS800
M3452-H1200K10	460-480 VAC						
M3452-U1600HM14	115-120 VAC	1600 HP	1600 A	1200 A	75%	0.47 Ω	N/A
M3452-H1600M14	460-480 VAC						
M3452-U1600HT10	115-120 VAC	1600 HP	1600 A	1200 A	75%	0.47 Ω	A100P1200
M3452-H1600T10	460-480 VAC						

Table 6-4: Module Ratings: 575 – 600 VAC Drives (940 VDC Setpoint)

Base Model Number	Control Voltage	Braking Power (Peak)	Braking Current (Peak)	Braking Current (RMS)	Duty Cycle	Minimum Resistance	Fusing
M3452-U200CK6	115-120 VAC	250 HP	200 A	200 A	100%	4.70 Ω	A100P200
M3452-C200K6	575-600 VAC						
M3452-U300CK6	115-120 VAC	380 HP	300 A	300 A	100%	3.20 Ω	A100P300
M3452-C300K6	575-600 VAC						
M3452-U600CK6	115-120 VAC	760 HP	600 A	300 A	50%	1.60 Ω	A70QS600
M3452-C600K6	575-600 VAC						
M3452-U800CK9	115-120 VAC	1000 HP	800 A	400 A	50%	1.20 Ω	A70QS800
M3452-C800K9	575-600 VAC						
M3452-U1200CK10	115-120 VAC	1500 HP	1200 A	600 A	50%	0.78 Ω	A70QS800
M3452-C1200K10	575-600 VAC						
M3452-U1600CM14	115-120 VAC	2015 HP	1600 A	1200 A	75%	0.58 Ω	N/A
M3452-C1600M14	575-600 VAC						
M3452-U1600CT10	115-120 VAC	2015 HP	1600 A	1200 A	75%	0.58 Ω	A100P1200
M3452-C1600T10	575-600 VAC						

Table 6-5: Module Ratings: 690VAC Drives (1090 VDC Setpoint)

Base Model Number	Control Voltage	Braking Power (Peak)	Braking Current (Peak)	Braking Current (RMS)	Duty Cycle	Minimum Resistance	Fusing
M3452-U200YK6	115-120 VAC	300 HP	200 A	200 A	100%	5.50 Ω	A100P200
M3452-U300YK6	115-120 VAC	440 HP	300 A	300 A	100%	3.60 Ω	A100P300
M3452-U600YK6	115-120 VAC	875 HP	600 A	300 A	50%	1.95 Ω	A70QS600
M3452-U800YK9	115-120 VAC	1170 HP	800 A	400 A	50%	1.40 Ω	A70QS800
M3452-U1200YK10	115-120 VAC	1750 HP	1200 A	600 A	50%	0.91 Ω	A70QS800
M3452-U1600YM14	115-120 VAC	2300 HP	1600 A	1200 A	75%	0.68 Ω	N/A

6.2. Watt Loss

Table 6-6: Watt Loss

Unit Peak Current	Control Power Watt Loss	Heatsink Watt Loss
200 A	55 W	500 W
300 A	55 W	750 W
600 A	55 W	750 W
800 A	55 W	1000 W
1200 A	55 W	1440 W
1600 A	55 W	2500 W

6.3. UL 508A Short Circuit Current Rating

When braking transistors are used with Underwriters Laboratories listed or recognized drives, the short circuit current rating (SCCR) is determined by the SCCR rating of the attached drive.

6.4. Fuse/Circuit Breaker Sizing and Rating

Each module (except the 1600 Amp M14 chassis) comes equipped with its own internal DC bus fuse. ***If the fuse happens to fail, it is not recommended to replace the fuse and reapply power. Further damages could result*.** Consult Bonitron if this situation arises.

If you wish to place fuses in your DC link, coordinate the fuse size with the proper wire size used in your link as per local codes and regulations. Fast acting semiconductor type fuses should be used.

6.5. DC Bus Link Length Limits

The distance that the chopper is mounted from the main DC bus filter capacitors within the drive is limited by the amount of inductance in the connection. During switching, the inductance in the DC bus between the chopper and capacitors stores energy that must be absorbed by the snubbing circuit in the chopper.

In general, this distance should be kept to a maximum of 30 feet total (10m), or 15 feet (5m) for the DC+ link and 15 feet (5m) for the DC- link.

The values listed in Table 6-7 are the maximum inductance allowed in the DC bus link to and from the filter capacitors in the drive and the chopper connections.

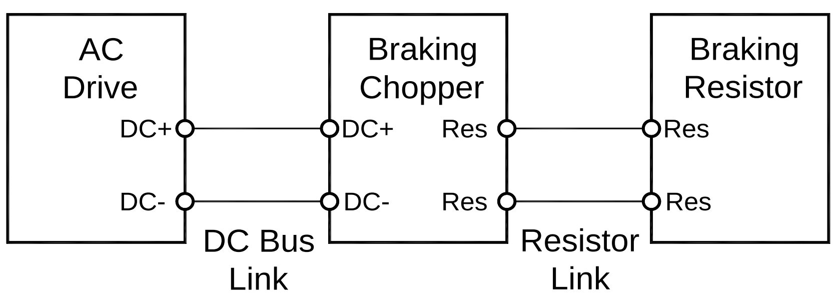
Table 6-7: Maximum Inductance for DC Link Cable

Unit Peak Current	Maximum Inductance
200 A	620 µH
300 A	275 µH
600 A	70 µH
800 A	39 µH
1200 A	34 µH
1600 A	58 µH

The distance between the DC bus filter capacitors and the braking chopper can be increased by using lowering the inductance of the buswork or cables. Typically this means using buswork or cable with a higher cross sectional area. The inductance of the buswork can be calculated from the length and inductance/foot published by the cable manufacturer. There are also standard tables to help this calculation.

If there is an extreme distance with inductance that cannot be removed from the DC bus, additional bulk capacitance can be added to decouple the DC bus inductance from the system, or the chopper can be repositioned to minimize the distance from the DC bus filter capacitance.

Figure 6-1: DC Link



6.6. Resistor Link Length Limits

The distance that the resistor is mounted from the chopper is not a concern for the chopper as the components used will not be affected by this inductance.

Some ceramic or wirewound resistors can have significant inductance, grid or plate resistors do not. In very extreme cases, the inductance of the resistor and connecting cables may limit the risetime of the current to the resistor, but this will not have an impact on chopper operation.

6.7. DIMENSIONS AND MECHANICAL DRAWINGS

Figure 6-2: M3452 K6 Chassis Dimensional Outline Drawing

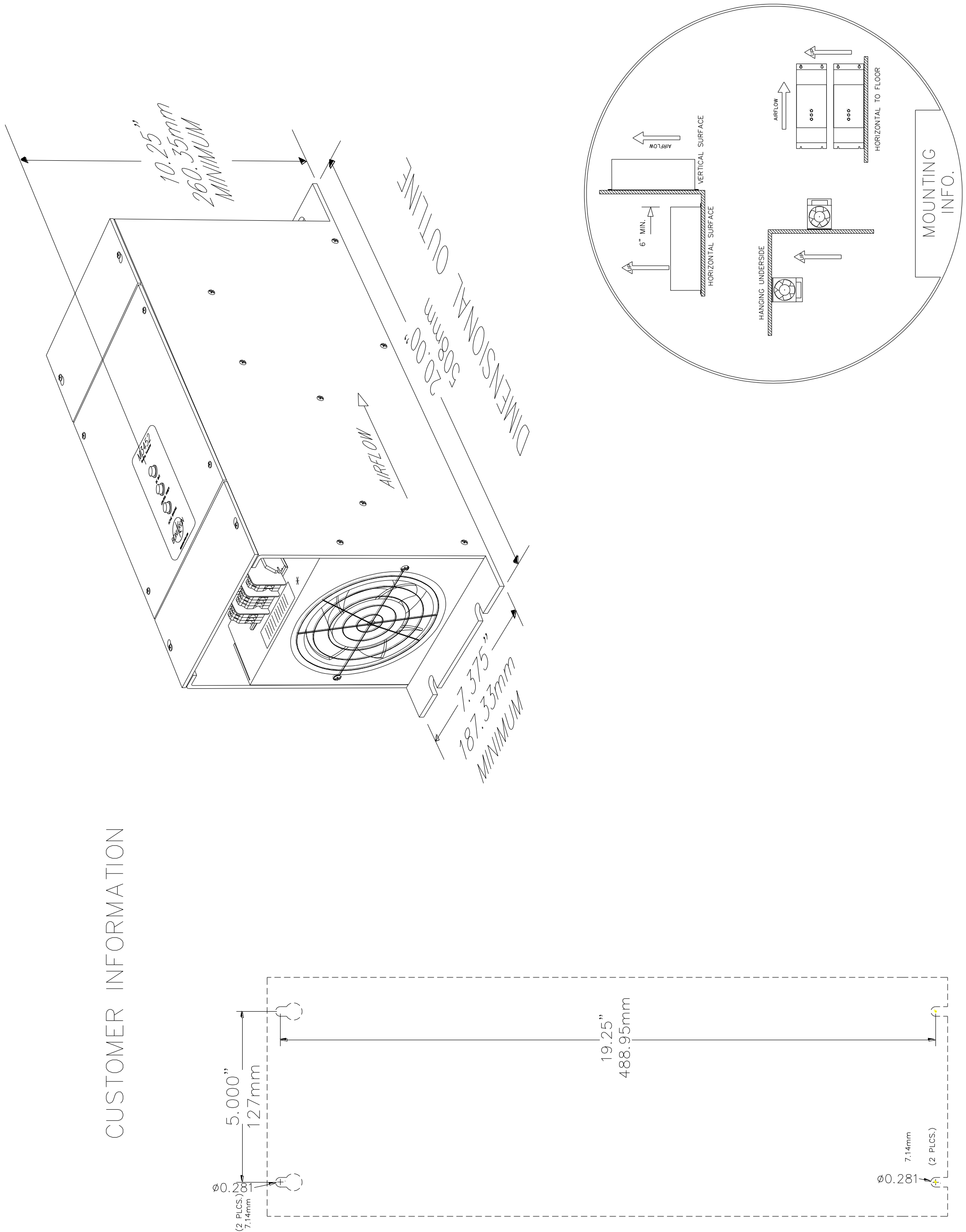


Figure 6-3: M3452 K9 Chassis Dimensional Outline Drawing

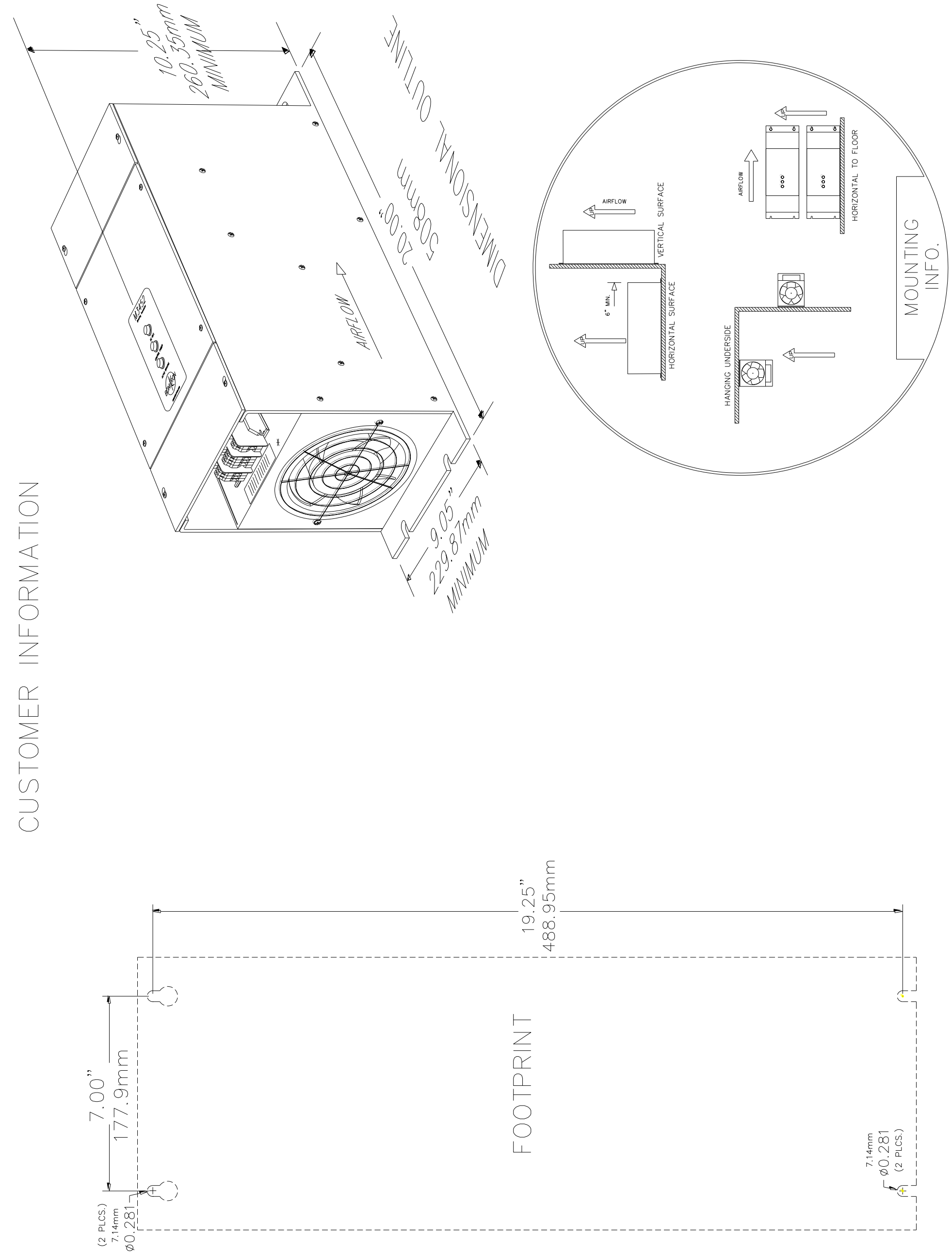
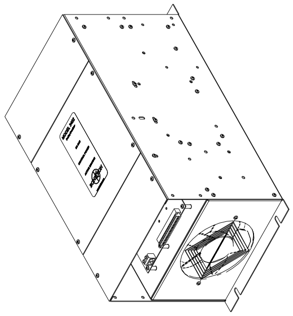
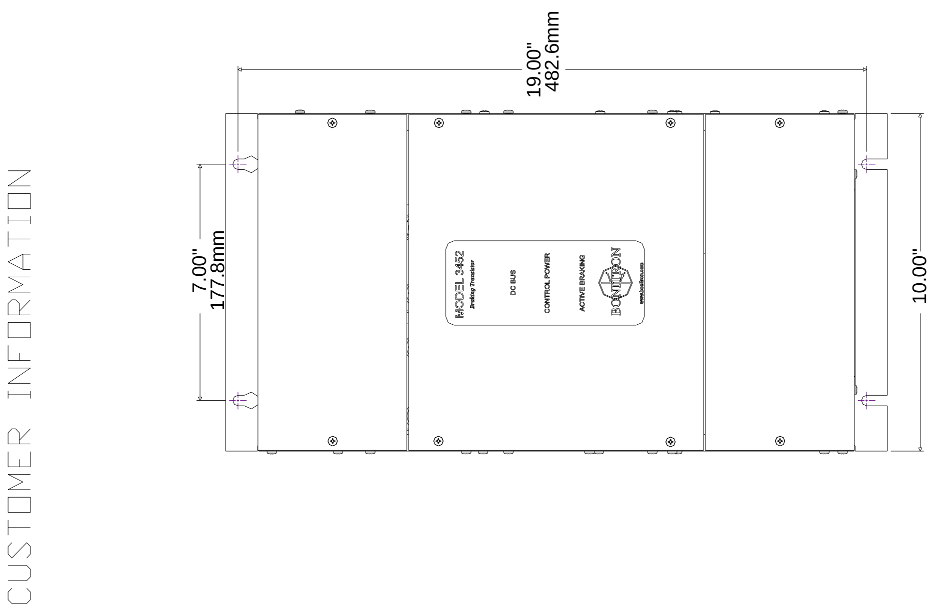


Figure 6-4: M3452 K10 Chassis Dimensional Outline Drawing





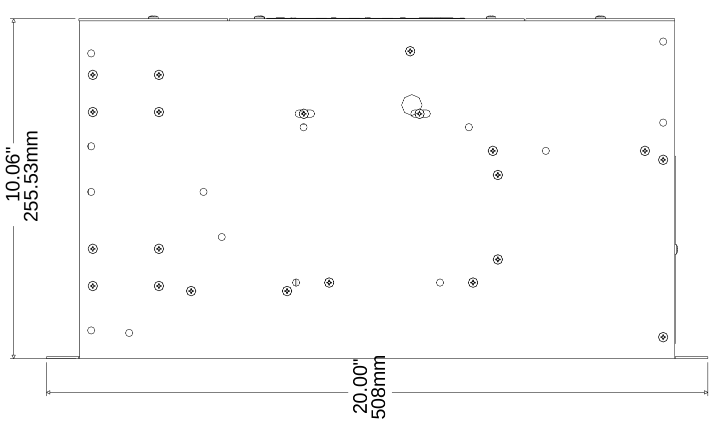
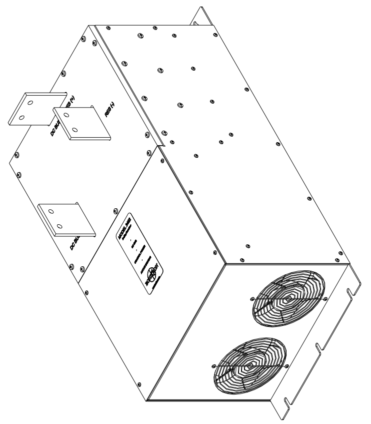
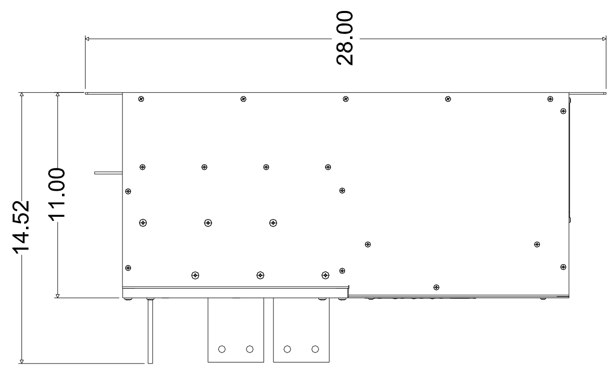


Figure 6-5: M3452 M14 Chassis Dimensional Outline Drawing





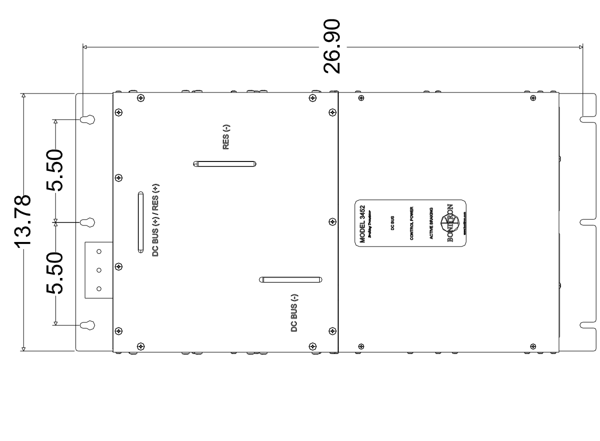
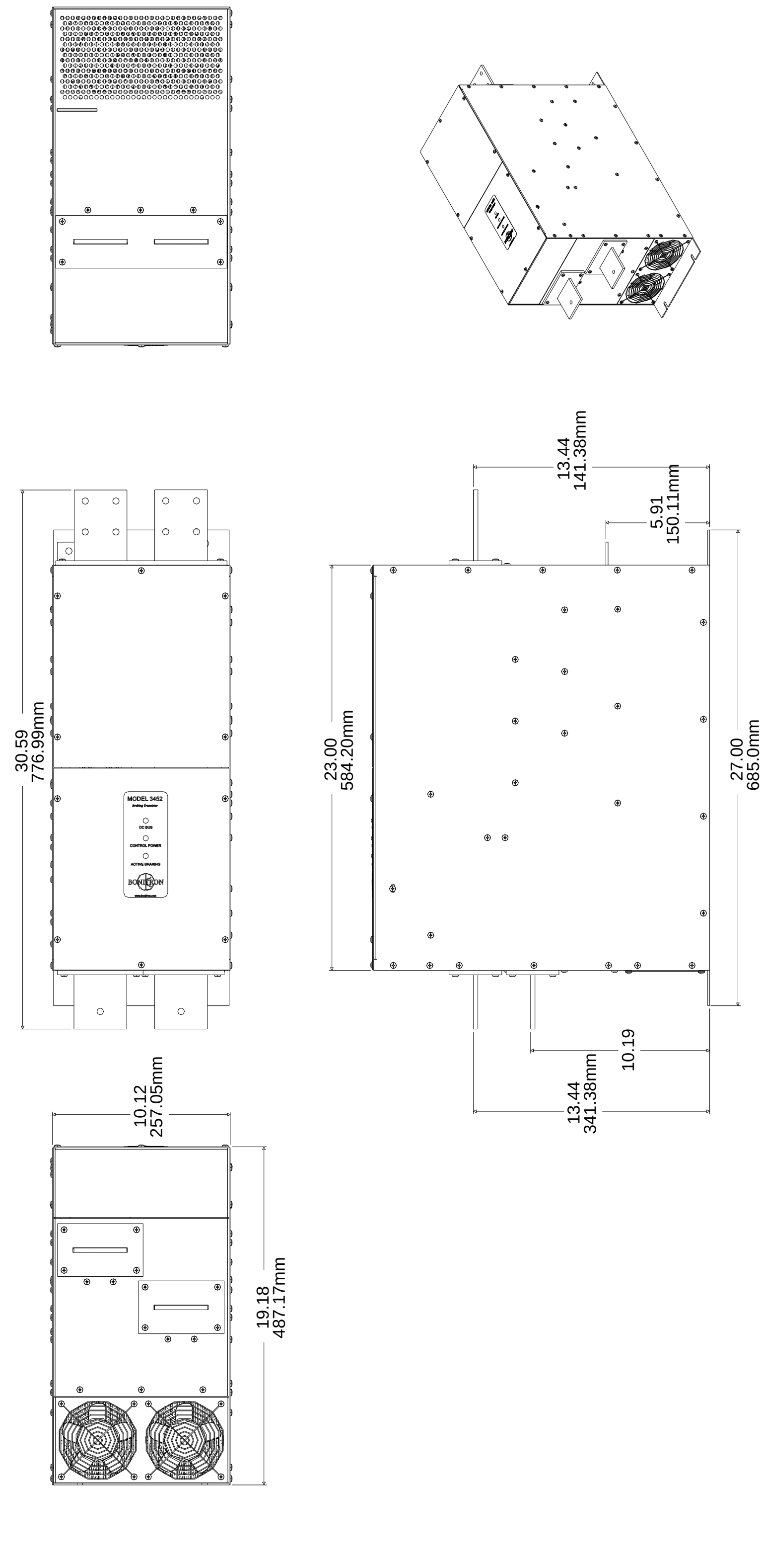


Figure 6-6: M3452 T10 Chassis Dimensional Outline Drawing



6.8. BLOCK DIAGRAMS

Figure 6-7: Block Diagram (All 200A thru 1200A and 1600A in T10 Chassis)

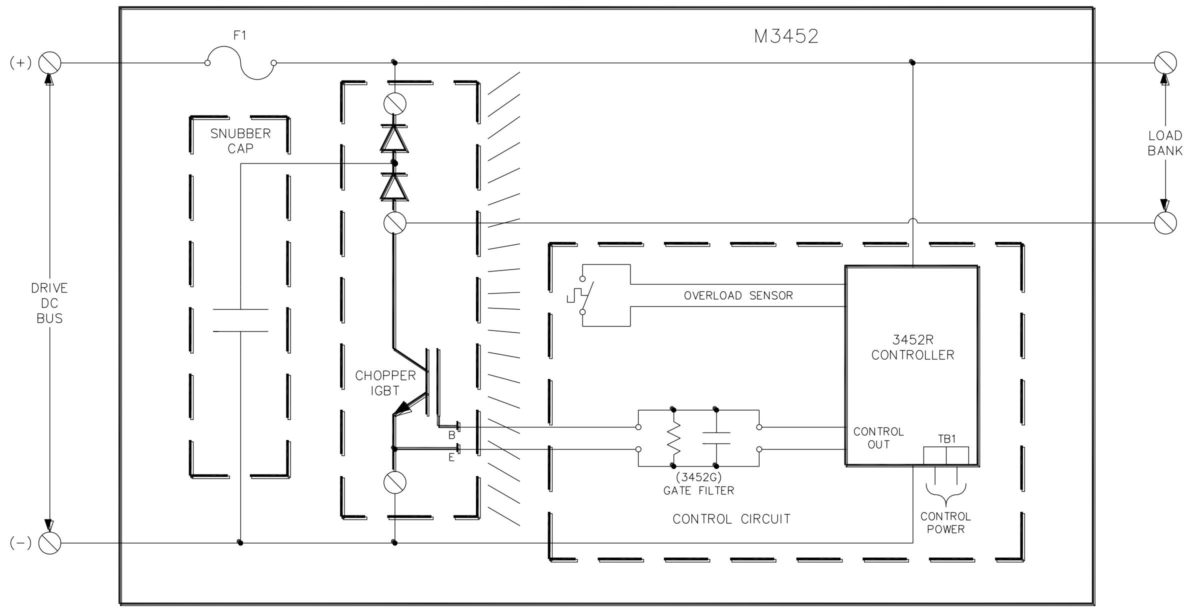
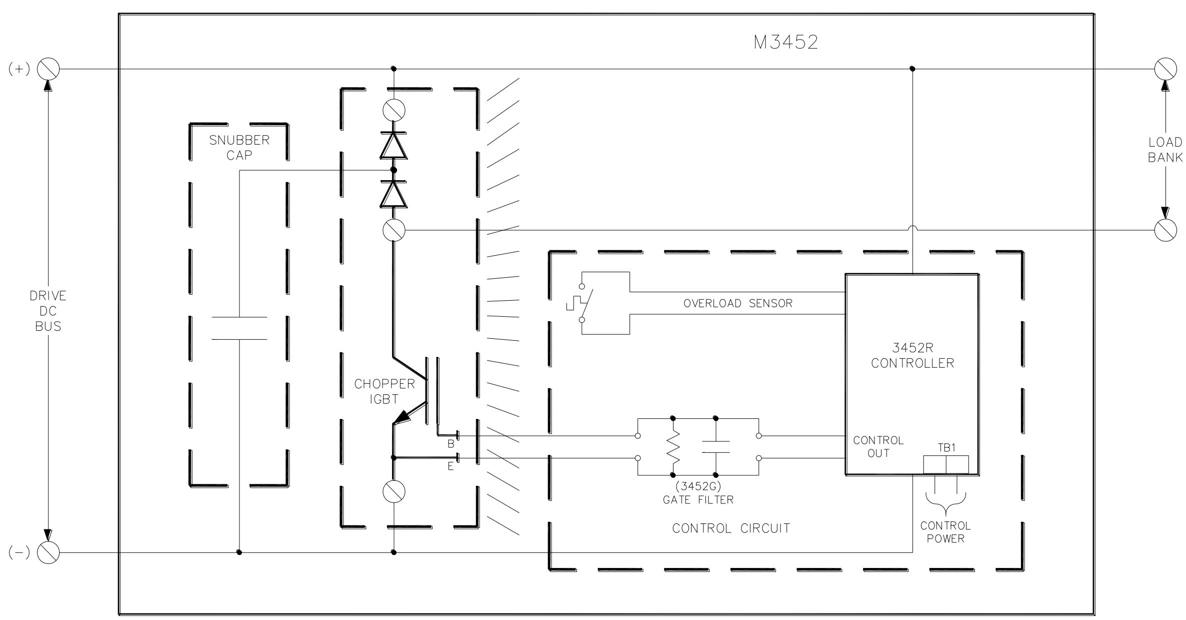


Figure 6-8: Block Diagram (1600A in M14 Chassis)



7. APPENDICES

7.1. APPLICATION NOTES

7.1.1. SIZING YOUR BRAKING REQUIREMENTS

Braking transistor modules are sized by peak current requirements and system voltage. Please use the following guidelines:

- Verify the amount of peak power needed for braking. This must be determined from the mechanical system layout, and should be calculated in either peak watts or horsepower.
- VFD's are rated for braking power as well as peak braking capacity. This information is available in the drive manual. This will be the maximum amount of power that the output inverter stage of the VFD can absorb from the load before having an overcurrent condition. Refer to your VFD documents for information on drive sizing. Keep in mind that the current rating of the drive is for three phase current, not DC bus current. The braking current in the DC bus will be higher than the AC current absorbed from the load.
- Because Bonitron braking transistor modules are rated for peak current, determine the *peak* braking power required.

7.1.1.1. HORSEPOWER TO WATTS

Once the braking requirements for the mechanical load are determined, multiply the horsepower by the scaling factor of 746 to determine the wattage required. For instance, with a 400 HP system, the peak braking power may be 600 hp. In this case the peak power required would be:

$$P_{brake} = H.P._{Braking} * 746 \qquad P_{brake} = 600\,H.P. * 746 = 447600\ watts$$

7.1.1.2. PEAK AMPERAGE

The peak amperage of the braking cycle can be determined by dividing the peak braking wattage by the system bus trip point of the braking transistor module used. If the above example were on a 480 VAC system, the trip point is 750 VDC, as determined from Table 2-3: In this case the peak current required would be:

$$I_{brake} = P._{Braking} / 750VDC \qquad I_{brake} = 447600\ watts / 750VDC = 596.8\text{ADC}$$

In this case, a 600 Amp module should be used.

7.1.1.3. OHMIC VALUE

The ohmic value of the resistive load can usually be determined from the Tables in Section 6-1. The ohmic value shown indicates the capacity of the braking transistor module, and may not be directly related to the horsepower of the drive. In order to calculate the required ohmic value for the braking load, use the following formula:

$$R_{brake} = {(V_{DCbus})^2} / {P_{brake}}$$

The DC bus voltage for the equation is determined by the level that the drive begins braking. For 460/480 VAC systems, this is typically 750

VDC, for 230 VAC systems, it is typically 375 VDC. Refer to your drive manual for specifics.

For the above example, the ohmic value would be:

$$R_{brake} = {(750VDC)^2}/{447600\ watts} = 1.26 ohms$$

This value must be verified with the ratings of the braking transistor module selected that it is not less than the “minimum ohmic value” for that model. If so, the braking requirements may be more than the braking transistor module can absorb, and a larger module may be required.

It is also possible to parallel two modules with two separate braking resistors to achieve the braking power required.

If the ohmic value calculated is greater than the value listed in the ratings table, it is possible to select a resistor value lower than the calculated value.

7.1.1.4. DUTY CYCLE

The duty cycle is based on the amount of time the drive is actually braking as opposed to accelerating, running at constant speed, or idle. For instance, if a pick and place operation requires 3 seconds to accelerate, traverses for 44 seconds and then decelerates for 3 seconds, the total cycle time is:

$$T_{cycle} = T_{acc} + T_{run} + T_{dec} = 3 + 44 + 3 = 50 \sec$$

The duty cycle for braking is:

$$\%_{duty} = {T_{dec}}/{T_{cycle}} = .06 = 6\%$$

This rating assumes the load will be linearly decreasing from peak braking power to zero braking as the load comes to a stop.

Check this rating against the modules duty cycle rating, and if it is higher than rated, go to the next higher rated module. If a duty cycle is required over 50%, please call for assistance with your application.

7.1.1.5. CONTINUOUS RATING

The continuous rating is listed for long term heating calculations should the unit be installed in an area where heat dissipation is an issue. The rating is based on a triangular cycle that starts at peak value and reduces to zero within the rated duty cycle. Therefore, the average braking power during the deceleration cycle is ½ the power required if full power was required during the entire braking cycle. This value is:

$$P_{continuous} = P_{peak} * \%_{duty} / 2$$

For the above example, the

$$P_{continuous} = 447600\text{W} \ * 6\% / 2 = 13428\, W$$

7.1.2. COMMON BUS APPLICATION NOTE

Bonitron dynamic braking transistor modules are designed to be compatible with individual stand-alone inverter/drive systems, or systems that incorporate a common DC bus arrangement. The common DC bus can be composed of multiple inverter/drive sections tied together where all or some of the sections use their respective AC input, or there may be a large independent master DC bus supply feeding the DC inputs of all inverter/ drive sections. In the case of the large master DC bus supply, it is common to find multiple rectifier sections in parallel to provide very high power levels. Some high power systems also include redundant or back up sections as well.

Once power is applied, all Bonitron modules are designed to be sourced from DC buses that have all the bus capacitors present.

Common DC bus systems composed of separate master DC bus or rectifier sections have important imbedded differences. It is common to have a main distributed DC bus, and this is typically where the dynamic braking transistor modules connect. In this way, the dynamic braking system is always present, even if some of the inverter/drive sections need to be removed from the bus for maintenance or other purposes. In emergency situations, it may even be necessary to "limp" along until repairs or swap outs can occur. Even though the modules are well suited for use in these systems, the following modes of operation could arise or exist and **<u>are not allowed</u>**:

- **<u>Do not</u>** connect the dynamic braking transistor module on the rectifier side of a DC link choke. The connections must always be made to the inverter/drive side directly to the DC bus capacitors. During normal system operation, the choke can cause the braking system to begin ringing. This ringing causes high voltages that will damage the system.
- **<u>Do not</u>** energize the system with no inverters/drives present on the distributed DC bus.
- **<u>Do not</u>** energize, operate, or run the system with less than 60% of the total expected system capacitance present.
- Operating the modules in conditions 2 and 3 may make the modules respond to inbound line transients caused by SCR type rectifiers, powering up the system, or any number of other sources. Without sufficient DC bus capacitance, the DC bus will not be filtered, and can cause ringing that will produce high voltages that will damage the system.
- In some drives, the pre-charge contactor may open under fault conditions, leaving the bulk system capacitance only resistively coupled to the dynamic braking transistor modules. **<u>Do not</u>** enable the modules in this situation. Review the inverter/drive DC bus pre-charge circuit operation with the drive manufacturer.

If there is the possibility of these situations:

- Open the enable input on the R8 option.
- Use a properly rated contactor in series with the modules' control voltage AC Input. The modules are effectively disabled when they do not have their control power.
- Keep the modules disabled during power up or any other time until all system capacitances are present.
- Disable the modules in the event system pre-charge contactors open.

Always consult Bonitron with any questions or concerns surrounding this topic.

7.1.3. Bonitron Line Regeneration Modules

The Bonitron line regens return regenerative energy back onto the AC line instead of dissipating the energy as heat in a resistor, and are ideal for applications with high duty cycles, frequent deceleration, or where heat from a resistor may be an issue. The regenerated energy is returned to the AC line with near-unity power factor and can be used to power other equipment, which quickly offsets the slightly higher initial investment of the line regen solution.

NOTES