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SpindleBlok®

Owner's Manual

©MTS Systems Corporation 2001
Version 1.0

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1. GENERAL SAFETY PRECAUTIONS

Before designing a system or machine that will contain a SpindleBlok module or before installing and operating a SpindleBlok module, it is extremely important that you read this section very thoroughly and carefully. The SpindleBlok module will deliver years of reliable, trouble-free, and safe operation if the cautions and warnings outlined in this section are heeded and the subsequent instructions in the remainder of this manual are followed.

Throughout this manual *three* unique symbols will be used to identity hazardous and potentially dangerous situations. The symbols are described here:



The electrical shock symbol shown to the left is used to indicate situations where ELECTRICAL SHOCK hazards may exist. Follow these warnings to avoid electrocution of the user or other serious potential issues that could result in serious injury or death.



The DANGER symbol shown to the left is used to indicate situations (other than electrical hazards), which are clearly dangerous to either you or to the product. Follow these warnings to avoid serious injury to you and damage to the product.



The CAUTION symbol shown to the left is used to indicate situations where the chance of minor or moderate injury to yourself or the product exists. Follow these warnings to avoid injury to you and damage to the product. The following indicates a partial list of warnings, precautions, and points of concern that must be addressed to ensure safe operation of the SpindleBlok module and the machine it is installed in. Other more specific precautions are indicated in the appropriate sections of this manual. As you read through the manual, pay particularly close attention to these cautions and warnings as they could save the life of the user!



Dangerous voltages, currents, temperatures, and energy levels exist within this unit, on certain accessible terminals, and at the motor. NEVER operate the unit with its protective cover removed! Exercise caution when installing and applying this product. Only qualified personnel should attempt to install and/or operate this product. It is essential that proper electrical practices, applicable electrical codes, common sense and suggestions in this manual be strictly adhered to.



Motors can develop high torque and speed. Use extreme caution during development of applications and integration into the system. Sudden motor motion may occur during execution of software programs. All software should be verified for proper operation before integration into your system. The motor may continue to rotate upon removal of power to the unit. It is your responsibility to ensure that no dangerous motion occurs due to gravity loading or free-running motors upon unit shutdown. Fail-safe brakes may be interfaced to the unit to prevent such dangerous conditions.



Rotating machinery can cause serious injury or death. Use extreme caution when near any rotating machine. Never wear loose clothing (e.g., neck ties) nor allow hands and feet anywhere near a rotating shaft. Always wear safety glasses when you operate rotating equipment. Refer to OSHA rules and regulations, as well as the CE Machinery (IEC 204-1), when

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designing a mechanical system that includes a motor and drive to ensure that the user is protected.



Motors can have surface temperatures of up to or exceeding 130°C, and can store heat for some time. Use caution when handling the motor or anything mounted directly to the motor or its shaft, as they can be hot enough to cause potentially serious injury even after the unit has been de-energized for some time.



Dangerous high voltages exist in this product. Be certain the power has been removed for at least 5 minutes before any service work or circuit board configuration changes are performed.



SpindleBlok products are not suitable for use in explosive atmosphere, or in a "Hazardous (Classified) Location". See Article 500 of the National Electric Code.

Temperature of the heatsink can exceed 60°C, which could cause discomfort or injury to an operator. The end user should be protected from casual contact with SpindleBlok heat exchangers. During diagnostic testing and machine development, exercise caution when determining the temperature or when touching the heat exchanger hardware.

Secure mounting and proper grounding of both the SpindleBlok and the BLDC motor is essential for proper operation of the system. Pay particular attention to the suggested wiring diagrams, as noise currents injected into the motor frame must be returned to the drive chassis, and the loop area must be minimized to meet applicable EMC standards.

It is your responsibility to follow the appropriate federal, state, and local electrical and occupational safety codes in the application of this product.

NEVER wire the unit with the power on! Serious injury as well as damage to the unit may result.

NONE of the inputs to the unit are to be used as EMERGENCY STOP in *any* application. These inputs go to a microprocessor-input port, where software determines the proper action - activation of these inputs will discontinue motion or disable motor current. However, these inputs are NOT designed as fail-safe E-STOP inputs. Relying exclusively on inputs of the unit to cease motion, which could cause dangerous conditions, is a violation of Machine Safety Codes (ref. IEC 204-1). Other measures such as mechanical stops and fail-safe brakes must be used in these situations.

All electronic equipment is susceptible to damage from static discharge. Static control precautions are required when crating and uncrating, storing (in inventory at your factory), moving to the factory floor, installing, testing and servicing the SpindleBlok product. Component damage may result if good static control procedures are ignored. When installing the module, connect the ground wire as soon as possible. Keep hands and tools away from the electronic circuits as much as possible. Non-conductive materials (paper, plastic, Styrofoam, tape, etc.) should not be used on or around the module as they can generate a high static charge.

Printed circuit boards are not field repairable. Attempting to modify or repair these components will invalidate the warranty and could negate the solid state protection features designed and tested into the SpindleBlok family of products, which could cause serious collateral damage if an impaired system is powered up.

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2. INTRODUCTION

Scope

The Purpose of this document is to provide the user with the required information to set up and run a SpindleBlok with a three phase AC induction motor. The intended audience is PC literate, is familiar with oscilloscopes and has a basic understanding of motor drive systems. If there are any questions or problems please contact an Applications Engineer at the New Ulm Facility 1-507-354-1616 or your local representative.

Unpacking and Inspection

Carefully unpack the drive and inspect it for visible damage. Check items against the packing list. Report any missing or damaged items to your supplier.

Warranty and Service

The servo drive is warranted to be free from defects in workmanship and materials for a period of two years from the original shipment by MTS Automation Division.

During the warranty period, a defective unit will be repaired or replaced as outlined below.

Before requesting return authorization, please try to verify that the problem is within the drive, and not with external devices.

To arrange for repair or replacement, please contact:

MTS Systems Corporation Automation Division Customer Service
(507) 354-1616
(800) 967-1785
Monday–Friday, 8:00–4:30 Central Time

- You must provide the model and serial number from the labels on the drive.
- You must provide an explanation as to why the unit is being returned.
- You will be issued a return authorization number, which must be marked on the return shipment and on all correspondence.

Service Under Warranty

- Return your defective unit, freight prepaid, and it will be repaired and returned within two weeks of receipt via regular UPS, freight prepaid.
- Upon request, a factory-repaired replacement unit will be sent via regular prepaid UPS, within 4 working days. Next day shipment for overnight delivery, freight collect, is available at an expediting charge of $100. The defective unit is to be returned via regular UPS, freight prepaid, upon your receipt of the replacement.

Non-Warranty Service

- Return your defective unit, freight prepaid, and it will be repaired on a time and material basis and returned within three weeks of receipt.
- OR contact your local distributor or MTS Automation Customer Service for a factory-repaired exchange unit, which is available at a flat rate price, assuming the defective unit is in repairable condition and is returned freight prepaid. Next day shipment for overnight delivery, freight collect, is available at an expediting charge of $100.

General Provisions

Except as specifically modified by this warranty statement, all MTS Automation Conditions of Sale and Warranty shall apply.

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Spindle Drive for Use on AC Motors

The SpindleBlok™ operates three-phase rotary AC spindle motors, 1-20Hp, without the need of a sensor. The leading edge SensorlessServo™ technology replaces the physical sensors such as encoder and resolver with a software algorithm. The algorithm calculates speed and torque information from current and voltage measurements. The rotor speed is fed to the PI servo system within the drive. The result is a three-phase sinusoidal vector drive without the need for a physical sensor on the motor.

SpindleBlok Features

The SpindleBlok incorporates MTS Automation's SensorlessServo technology with four-quadrant torque and speed control without the need of a motor mounted feedback device. In addition, SpindleBlok also offers the following unique features.

100:1Constant Torque Speed Range

SensorlessServo control delivers full torque down to 1% of motor rated speed eliminating mechanical gear changes for your heaviest cuts.

5:1 Constant Power Range

SensorlessServo control delivers high-speed output performance eliminating mechanical gear changes for your finishing operating.

400 Microsecond Servo Velocity Loop Update Rate

Spindle speed is controller by the SensorlessServo Algorithm providing dynamic control over the full range of cutting load.

Up to 250% Overdrive Torque

The available torque from 1% of rated speed to rated speed of the spindle motor prevents the spindle from stalling due to transient overloads.

Programmable Application Features

Flexibility is built in to meet the expectations of the machinery builders (Spindle Orient, High/Low Inertia Tuning, Constant Torque, and Constant Power).

Motor Application Features

SensorlessServo control can be configured to match the constant torque, constant power, and constant slip region of your spindle motor to optimize spindle performance requirements.

SpindleBlok Configuration Tool

Software for motor setup, tuning, and application configuration.

Data I/O

- RS485 Serial Communications
- ±10V Analog Input
- 1 Fixed Digital Inputs (Run Enable)
- 7 Programmable Digital Inputs
- 2 Programmable Open Collector Outputs
- 2 Programmable Analog Outputs
- 2 Programmable Relay Outputs

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Ordering Information

Part Numbering System

The following information explains how a SpindleBlok part number is established.

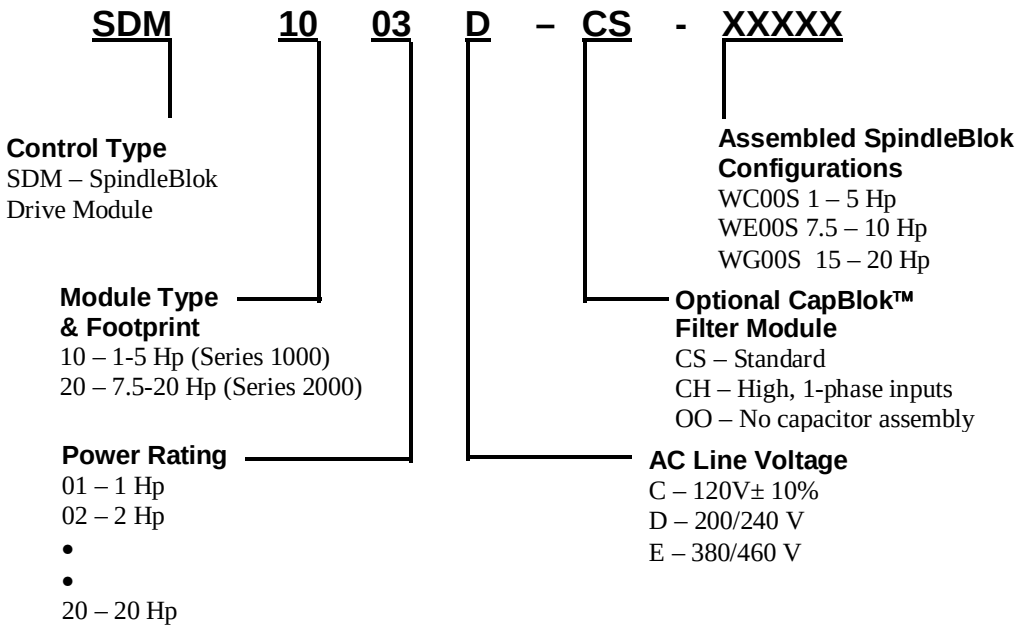


Figure 2-1

Part Number Description

SpindleBlok with CapBlok™ DC Bus Filter Capacitor

By including the additional capacitor assembly part number to the module ordering number, the module would be supplied with the appropriately rated electrolytic filter CapBlok capacitor assembly. The capacitor assembly and PowerBlok are shipped together in the same box, however final assembly is required. Assembly instructions are provided later in this manual.

SpindleBlok Module Only

The first 8 digits of the ordering part number identify the basic SpindleBlok module.

Assembled SpindleBlok Configurations

MTS Automation offers standard assembled drive configurations that include the CapBlok, heat sink, fan and other options. Refer to the section later in this manual or contact the factory for availability and form factor specifications.

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3. WIRING AND INSTALLATION

Connection Diagrams

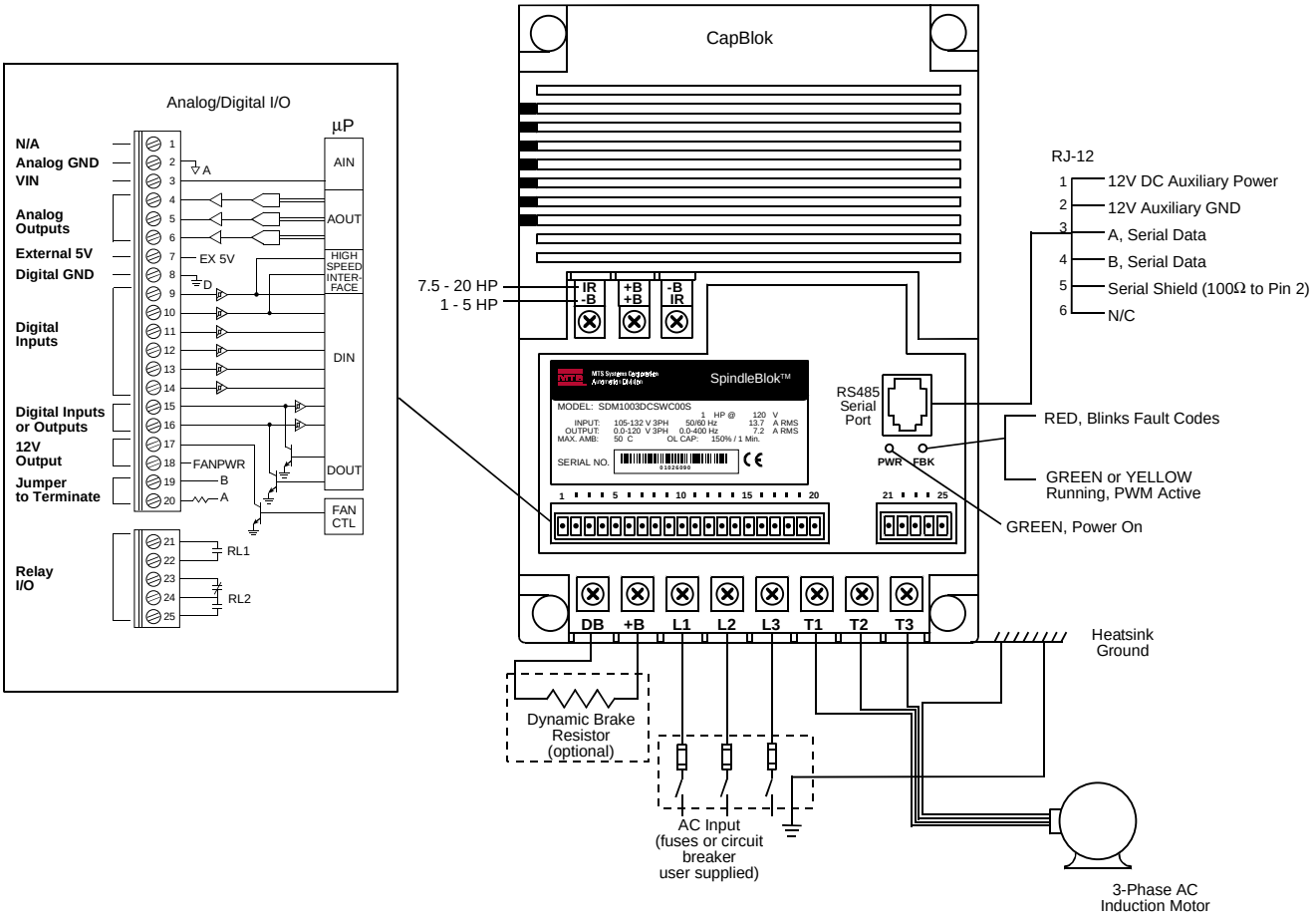


Figure 3-1

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Mounting and Environmental Considerations

Mounting Location

SpindleBlok AC drives are designed to be wall or panel mounted, depending upon the drive enclosure rating. Ambient temperature should be within the drive specification. If drives are installed inside of another enclosure, the specified ambient temperature range must be maintained inside the enclosure containing the drives. The mounting location must be rated to handle the heatsink temperatures of up to 88°C (190°F).



CAUTION AVOID TOUCHING THE DRIVE HEATSINK DURING AND FOR SEVERAL MINUTES AFTER OPERATION. NORMAL OPERATING TEMPERATURES MAY CAUSE BURNS. INSURE THAT THE MOUNTING LOCATION IS SUITABLE FOR THE EXPECTED TEMPERATURES.

In general, the mounting location should meet the following criteria.

- Temperature maintained within the drive specified operating range discussed on the preceding page.
- Not prone to large temperature swings which could cause condensation.
- Humidity maintained within a range that will not result in condensation.
- Away from dripping or splashing liquids unless the enclosure carries a NEMA 4 rating.
- Atmosphere is free from corrosive gases and/or conductive dust.
- Vibration does not exceed the specified rating.

If the drive is installed in an area where ambient temperature may drop below freezing when it is required to operate, the drive should be installed in an enclosure equipped with a thermostatically controller space heater with sufficient wattage to keep the temperature inside the enclosure above freezing. Space heaters should also be considered when temperature and relative humidity are such that condensation is probable.

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Recommended Clearances

Drives must be mounted in a manner to allow sufficient cooling of the heatsinks. Refer to the diagram below for suggested mounting configurations. Note the minimum spacing required to mount multiple drives in close proximity to each other.

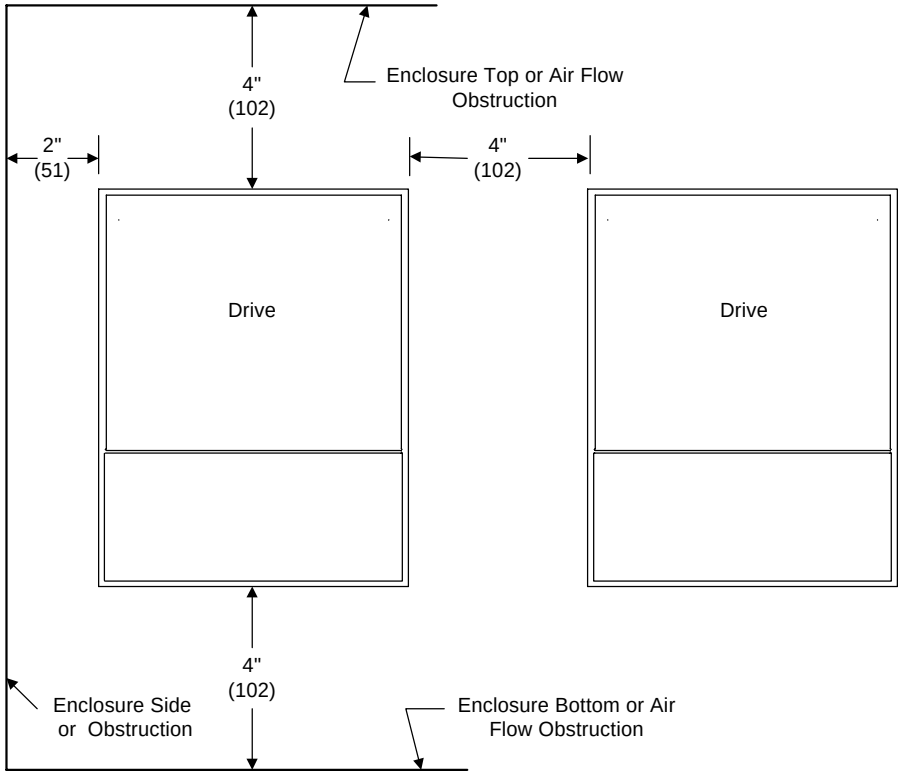


Figure 3-2

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Motor Selection

The SpindleBlok is designed to be connected directly to a single, three-phase permanent magnet brushless motor. The motor must be selected and applied so that the average operating motor current and kW do not exceed the continuous current and kW ratings of the drive. The intermittent operating current must not exceed the intermittent current rating of the drive.

Today, most brushless servo motors and drives are oversized with significant amount of headroom. Our goal is for you to choose the smallest motor and drive system to meet your application requirements. Choose a motor with the highest BEMF constant by calculating the largest BEMF constant based on the maximum speed, maximum current and bus voltage (e.g. Max speed – 2000 rpm, Input Voltage = 230VAC, find largest BEMF = 230V rms/2 krpm = 115 Vrms = 162 V pk). For more information, consult the MTS Automation product catalog, contact our Application Engineering Department, or visit our website http://www.mtsautomation.com

Heatsinking and Thermal Design - Cooling the SpindleBlok

The total energy delivered from the motor shaft has to flow through the drive module – and the more rugged the application is the more heat the SpindleBlok will generate. Keep the SpindleBlok mounting surface below 90°C under absolute worst case conditions. Internal device temperatures are guaranteed to be at safe levels if you do not exceed maximum rated RMS output current and maintain the baseplate at or below 90°C. **Failure to follow this guideline will cause nuisance over temperature trip and may degrade the life of the SpindleBlok module.**

There is more information on the MTS Automation website http://www.mtsautomation.com concerning this critical issue. Find and evaluate the Application Notes and software tools provided to calculate the required device heatsinking and airflow to maintain a reliable design margin.

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Quick Start

In our product literature certain items are labeled “Quick Start” these items are written for a user who is familiar with *installing*, *configuring*, and *operating* motion control products.

1. Mount the drive module to the HEATSINK *if not already mounted*.
2. Mount the CAPACITOR ASSEMBLY *if not already mounted*.
3. Connect the Dynamic Brake Resistor Bank *if appropriate*.
4. Connect the COMPUTER.
5. Connect the MOTOR.
6. Connect the POWER CABLES.

Without a proper cooling system (e.g. heatsink, fan), the drive module will not operate reliably. Visit the following website address, http://www.mtsautomation.com for information and tools to design an appropriate cooling system.

Without a proper capacitor assembly, the drive module will not operate reliably. Please visit the following website address, http://www.mtsautomation.com for information and tools to design a proper capacitor assembly.

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Wire Size, Circuit Breaker, Fuse Information Table

120 V, 1-phase	Module	1001C	1002C	1003C	200V – 240V, 1-Phase	1001D	1002D	1003D
Input								
Input Current	Arms	8	15	20		6.5	12	18
Max Wire Size[1] (AWG)		12	10	8		12	10	8
Line Fuse, Bussman type		KTK-30	JNN-70	JNN-80		JJN-70	JJN-70	JJN-80
Fuse Class		KTK	300V T	300V T		300V T	300V T	300V T
Branch Circuit Breaker	Arms	15	30	40		20	30	40
Inductance $_{1\%\ 120\ VAC}$	mH							
Inductance $_{5\%\ 120\ VAC}$	mH							
Output								
Cont. Output Cur.	Arms	4	7.2	10.4		3.6	6.8	9.6
Braking Resistance $_{Min}$	Ohms	30	22	15		50	50	35
Brake Resistor Inductance $_{Max}$	mH	1.3	1	0.7		2.3	2.4	1.5
Fan Start Current $_{Max}$	Amps	0.6	0.6	0.6		0.6	0.6	0.6
Fan Run Current $_{Max}$	Amps	0.3	0.3	0.3		0.3	0.3	0.3

200V – 240V, 3-Phase	Module	1001D	1002D	1003D	1005D	2007D	2010D
Input							
Input Current		4	7.5	10.5	16.7	24	31
Max Wire Size[1] (AWG)		14	14	12	8	8	6
Line Fuse, Bussman type		KTK-8	KTK-15	KTK-20	JNN-80	JNN-50	JJN-60
Fuse Class		KTK	KTK	KTK	300V T	300V T	300V T
Branch Circuit Breaker		15	15	20	30	40	60
Inductance $_{1\%\ 230\ VAC}$	mH	1	0.5	0.36	0.24	0.16	0.12
Inductance $_{5\%\ 230\ VAC}$	mH	5	2.5	1.8	1.2	0.8	0.6
Output							
Cont. Output Cur.	Arms	3.6	6.8	9.6	15.2	22.0	28.0
Braking Resistance $_{Min}$	Ohms	50	50	35	20	15	10
Brake Resistor Inductance $_{Max}$	mH	2.3	2.3	1.5	0.9	0.6	0.5
Fan Start Current $_{Max}$	Amps	0.6	0.6	0.6	0.6	1.2	1.2
Fan Run Current $_{Max}$	Amps	0.3	0.3	0.3	0.3	0.6	0.6

380 V-480 V, 3-Phase		Module	1001E	1002E	1003E	1005E	2007E	2010E	2015E	2020E
Input										
kW			1.4	2.7	3.8	6	8.8	11.2	16.7	21.5
Input Current	380 VAC	Arms	2.5	4.7	6.7	10.7	15	20	30	37
	460 VAC		2.0	3.7	5.3	8.4	12.1	15	23	30
Min Wire Size[1] (AWG)			14	14	14	14	12	10	8	6
Line Fuse, Bussman type			KTK-10	KTK-10	KTK-15	KTK-20	JJS-25	JJS-35	JJS-50	JJS-60
Fuse Class			KTK	KTK	KTK	KTK	600V T	600V T	600V T	600V T
Branch Circuit Breaker			15	15	15	15	20	30	40	60
Inductance $_{1\%\ 460\ VAC}$		mH	4	2	1.5	1	0.6	0.5	0.34	0.26
Inductance $_{5\%\ 460\ VAC}$		mH	20	10	7.5	5	3	2.5	1.7	1.3
Output										
Cont. Output Cur.		Arms	1.8	3.4	4.8	7.6	11	14	21	27
Braking Resistance $_{Min}$		Ohms	200	200	140	80	60	40	30	20
Brake Resistor Inductance $_{Max}$		mH	9	9	6	3.6	2.4	1.8	1.2	0.9
Fan Start Current $_{Max}$		Amps	0.6	0.6	0.6	0.6	1.2	1.2	1.2	1.2
Fan Run Current $_{Max}$		Amps	0.3	0.3	0.3	0.3	0.6	0.6	0.6	0.6

Table 3-1

Bussman	Gould	Littlefuse	Classification
KTK-xx	ATM-xx	KLK-xx	KTK
JJN-xx	A3T-xx	JLLN-xx	300 V Class T
JJS-xx	A6T-xx	JLLS-xx	600 V Class T

Figure 3-2

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Line Input Considerations

- The input line conductors must be made of copper with a temperature rating of at least 167°F (75°C). Use a conductor of at least the size specified in Table A.
- Note: Verify that the input line conductor size and branch circuit overload protection are in accordance with applicable local code requirements.
- The input line and branch circuit overload protection must be rated for the input voltage and current stated on the nameplate of the drive, and repeated here in Table A.
- In addition, consider the wire size capacity of the integral module input line terminals:
- For SDM1000 type modules maximum wire size is #8 AWG
- For SDM2000 type modules maximum wire size is #4 AWG
- Input Line Fuses are required for safe application of the drive module or open-frame drive. These fast acting fuses are designed to limit the let-through current by disconnecting the drive from the power line in the event of a catastrophic failure of the power semiconductors in the drive; and to reduce or eliminate the chance of consequential damage to the drive and any associated equipment in the machine. Fuse recommendations are listed in Table A.
- The power terminal tightening torque range is 16-18 in./lbs. on input power terminals (including L1, L2, L3, T1, T2, T3, and the ground lugs).
- An input line impedance of at least 1% and not over 5% is required for proper drive operation.
- Order a 3% or 5% input line reactor to improve input line harmonic distortion as required.
- A circuit breaker is usually required for disconnecting the motor from the power source.



CAUTION An input line fuse is **ALWAYS** required to limit the current available to a failed semiconductor device. The fuse limits or eliminates the collateral damage that can occur when a drive fails catastrophically and the possibility of fire could occur. While this is a remote circumstance, it is important that all reasonable precautions should be taken to avoid the chance of consequential damages. Refer to Table A for more details on determining the correct fuse type and rating for your application. The recommended line input fuse vendor is:

Cooper Bussmann, Inc.
Post Office Box 14460
St. Louis, MO 63178-4460

Phone: 314 394 2877
Fax: 800 544 2570

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Grounding Connections and Conductor Routing

For personal safety and reliable equipment operation, *firmly* connect each chassis to earth ground as shown in the connection diagrams in the *Drawings* section of this manual.



The SpindleBlok chassis ground conductor should be the same size as the input line conductors or sized according to electrical code requirements. Use a copper or aluminum conductor. **Connection to a grounded conduit does not provide an adequate equipment ground. Ensure that all operators' control stations and motor frames are adequately grounded.**

If conduit is used, use a separate conduit for input line conductors and output power conductors. **NEVER** route analog and digital wiring from any equipment in the same conduit as input or output power wiring.

If cable trays are used, use a separate cable tray for input line conductors and output line conductors. **NEVER** route analog and digital wiring from any equipment in the same cable tray as input or output power wiring.

ALWAYS route the Input and Output Grounding conductors in the same conduit or cable tray as the respective Input or Output power leads. Preferably, these conductors should be bundled.

If multi-conductor wiring is used, a separate multi-conductor cable must be used for the input line wiring for each drive.

Isolation Transformers

Isolation transformers can be used with drive modules. Remember that the input line impedance must be at least 1% and not over 5% with the drive running. See the previous discussion on Input Line Impedance.

Power Factor Correction

The displacement power factor at the input terminals of the drive is approximately 0.95 at all operating speeds and loads. Power factor correction capacitors are not required. Furthermore, they cannot alone improve Power Factor and should not be installed. If capacitors for correcting the power factor of other equipment are installed too close to the drive, nuisance tripping of the drive may be experienced.

Standby Power Generation

Three phase standby power generators can be used with drive modules as long as the input line impedance is within the 1% to 5% range.

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Output Wiring Considerations

Use the most currently approved version of all applicable codes when installed the SpindleBlok.

Output Power Conductor and Ground Conductor Sizing

These conductor-sizing issued were discussed in the previous section and Table A. Refer to that section for details.

Output Power Conductor Routing



Long output cable runs from multiple drives in the same raceway present a unique safety concern. Since the output leads are electrically coupled when they share the same raceway, the PWM action of the inverter power stage in one unit can couple sufficient energy into the DC link of another unpowered drive to present an electrical shock hazard.

NEVER work on a drive when other drives are energized in the system.

Although the input power has been opened, **NEVER** assume the drive is intrinsically safe.

Verify that the DC link is below 30 VDC with a voltmeter before commencing service.

- *If* conduit is used, use a separate conduit for input line conductors and output power conductors. **NEVER** route analog and digital wiring from any equipment in the same conduit as input or output power wiring.
- **If** cable trays are used, use a separate cable tray for input line conductors and output line conductors. **NEVER** route analog and digital wiring from any equipment in the same cable tray as input or output power wiring.
- **ALWAYS** route the Input and Output Grounding conductors in the same conduit or cable tray as the respective Input or Output power leads. Preferably, these conductors should be bundled.
- *If* multi-conductor wiring is used, a separate multi-conductor cable must be used for the input line wiring for each drive.

Overcurrent Protection

Drive modules are designed to automatically provide overcurrent protection for the output power circuit if only one motor is connected to the drive and sized to match the drive.

If more than one motor is connected to the drive, each motor must have its own overcurrent protection. In addition, the combined current rating on the nameplate of each motor must not exceed the output current rating of the drive.

Power Factor Correction

Power factor correction capacitors must NEVER be connected to the output of the drive. They will cause severe damage to the drive and would not serve any useful purpose.

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Analog and Digital I/O Connections

Comply with local and nationally recognized codes when designing and installing the SpindleBlok in the equipment. Consider proper analog and digital signal wiring practices carefully when you are planning the application.

Analog and Digital Signal Wiring

- 18 AWG wire size is recommended. Minimum wire size is 20 AWG; maximum is 14 AWG.
- *One* conductor per terminal for 14 AWG conductors. *Two* conductors per terminal at 18 AWG. *Three* conductors per terminal at 20 AWG.
- Maximum length is 500 feet.
- Use shielded cable for the analog signal conductors where indicated on the terminal block connection diagram. Typically, shielding is required for all analog input and output runs.
- All digital signal runs should be shielded.
- Ground the shield conductor of shielded cable at both ends of the terminal block of the drive for input signals only. Output signals should not be grounded at the drive end of the cable but should be grounded at the device. Shields should be grounded wherever the best ground can be found. All grounds being equal, the shield should be grounded at the signal source, which for an output, would be at the drive.
- The analog and digital signal conductors must be made of copper with an insulation temperature rating of at least 167°F (75°C).
- 18 AWG wire size is recommended. Minimum wire size is 20 AWG; maximum is 14 AWG.

Analog and Digital Conductor Routing

If conduit is used, use separate conduit for input and output power and SpindleBlok control wiring, up to the drive. If cable trays are used, **NEVER** route analog and digital wiring from any equipment in the same cable tray as input or output power wiring.

Separate analog and digital wiring for the SpindleBlok from other control equipment wiring by using a metal tray divider or by bundling to keep the conductors at least 2 inches apart.

Trays containing analog and digital wiring should be separated from trays containing AC power wiring.

Analog Input and output Connections

There are two analog inputs: 1) a ±10 V input with 10-bit plus sign resolution and 2) a 4 – 20 mA current loop with 10-bit resolution. The inputs are protected from continuous overload Vin ±25V, Iin to +25/-5 VDC. There is no isolation from internal logic supply is provided.

The current loop input is intended to interface to a 0 - 20 mA signal, usually from a process feedback sensor. The SpindleBlok does not power the current loop - you must provide this source externally if one is required.

The voltage input (Vin) accepts a -10 to +10 V signal, which may come from any low impedance source including a potentiometer. The SpindleBlok does not provide -10V, so if you do not have it available an external supply must be provided. For a potentiometer reference, it is recommended that one of the analog outputs be programmed to +5 or +10V and used to drive the top of the speed pot.

The inputs are configurable from a list of functions. [See Appendix E.]

[See Figure 14.]

There are thee analog outputs. The outputs have 8-bit resolution and produce an output voltage of 0 – 10 volts. The outputs are protected from continuous overload of up to +25/-5 VDC. There is no isolation from internal logic supply.

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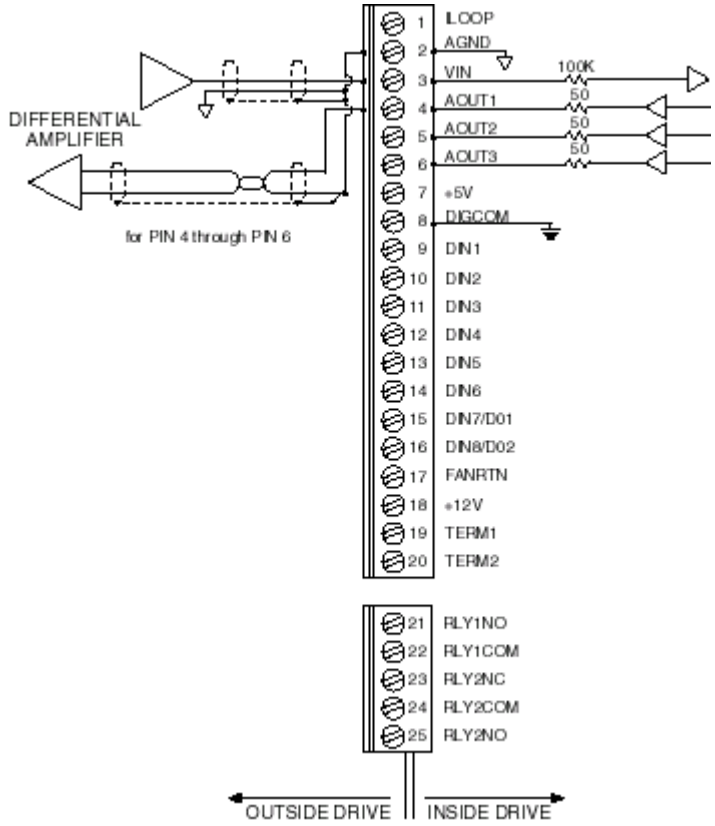


Figure 3-3

Analog Output Connection and Schematic

Digital Input Connections

There are eight digital inputs. The inputs are intended for dry contact closure and open collector use. These inputs can be configured as sourcing, sinking or passive closure and are programmable from a list of 19 functions. The logic threshold is 2.5 V. The inputs are protected from continuous overload of up to +25/-5 VDC (where shared I/O PIN 15 and 16 require a minimum external impedance of 750Ω due to their dual functions). There is no isolation from internal logic supply.

The six digital input pins (i.e., PIN 9 through 14) may be configured to be all PULLED UP or PULLED DOWN.

The two digital input/output pins (i.e., PIN 15 and 16) are PULLED UP only.

Two of the digital inputs (i.e., DIN1 and DIN2) are high-speed inputs for a home or registration input.

The inputs are configurable from a list of functions. [See **Digital Input Section**.]

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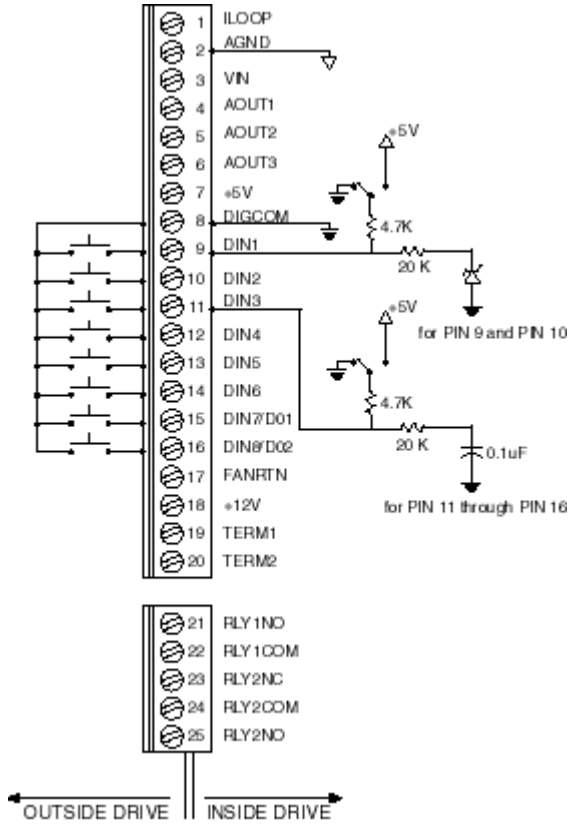


Figure 3-4

Digital Input Connections and Schematics

Digital Output Connections

There are two open-collector outputs. The outputs can be externally pulled up to +5VDC, +12 VDC, or +24 VDC and are rated at 50 mA. The outputs are internally pulled up to +5V through 4.7kΩ. The response time is 2 msec.

The outputs are configurable from a list of functions. [See **Digital Output Section**.]

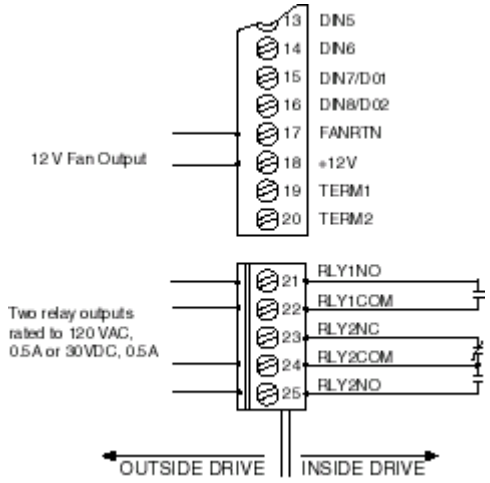


Figure 3-5

Digital Output Connections and Schematics

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Braking Resistor

Provisions are made for the connection of an external braking resistor when braking is required. There is no provision for an internal braking resistor. The braking transistor is protected from ground fault and short circuit via internal circuits. When no braking resistor is provided, braking torque is limited to the power consumed by the internal and external losses. Braking transistor duty cycle and frequency vary depending on the required braking torque, the total bus capacitance, the line voltage, and the brake circuit inductance. The braking circuit activates at a DC bus voltage of 410 VDC for 200/240 VAC drives and 820 VDC for 380/480 VAC drives. The braking resistor value can be no lower than the minimum specified value. The inductance of the braking resistor (and associated wiring) can be no larger than the maximum value specified.

Module Type	Voltage Class, VAC	Minimum Braking Resistance, Ohms	Maximum Braking Resistor Inductance mH (includes wiring)
1001C	120	25	4.6
1002C	120	25	4.6
1003C	120	18	3
1001D	200-240	50	2.3
1002D	200-240	50	2.4
1003D	200-240	35	1.5
1005D	200-240	20	0.9
2007D	200-240	15	0.6
2010D	200-240	10	0.5
1001E	200-240	200	9
1002E	200-240	200	9
1003E	200-240	140	6
1005E	200-240	80	3.6
2007E	200-240	60	2.4
2010E	200-240	40	1.8
2015E	200-240	30	1.2
2020E	200-240	20	0.9

Table 3-2

Min. Braking Resistance and Max. Inductance

For more information on sizing and applying brake resistors can be found in application notes on our web site, http://www.mtsautomation.com. The Parameters G10 (load_lim), J0C (db_pt_lim) and J0B (db_pt_wdt) are set to make an accurate thermal model of the braking resistor. With an accurate thermal model, the SpindleBlok can keep track of how much energy has been dissipated in the braking resistor and produce an estimate its operating temperature in real time. Once the parameters have been entered into the SpindleBlok, the circuitry in the SpindleBlok will protect the brake resistor even if it as been undersized for a particular application.

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Fan

Provision has been included within SpindleBlok to power an external 12 VDC fan to provide forced air cooling of the heat sink the SpindleBlok is mounted on. See table below for the maximum allowable current. See **Figure 8** for the wiring diagram of the fan(s) the drive.

Module Type	Allowable Fan Start Current, A	Allowable Fan Run Current, A	Voltage, VDC
SDM1001D	0.6	0.3	12.6
SDM1002D	0.6	0.3	12.6
SDM1003D	0.6	0.3	12.6
SDM1005D	0.6	0.3	12.6
SDM2007D	1.2	0.6	12.6
SDM2010D	1.2	0.6	12.6
SDM1001E	0.6	0.3	12.6
SDM1002E	0.6	0.3	12.6
SDM1003E	0.6	0.3	12.6
SDM1005E	0.6	0.3	12.6
SDM2007E	1.2	0.6	12.6
SDM2010E	1.2	0.6	12.6
SDM2015E	1.2	0.6	12.6
SDM2020E	1.2	0.6	12.6

Table 3-3

Allowable Fan Currents

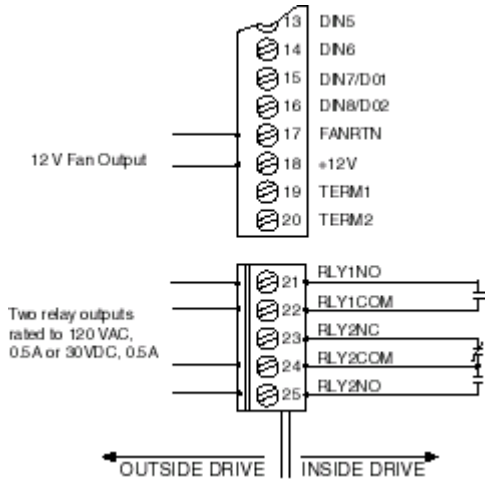


Table 3-4

Fan Output Connection

CapBlok Assembly

Semipower offers an electrolytic filter capacitor CapBlok which can be coupled with the appropriate module type or purchased as a separate item . In the table below capacitance is given for the *standard* CapBlok for the respective module types.

In the event that *more* capacitance is desired for a given drive module, a higher capacitance CapBlok can be used. However, there are few restrictions:

- The higher capacitance CapBlok must have the same voltage rating as the CapBlok it is replacing.

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- A CapBlok used on a 1000 series module can only be used on another 1000 series module . For example, a CapBlok used on an SDM1005D module type can be used on an SDM1001D module type.
- A CapBlok used on a 2000 series module can only be used on the SDM2010E and SDM2007E module types.
- A CapBlok used on an SDM2020E module type can only be used on the SDM2020E and SDM2015E module types.
- A High Capacity CapBlok (Indicated by a CH in the model number) is one size greater than the standard CapBlok (Indicated by a CS in the model number). High capacity CapBloks are not available as standard for 460V 15 Hp and 20 Hp Units.

120 VAC CapBloks

CS-1-C	0.5 Hp	CapBlok Module	120 VAC	2800 µF	50/60 Hz
CS-2-C	1.0 Hp	CapBlok Module	120 VAC	4200 µF	50/60 Hz
CS-3-C	1.5 Hp	CapBlok Module	120 VAC	4200 µF	50/60 Hz

230 VAC CapBloks

CS-1-D	1 Hp	CapBlok Module	200-240 VAC	540 µF	50/60 Hz
CS-2-D	2 Hp	CapBlok Module	200-240 VAC	1080 µF	50/60 Hz
CS-3-D	3 Hp	CapBlok Module	200-240 VAC	1080 µF	50/60 Hz
CS-5-D	5 Hp	CapBlok Module	200-240 VAC	1620 µF	50/60 Hz
CS-7-D	7 Hp	CapBlok Module	200-240 VAC	3000 µF	50/60 Hz
CS-10-D	10 Hp	CapBlok Module	200-240 VAC	3000 µF	50/60 Hz

460 VAC CapBloks

CS-1-E	1 Hp	CapBlok Module	380-480 VAC	135 µF	50/60 Hz
CS-2-E	2 Hp	CapBlok Module	380-480 VAC	270 µF	50/60 Hz
CS-3-E	3 Hp	CapBlok Module	380-480 VAC	270 µF	50/60 Hz
CS-5-E	5 Hp	CapBlok Module	380-480 VAC	405 µF	50/60 Hz
CS-7-E	7 Hp	CapBlok Module	380-480 VAC	750 µF	50/60 Hz
CS-10-E	10 Hp	CapBlok Module	380-480 VAC	750 µF	50/60 Hz
CS-15-E	15 Hp	CapBlok Module	380-480 VAC	1350 µF	50/60 Hz
CS-20-E	20 Hp	CapBlok Module	380-480 VAC	1350 µF	50/60 Hz

*Mounting hardware is not included within the CapBlok ship kit, but may be ordered separately.

Table 3-5
Standard CapBlok Assemblies

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SpindleBlok Ratings

1000 Series

SpindleBlok Module Type Number		1001C	1002C	1003C	1001D	1002D	1003D	1005D	1001E	1002E	1003E	1005E
SDM, AC Induction Motor												
AC Line Input Voltage	VAC	120V±10%			200/240V±10%				380/480V±10%			
Cont. Output Cur. (RMS)	Arms	4.0	7.2	10.4	3.6	6.8	9.6	15.2	1.8	3.4	4.8	7.6
	Hp	0.5	1.0	1.5	1	2	3	5	1	2	3	5
	kW	0.38	0.75	1.12	0.75	1.5	2.2	3.7	0.75	1.5	2.2	3.7
% Overload 1 min	%	150%	150%	150%	150%	150%	150%	150%	150%	150%	150%	150%
% Overload 3 sec	%	200%	200%	200%	200%	200%	200%	200%	200%	200%	200%	200%

2000 Series

SpindleBlok Module Type Number		2007D	2010D	2007E	2010E	2015E	2020E
SDM, AC Induction Motor							
AC Line Input Voltage	VAC	200/240V±10%		380/480V±10%			
Cont. Output Cur. (RMS)	Arms	22	28	11	14	21	27
	Hp	7.5	10	7.5	10	15	20
	kW	5.6	7.5	5.6	7.5	11	15
% Overload 1 min	%	150%	150%	150%	150%	150%	110%
% Overload 3 sec	%	200%	200%	200%	200%	150%	130%

Table 3-6
SpindleBlok technical specifications

Web: www.mtsautomation.com

Document # 0A-0042-01-B, May 21, 2001

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4. General Setup Information

Spindleblok Introduction

Spindleblok is a variable speed sensorless flux vector drive for three phase AC induction motors. It uses the direct method for field orientation. A spindleblok can be used to control most AC induction motors in precise speed control applications and has special features for spindle type applications where the motor is controlled over a wide speed range from a fraction of base speed to several times base speed. Base speed is the loweset speed at which full voltage is applied to the motor. Above base speed, the motor is in the field-weakening region.

A Spindleblok achieves its precise torque and flux control by continuously measuring phase currents and voltages. From these measurements, it generates an accurate estimate of the rotor flux vector and speed through an internal motor model. Once current and flux are known, torque and speed can be easily calculated and controlled. The key, though, is an accurate motor model. It is very important that the proper motor information is programmed into the Spindleblok More on this later.

Another key setup step with Spindleblok is the tuning of the speed regulator. Unlike most flux vector drives on the market today, Spindleblok is a torque controller. The speed of the motor is regulated by comparing the estimated speed from the commanded speed. The error is fed into a PI regulator, the output of which is the torque command. To achieve good speed regulation, the speed controller must be tuned. This step is not needed with open loop flux vector drives but should be familiar to anyone who has worked with a servo drive. A spreadsheet, “Spindleblok speed regulator.xls”, is supplied to help the user.

Also, the power range of the Spindleblok chosen must be matched to the power rating of the motor for optimal performance. The motor current rating and the Spindleblok current rating should not differ by more than a factor of two. This guarantees that the current sensors have sufficient resolution to provide adequate feedback to the flux vector controller.

A Spindleblok is designed to provide full speed control down to one percent of the rated speed of the motor. If the commanded speed drops below this level, the drive will enter a DC hold mode where DC current is injected into the motor phases. The drive will switch back to sensorless flux vector mode as soon as the speed command exceeds one percent of the rated speed. Note that rated speed is defined as the minimum speed at which the motor requires full line voltage. Above this speed, the motor enters the constant power, field weakening range.

If the motor must run smoothly all the way down to zero speed, the Spindleblok has an open loop, volts-per-hertz mode. This is useful for spindle orient modes where an external controller closes a position loop based on a shaft sensor. During open loop mode, the tight speed regulation and torque control is disabled.

Methods of setup and control

A Spindleblok is configured for a specific application by programming a set of parameters. All setup parameters are stored in non-volatile memory so that the configuration is preserved through power down cycles. The parameters are programmed through the built in RS485 port. Cables and adapters are available through MTS customer service to connect a Spindleblok to your PC’s serial port. SBconfig, a windows based program, is provided to facilitate reading and writing parameters. Some of the parameters are numerical, such as the speed command C02 (***omega_cmd_save***) and some parameters

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are bit based, such as C01 (***drive_mode***) through which specific modes of operations are enabled or disabled by setting or clearing individual bits.

A Spindleblok can also be directly controlled through the serial port. The serial protocol is straightforward to program and includes error detection through a check-sum. In addition to the configuration parameters, there is a set of control parameters to start and stop the drive as well as adjust the speed setpoint. There is also a set of read-only feedback parameters that are updated real time to provide application monitoring.

The serial protocol is an ASCII based, master-slave protocol where the controller (master) requests parameter reads or parameter writes. The Spindleblok (slave) answers each request with success and optional data, or an error message, or a message that the drive is in the fault condition. The Spindleblok must be correctly addressed with one of 35 available address. This allows a single RS485 based controller to control multiple Spindlebloks. Details about the protocol and syntax can be found in the document: “9700 Series IDM Communication Protocol”.

As an alternative to serial programming, the drive can be controlled through local I/O. The I/O functions are programmed through a page of parameters and can be configured for most PLC setups.

With local setpoint control, the speed command can come from an analog input (+/- 10 volts or 0 – 10 volts) or from preset speeds.

Spindleblok Parameters

The Spindleblok parameters are grouped in pages, the pages are referred to by the letters A through M. In each page, the parameters are numbered by a two hex digit number. Each parameter is uniquely addressed by a three character address, the first character is the page letter and the last two characters are the hex digits of the address.

Each parameter also has a name. The names, addresses, access level, and description of all parameters are found in the “Drive Parameter Definitions” document.

There are several levels of access to parameters. Most are read/write and can be read or written at any time. Others are read only and include drive identification parameters (serial number, ratings, scale factors, . . .) or are real time updated feedback information (output current, torque, . . .) Attempting to write to a read only parameter will result in an error message. Other parameters are run locked. These can be read at any time but can only be written to when the drive is off. Many of the motor nameplate parameters are run locked because they are used to configure the internal motor model at start. Finally, certain parameters are reserved. Reserved parameters are used by the factory to calibrate the drive and set its protection levels. Attempting to write to reserved parameters will result in an error message.

An overview of the parameter pages follows. For more detail on each parameter, refer to the Drive Parameter Definition document. Information on how to setup the parameters will be described below.

Page A: These parameters are drive identification parameters and include the voltage and horsepower of the drive, the software version, the serial number, as well as voltage and current scaling factors used to scale other parameters. All of these parameters are read-only.

Page B: These parameters set up the serial communications and include the baud rate and drive address. The default values are 9600 baud and address ‘1’. See the Setup section under **Serial Control** for details on these parameters.

Page C: These parameters are drive commands. They include the bit oriented command register (C00 ***drive_command***) that serially starts and stops the drive as well as other commands, the bit oriented mode register (C01 ***drive_mode***) and the serial speed command (C02 and C03 ***omega_cmd_save***). The two addresses for the speed command differ in that C02 only writes to volatile ram memory while C03 writes to both ram and non-volatile ee-prom. Parameter C03 is typically used in fixed speed

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applications where the speed command needs to be remembered through power down cycles, parameter C02 is used for serial control applications where the speed command is written on a periodic basis. Repeatedly writing to non-volatile ee-prom will compromise the limited life of the part.

Page D: These parameters are feedback values and include most of the real time information of interest. Most of these values are filtered to smooth the high frequency dynamics. Parameter D01 (***drive_status_save***) has a special function. Reading this parameter when the drive is faulted will clear the fault. This is the primary way to clear faults under serial control. See the section under **Serial Control** for further details.

Page E: This is the fault cue and holds data on four most recent faults in a circular cue as well as the first fault since the fault cue was last reset. The fault cue is reset by writing 0FBFFh to parameter C00 (***drive_command***). The data preserved at the instant of each fault are the status of the drive when it faulted (this is a copy of parameter D01 (***drive_status_save***)), the time of fault (this is a copy of the elapsed time timer (D0D and D0E)), the state of the drive immediately prior to the fault (this is a copy of parameter D00 (***drive_state***)), The current, DC link voltage, and estimated speed, and the extended fault code.

To decipher the fault cue, first read parameters E00 (***fault_cue_full***) and E01 (***last_fault_index***). If E00 is one then the fault cue is full and all entries are valid. Subsequent faults will overwrite the oldest data. If E00 is zero then the fault cue is not full and the only valid faults are in fault 1 to the fault indicated by E01 which holds the most recent fault index. If E01 is zero then the fault cue is empty. If E01 is non-zero then the fault cue holds valid fault data, for example: if E01 is 3, the most recent fault data is held in E1D (***fault_3_status***) through E24 (***fault_3_ext_error***). The previous fault data is held in E14 (***fault_2_status***) through E1B (***fault_2_ext_error***). The oldest fault data is held in E26 (***fault_4_status***) through E2D (***fault_4_ext_error***).

Page F: These parameters control the maximum speed the motor is allowed to run at and the acceleration and deceleration rates. There are three sets of acceleration and deceleration rates. The default set, F01 and F02 control the acceleration and deceleration when the drive is in sensorless flux vector mode (bit 3 of D00 (***drive_state***) is clear). The alternate set, F03 and F04, can be chosen in sensorless flux vector mode by clearing bit 10 of C01 (***drive_mode***). This is typically used when a spindle or motor can be configured with two very different load inertias, the high inertia usually requiring lower acceleration rates. Finally, the open loop set, F05 and F06, controls the acceleration and deceleration when the drive is in open loop mode (bit 3 of D00 (***drive_mode***) is set).

Page G: These are the motor parameters and set up the internal motor model. There are two methods of using these parameters: Nameplate Mode and Internal Model Mode. The mode selection is determined by the state of bit 1 of ***drive_mode*** (C01). If bit 1 is set, nameplate mode is used. In nameplate mode, the user must provide the following parameters: G00 (***rated_volts***), G01 (***rated_hp***), G02 (***rated_speed***), G03 (***i_rated***), and G04 (***rated_freq***). The values can be typically found on a motor nameplate. For Internal Model Mode, the user must provide the following parameters: G03 (***i_rated***), G08 (***fluxr_cmd_nom***), G09 (***iq_rated***), G0A (***rs***), G0B (***rr_kw***), and G0F (***half_poles***). See the “Drive Parameter Definitions” for definition and scaling of these parameters. In both modes, the magnetizing current can be adjusted by G18 (***k_id***) and the leakage inductance can be fine-tuned by G06 (***ll_lm***). Commissioning the drive automatically tunes G0A (***rs***) in standard mode and, additionally, G18 (***k_id***) in enhanced mode. Note that in nameplate mode, all of the parameters needed for Internal Model Mode are calculated on the first start, thus it is always recommended that the user begin the motor setup in nameplate mode (even if the nameplate values are an educated guess). After commissioning the drive, the mode can be switched to Internal Model Mode and the internal values adjusted as needed. More details are covered below in **Setting up the Motor**.

Page G also contains G10 (***load_lim***) and G11 (***slip_lim***) that control the maximum torque that the motor will produce. See **Setting up the Load Limit** below.

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Page H: This page sets up the dc hold braking. There is only one parameter, H00 (***dc_inject_time***), that sets up the time that DC current is injected after the motor has reached zero speed. The level of dc injection current is set at the level of magnetizing current.

Page I: This page holds the calibration data for the current sensors, voltage sensor, and switching delays of the drive. These parameters are set by automated calibration equipment at the factory and should not be changed, as they are unique to each drive. These parameters are reserved.

Page J: These parameters are used for drive protection. Many of them are reserved and should not be changed as they protect the drive from physical damage by causing it to fault in conditions that exceed its safe operating range. Other parameters set up optional protection such as thermal protection for the motor, serial communications time-out protection, and breaking resistor setup and protection. Parameters J00 (***i_sqr_t_wdt***) and J01 (***i_sqr_t_lim***) set up the thermal time constant and service factor of the motor for thermal protection. Parameter J02 (***comm_timer_max***) enables the serial communications time-out fault. The default value of zero disables this fault. Any non-zero value sets the maximum time that the drive will operate without a valid serial command. The braking resistor is set up by specifying the voltage at which the braking circuit will turn on (J09 ***vdc_braking***) and setting up thermal protection for the brake (J0B ***db_pt_wdt*** and J0C ***db_pt_lim***). See **Dynamic Braking Resistor Setup** below.

Page K: These parameters set the gains of the various regulators, including the speed regulator, the dynamic brake regulator, the current regulators, and the flux-tracking regulator. Typically, the only regulators that need adjusting are the speed regulator (always) and the current regulator (sometimes).

There are two sets of gains for the PI speed regulator. K00 (***kp_trq_dflt***), K01 (***ki_trq_dflt***), and K02 (***iq_wdt_dflt***) set the speed regulator gains when bit 10 of C01 (***drive_mode***) is set. K03 (***kp_trq_hi_j***), K04 (***ki_trq_hi_j***), and K05 (***iq_wdt_hi_j***) set the speed regulator gains when bit 10 of C01 (***drive_mode***) is clear. These two sets are provided so that systems with mechanical configurations with widely varying load inertias can be accommodated, such as a spindle with a multiple gear ratio transmission The Microsoft Excel spreadsheet “Spindleblok speed regulator.xls” is provided to aid in tuning the speed regulator. See the section **Setting up the Speed Regulator** below.

The current regulator is a PD regulator and the gains are K07 (***kp_i_nom***) and K08 (***kd_i_nom***). See the section **Tuning the Current Regulators** below.

Page L: These are internal parameters and most should not be changed. Three parameters of interest are: L04 (***flx_rate_lim_pos***), L05 (***flx_rate_lim_neg***), and L06 (***flux_volt_max***). L04 and L05 set the rate limit for increasing and decreasing flux. The default values work well in most applications. If the drive trips off during acceleration or deceleration in the field weakening region then you may want to reduce the values, particularly for low slip, high efficiency motors. For small motors that use very high acceleration and deceleration rates, you may want to increase these values.

Parameter L06 (***flux_volt_max***) controls the portion of the available voltage reserved for steady-state BEMF. A value of 32,767 (07FFFh) means all that is available. The magnetizing inductance estimator can use voltage not reserved for the BEMF. To determine if the L06 (***flux_volt_max***) is set correctly, run the motor at various speeds in field weakening and review parameter D11 (***invrs_lm***), the estimated magnetizing reactance. If D11 is not changing at all then the estimator does not have enough voltage to operate. Reduce parameter L06 (***flux_volt_max***) by 1% and repeat the test until D11 (***invrs_lm***) dithers around a steady value.

Page M: These parameters setup the local I/O. See the section **Setting Up the Local I/O** below.

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SbConfig Tool

SBconfig is a windows based tool to help configure a Spindleblok to a specific motor and application. In the future, it will be replaced with a more user-friendly program, similar to wInControl and IndexWare to ease the setup process.

With SBconfig, you can read and write to the drive parameters. SBconfig also continuously poles the status and feedback parameters to monitor the drive.

When you start SBconfig, you must first insure that it is setup for the serial port that you are using. Under the the Utils menu, click on the Comm Setup item. Select the serial port that you are using on your computer. Drives from the factory are configured as address 1 and baud rate of 9600. Make sure that SBconfig is set to match the baud rate and address of the drive. When the drive is communicating, “Drive On-Line” will appear under drive status.

Under the File menu, you can open one of six special parameter lists or a previously saved custom list. The six parameter lists are:

Application Setup Parameters

This list includes all parameters to set up the drive mode, acceleration and deceleration rates, and local I/O. See the section “Setting up the application” below.

Motor Setup Parameters

This list includes all parameters related to configuring the motor. See the section “Setting up the motor” below.

Duplicate Drive

This list includes all setup parameters for a specific drive. If this list of parameters is read from one drive and written to another drive of the same ratings, followed by an I/O initiation and a drive commission, the second drive will be setup the same as the first. It is very important that all drives to be duplicated must be of the same voltage and power rating as some of the parameters, namely the internal motor parameters and the regulator gains, are scaled by the drive ratings. To duplicate drives with different cove versions, contact MTS applications engineering. The code version can be determined by reading parameter A03 (***code_version***).

Tuning Parameters

This list includes the default and alternate set of speed regulator tuning parameters. Initial values for these can be generated using the Microsoft Excel spreadsheet, “Spindleblok speed regulator.xls”. See the section “Setting Up the Speed Regulator”. The current regulator gains are also in this table. See the section “Tuning the Current Regulators”.

Drive Identification

This list includes the read only parameters that identify the drive. This includes the software version, serial number, rating, and scaling factors as well as the current drive status code.

All Parameters

This list includes all of the drive parameters and is useful to capture a snapshot of a drive setup and feedback.

Once a parameter list is opened, the parameter can be read by highlighting the value box of the parameter of interest (use the up / down arrow keys or point left click with the mouse) and clicking the Get button. A value should appear and “Read Successful” should be the last message. You can also click on Get All to read all parameters. To write to a parameter, highlight the value box and type the desired parameter value. Click the Set button to write to the drive. The message “Write Successful” should appear in the last message box upon completion of the write. If the parameter was read-only or

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reserved, then the error message, “Write Error: Write to read-only parameter” will appear and a read of the parameter will reveal that it did not change.

You can also save a parameter list, with its listed values by clicking on the “Save User List As” item in the file menu. You can also reopen a saved parameter list with the “Open User List” item. Note that if you open a previously saved parameter list then the parameter values displayed will be the values in the saved file – not the drive. You must explicitly read the parameters out of the drive by clicking the “Get All” button.

The Display menu can be used to switch the parameter display between decimal and hex mode. Some parameters, such as C01 (***drive_mode***), are best viewed in hex mode, most parameters are better displayed in decimal mode.

The DriveMode menu can be used to set the desired value of parameter C01 (***drive_mode***). Setting and clearing individual bits of ***drive_mode*** change the configuration of the drive and I/O. After clicking the desired radio buttons, you must click the OK button to set ***drive_mode***. To observe the change, you can highlight the value box of parameter C01 (***drive_mode***) and click the “Get” button.

The Speed Adjust submenu provides a convenient slider bar to set the speed command (parameter C02).

The Feedback menu opens a window that continuously displays some of the drive’s feedback parameters. These have been converted to real units for your convenience. Check the boxes that you wish to observe.

The Utils menu has some useful choices. The IDM Version submenu will tell you which version of firmware is in your drive. This is also available by reading parameter A03. Note that the IDM Version submenu displays the firmware version as a hex number.

The Comm Setup submenu has been discussed above. If you would like to change the baud rate that you use to communicate to the drive, you must first write the value to parameter B01. Then you must reinitialize the serial system by writing FF7Fh to parameter C00 (see the description of ***drive_command*** C00 in the Drive Parameter Definitions or in the Setup and Control Specification). Note that after this step, the drive will go off line because the baud rate between SBconfig and the Spindleblok do not match. The final step is to set the baud rate in the Comm Setup submenu to match the drive. To change the drive address, write the ASCII code for 1 – 9, A – Z to parameter B00 then set the matching address in the Comm Setup submenu. ***It is strongly recommended that you label a drive setup with any non-default baud rate or address.***

The Motor Setup submenu will be covered in the section on Setting up the Motor.

The Fault Cue submenu displays the data stored in the Fault page of parameters (E00 – E2D). The current version of SbConfig, version 0.2, does not display the fault cue correctly and the fault data must be accessed by directly reading the fault cue parameters. See the section above on page E of the Spindleblok parameters.

The start and stop buttons can be used to start and stop the drive. The start button simply writes FFFDh to parameter C00 (***drive_command***) and the stop button writes FFFEh to parameter C00. Note that the drive will only start when you click the start button if the drive is in serial start mode and enabled to run. Run Enable is controlled by DIN 1 (pin 9) on the I/O terminal. In the default setup the digital inputs are internally pulled up and must be tied to DIGCOM (pin 8) to be asserted. By setting bit 0 of parameter M05 (***dig_in_polarity***) you can invert the polarity of the Run Enable pin and eliminate the need for the jumper between DIN1 (pin 9) and DIGCOM (pin8). Serial start mode is controlled by bit 9 of parameter C01 (***drive_mode***). The default value is set to serial start. The stop button is always active and will stop the drive even if it is under local start control. Please read the notes in section VII of the Setup and Control Specification for details on serial and local starts and stops.

If the drive faults while operating from SBconfig, a fault window will open to announce the fault. The window gives a brief description of the fault and includes a fault-reset button.

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Clicking the fault-reset button simply causes parameter D01 (***drive_status_save***) to be read. This is the means that faults can be cleared through serial control.

Detailed data on the fault can be gleaned by reviewing the fault cue (see the section on Page E of the Spindleblok Parameters above). Review the document, “Extended Fault Codes” to determine causes and cures for the specific fault condition.

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5. Quick Start, a Set Up Overview

Step zero: Wire the power terminals

Connect the three motor leads to T1, T2, and T3. If you are using an optional shunt resistor for braking, connect it between DB and B+ (on the forward terminal strip). Connect incoming three-phase power to L1, L2, and L3. For single phase power, use any two of the power leads. Refer to the SpindleBlok manual for wiring and shunt resistor sizing and considerations.

Step one: Connect the drive to a PC

Disconnect any I/O wiring from pins 1 through 16.

Connect the RS485 port of the SpindleBlok to a serial port of a PC using an RS485 to RS232 converter. Start the program SbConfig.exe. Using the Comm Setup submenu under the Utils Menu set the baud rate to 9600 and the drive address to 1. Set the Comm Port to the serial port connected to the SpindleBlok.

Verify that all wiring is correct and apply power to the drive. The PWR L.E.D. should glow green on the SpindleBlok and the Drive Status in SbConfig should change from “Drive Off-Line” to “Drive On-Line”. If it does not verify power wiring and the serial setup.

Under the File menu, select “All Parameters”. This will open a blank list of all of the parameters in the drive. Click the “Get All” button to read the parameter values out of the drive. Under the Display menu, you can choose to display and enter values in hex or decimal, as appropriate.

Step two: Initialize drive mode and run enable

Set parameter C01 (***drive_mode***) to 65,535 or 0FFFFh. This will ensure the drive is in sensorless flux vector mode, with normal commissioning only, and is setup for serial start/stop and serial setpoint. See the section on **Drive Mode** below.

Set parameter M05 (***dig_in_polarity***) to 1. Reinitialize the I/O by writing 0F7FFh to parameter C00 (***drive_command***). This will set up Run Enable to be asserted without a jumper between pins 8 and 9.

Step three: Motor Nameplate Setup

Now enter the motor nameplate parameters in G00 through G04. Use the default value of 30 for G06 (***ll_lm***) and 40 for G18 (***k_id***) unless you have more accurate numbers. Review the section below on **Setting Up the Motor** if the nameplate parameters are not obvious.

Step four: tune the current regulators

Next, tune the current regulators. This is accomplished using standard commissioning. Make sure that bit 3 of C01 (***drive_mode***) is set. The idea is to increase the gain of the current regulator until it is unstable then back off by a safety margin. See the section **Tuning the Current Regulators** below for details.

Perform a final standard commission with the tuned gains to auto-tune the stator resistance and the inverter switching characteristics.

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Step five: Initialize the Speed Regulator

Next, set up the speed limit (F00 ***max_speed***) and the acceleration rates (F01 and F02). See the sections on **Acceleration and Deceleration** and **Max Speed** below. You may want to start with moderate acceleration rates and fine-tune them later. A value of 1800 will accelerate a 4-pole motor to 1800 rpm in two seconds and is a good starting point unless your load inertia is very large. You may want to use a lower rate for the deceleration unless you have installed an optional shunt resistor.

Set an initial tuning of the speed regulator. Use the Excel spreadsheet "Spindleblok speed regulator.xls" for this. Review the section **Setting Up the Speed Regulator** below. The goal is to find a speed regulator setting that gives stable performance – we will optimize later. If the motor and load inertia are not well known then start with very broad settings for the range of load inertias.

Step six: Set up the optional shunt resistor

If you are using an optional shunt resistor, confirm that parameter J09 (***vdc_braking***) is set to activate braking at a value less than the over-voltage trip voltage (J08 ***vdc_max***). Standard values are 200 volts for the 115-volt drives, 380 volts for the 240-volt drives, and 760 volts for the 480-volt drives. If you change parameter J09, you must cycle the power to drive for the change to take affect. Allow the capacitor bank to discharge before re-powering the drive.

You should also enter the rated wattage of the shunt resistor in parameter J0C (***db_pt_lim***) to enable the software DB protection.

See the section **Dynamic Braking Resistor Setup** below for more details.

Step seven: Commission the Motor

Perform an enhanced commission. Clear bit 3 of C01 (***drive_mode***) to enable enhanced commissioning then write FFFBh (65,531) to parameter C00 (***drive_command***) to start a commission. Alternatively, you can click the "Commission Drive" button in the "Motor Setup" submenu of the "Utils" menu of SBconfig. The drive will first repeat a standard commission then will accelerate the motor to roughly half of the rated speed. Once the speed has settled, the magnetizing current will be automatically tuned. Once this is completed, the drive will stop.

If the motion is very rough, then the speed regulator should be re-tuned using a smaller inertia. If the speed overshoots and settles slowly or oscillates then the speed regulator should be re-tuned using a higher inertia.

See the section on **extended auto-tuning** to confirm that parameter G00 (***rated_volts***) is optimal for the motor and drive.

Step eight: Confirm proper motor direction

Set the speed (C02 ***omega_cmd_save***) to a low positive value, 50 rpm is a good value. Start and stop the drive and confirm that the motor is spinning in the forward direction, stop the drive. If it was spinning in the wrong direction, remove power from the drive and allow the capacitor bank to discharge. Swap any two the motor leads (T1, T2, and T3). Re-apply power to drive and repeat this test.

Step nine: Fine tune the speed regulator

Review the section on **Setting Up the Speed Regulator** to fine tune parameters K00 through K02. You may want to increase the bandwidth until K00 is in the range 4,000 to 5,000 for the fastest response. If you began with a broad inertia range because the actual

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inertia was uncertain you may want to try narrower ranges. This will allow the motor to respond as quickly as possible without rough operation. If you began with a load inertial range of one to four, try narrowing it to the lower end, say one to two. Transfer the recalculated gains (K00 through K02) to the drive and test them. Compare this with the gains calculated when the inertial range is set to your initial high end, say three to four.

A good test of the speed regulator is the step the speed a small amount from an intermediate speed with the acceleration rate set very high. For example, a good setup for a motor with a rated speed of 1760 rpm is to run it at 900 rpm and step the speed command to 100 rpm. If the acceleration rate for the application will be 3600 rpm per second then use a test around 14,400 rpm per second**. Caution: only step the speed in small increments when the acceleration rate is set high**. It is best to start the motor and accelerate it to 900 rpm with the nominal acceleration rate then change the rate to the high test value. When you are finished, restore the acceleration rate to the application value.

Step ten: Test at all speeds, fine tune the acceleration and load and slip limits, set up protections

Review the section **Setting Up the Load Limit** to set parameters G10 (***load_lim***) and G11 (***slip_lim***).

Next choose the acceleration profile that you desire, linear or optimum spindle. See the section **Acceleration and Deceleration** for a discussion of this option. Set the acceleration and deceleration rates in parameters F01 (***accel_rate_dflt***) and F02 (***decel_rate_dflt***).

You should configure the thermal protection of your motor. See the section **Setting Up Thermal Protection of the Motor** to accomplish this.

If your application is controlled through the serial port then you should enable the serial timeout fault by writing a non-zero value to J02 (***comm_timer_max***). A value of 96 gives a communications time-out of five seconds.

If your application operates in the field weakening range then check the settings for L04 (***flx_rate_lim_pos***), L05 (***flx_rate_lim_neg***), and L06 (***flux_volt_max***). See the section on **Page L** of **SpindleBlok Parameters** above**.**

Finally, test the performance of system over its entire speed range. Test starting capability and high-speed loading to determine if parameter G06 (***ll_lm***) is set correctly. See the section **Additional Parameters, LL_LM, K_Id, and Omega_Base** below for details.

Step eleven: Setup the I/O

Review the section **Setting Up the Local I/O** to configure the i/o functions. If you have a Run Enable input then you may need to reset the polarity of the run_enable input, DIN1. Reset parameter M05 (***dig_in_polarity***) to zero.

Step twelve: Upload and save the final configuration

When the setup of the drive is complete, upload all of the parameters and save the list for future reference. This can also be used to duplicate the setup on drives of the same rating. Note that care must be taken if you are going to transfer a setup to a drive with a different rating as many parameters, specifically internal motor parameters and regulator gains are scaled by drive voltage and current ratings.

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6. Set Up and Testing Instructions

Setting up the Motor

It is crucial for the Spindleblok to be programmed with accurate motor information for it to precisely control flux and torque. There are two methods of entering motor data, Nameplate Mode and Equivalent Circuit Mode. The choice is set by bit 1 of parameter C01 (***drive_mode***). In most cases, Nameplate Mode is recommended for all initial setups and is the default mode.

Nameplate Mode

In Nameplate Mode, the Spindleblok translates standard motor nameplate data (motor rated power, voltage, current, frequency, and speed) into the equivalent circuit parameters that the internal motor model uses. The nameplate data represents an operating point of the motor where the optimal voltage is applied for the power and frequency. Typically this operating point is very near the thermal limits of the motor.

Setting bit 1 of parameter C01 (***drive_mode***) enables nameplate mode. This is the default mode and is recommended for all first time setups. The nameplate data are entered into parameters: G00 (***rated_volts***), G01 (***rated_hp***), G02 (***rated_speed***), G03 (***i_rated***), and G04 (***rated_freq***). Review the Drive Parameter Definitions document for parameter scaling.

The parameters can also be set by using the Motor Setup submenu under the Utils menu. After entering the nameplate data, you must click the Download Nameplate button.

Many high-speed spindle motors do not list accurate operating point conditions on their nameplate but instead list peak values for each parameter. Note that these peaks do not occur under the same condition. For example, maximum rated speed occurs at a no load condition with a fixed frequency power source while maximum rated current occurs at full load. If maximum rated speed is listed as a no load or synchronous speed, that is with zero slip, then it is important to determine rated speed at rated load. This value is used not only to determine rated slip (which allows the drive to achieve very accurate speed control) but also to determine magnetizing current dynamics which yields fast starts and rapid acceleration and deceleration during field weakening. Typical slip ranges from 1% to 6% with higher slips on smaller motors.

Some high-speed spindle motors list multiple operating points on their nameplate. If this is the case, use the lowest speed (lowest frequency) operating point at rated voltage.

Additional Parameters, LL_LM, K_Id, and Omega_Base

In addition to the five nameplate parameters listed above, two parameters not typically found on motor nameplates are used in the motor parameter calculations. These are G06 (***ll_lm***) and G18 (***k_id***). In addition, an internal scaling parameter G1C (***omega_base***) should be set.

K_id is the magnetizing current percentage (magnetizing current / rated current * 100) used at motor start. Typical values range from 25% to 60%. A typical value is 40%. If the motor nameplate or data sheet gives no-load current then the value can be estimated by substituting no-load current for rated current. This value can also auto-tuned by the motor. This is covered below.

If ***k_id*** is too low then the motor may not develop full starting torque. If it is too high, then the motor may start rough. Once the motor has started, the magnetizing current is automatically adjusted.

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Ll_lm (G06) is the ratio of leakage inductance to magnetizing inductance. Typical values for a four pole spindle motor is 4%. The equivalent value for G06 is 40, it is scaled up from percent by ten. Ranges for motors vary from 1.5% to 6% (G06 = 15 to 60). If the programmed value is too high, then the motor will be unstable at high speed or high load. If the programmed value is too low, then starting torque is compromised. It is recommended to start with a value of 30 for G06. If this works fine at high speed and high load then try 40 and check if starting is improved. If a value of 30 causes instability at higher speeds or heavy loads, reduce the value to 20.

Omega_base (G1C) is a parameter used to scale the internal flux command. Nominally, it should be set to the frequency in rad/sec that the motor enters field weakening. The flux regulator is the primary blocks that is sensitive to this parameter. A value of 377, the default value, is fine for 50 or 60 Hz motors. If the frequency at which the motor enters field weakening is less than 50 Hz or greater than 120 Hz, then omega_base should be changed appropriately.

Equivalent Circuit Mode

In equivalent circuit mode, calculating the motor parameters from the nameplate parameters G00 (***rated_volts***), G01 (***rated_hp***), G02 (***rated_speed***), and G04 (***rated_freq***) is bypassed. Instead, the parameters G03 (***i_rated***), G06 (***ll_lm***), G08 (***fluxr_cmd_nom***), G09 (***iq_rated***), G0A (***rs***), G0B (***rr_kw***), G0F (***half_poles***), and G18 (***k_id***) must be directly entered. Please review the Drive Parameter Definition document for meaning and scaling of these parameters. G0A (***rs***) and G18 (***k_id***) can be set with standard and extended auto-tuning, although good initial estimates are required, this is covered in a later section. The drive is put into equivalent circuit mode by clearing bit 1 of C01 (***drive_mode***).

Equivalent circuit mode is most useful if good nameplate data is not available. In this case it is best to start in nameplate mode with your best estimate of nameplate parameters. After a standard auto-tune to estimate parameter G0A (***rs***) and to fill the rest of the equivalent circuit parameters with initial values, you may want to place the drive in equivalent circuit mode and tweak parameters G06, G08, G0B, and G18 directly to tune the motor.

Setting up the Load Limit

The Spindleblok is a torque controlled drive, therefore it can provide rapid and accurate torque limits. The torque limit is controlled by two parameters, G10 (***load_lim***) and G11 (***slip_lim***). G10 (***load_lim***) sets the torque current limit. It is expressed as a percentage of rated torque current. Rated torque current is parameter G09 (***iq_rated***). This parameter is calculated for you in nameplate mode but must be provided in equivalent circuit mode.

Note that G11 (***slip_lim***) should never be less than G10 (***load_lim***). Also if the motor rated power (G01 ***rated_hp***) or rated current (G03 ***i_rated***) match the drive ratings then G10 (***load_lim***) should not exceed 200 or over-current trips will occur before the load limit is met. If the motor rated power is less than the drive rated power then the load limit can increase beyond 200 and, conversely, if the motor rated power is more than the drive rated power then the load limit should be less than 200.

Motor torque is proportional to torque current and rotor flux. Rotor flux is held constant until full voltage is applied to the motor. Therefore, ***load_lim*** provides a constant torque limit until full voltage is reached. Above this point, flux is reduced with speed and the torque limit (with constant torque producing current) reduces with speed. This is the field weakening and constant power region.

At some higher speed, typically between two and four times the speed which field weakening begins, the motor cannot continue to produce constant power. The slip becomes so large that the motor pulls out and will stall if the frequency is not appropriately folded back. This is where G11 (***slip_lim***) comes into play. G11 is scaled as percent of rated slip. G11 will dynamically reduce the torque producing current limit

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when the programmed ***load_lim*** would result in slip greater than the programmed slip limit.

Typical values to start with for G10 (***load_lim***) is 150 and G11 (***slip_lim***) is 250. Some motors will pull out with 2.5 times rated slip and G11 should be reduced to 200. Many motors will not pull out until over four times rated slip is reached. To determine the maximum setting for your motor set G11 (***slip_lim***) to 400, accelerate rapidly from low speed (below the field weakening point) to full speed. If the motor appears to bog down or stall at the end of the acceleration, it is pulling out. You may need to increase the acceleration rate to see this because you must reach the torque limit to see the effect. If lowering G11 (***slip_lim***) actually decreases the time to accelerate to full speed, then your motor is pulling out at the higher slip limit. Tune G11 (***slip_lim***) to the value that gives the minimum acceleration rate without exceeding 500. You may want to lower it by another 25 or 50 as the pull out point can reduce when the motor becomes hot. If you must lower G11 (***slip_lim***) to a value below the G10 (***load_lim***) then reduce G10 (***load_lim***) to the same value.

The plot below shows the torque limit of a four-pole, five horsepower motor with G10 (***load_lim***) set to 150 and G11 (***slip_lim***) set to 300. Note that the torque is constant up to the rated speed then falls off in the constant power region. At 3600 RPM, the constant slip region is entered and the available torque is further reduced so that the motor will not pull-out

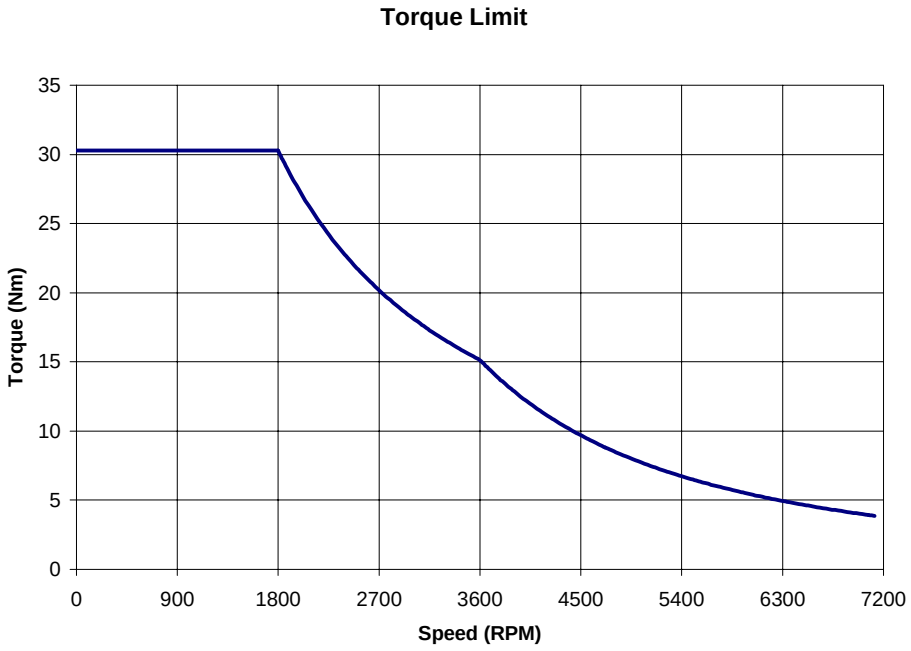


Figure 6-1

Setting up Thermal Protection of the Motor

Anytime the motor runs at over rated current, there is a risk of thermal damage. If the motor is equipped with internal thermal protection switches, these can be wired to an external fault input.

Spindleblok also has a firmware based indirect motor thermal protection. Three parameters affect it. The first is G03 (***i_rated***), the motor rated current. This, along with J01 (***i_sqr_t_lim***), sets the sustained current level required for a motor thermal fault. J01 (***i_sqr_t_lim***) is defined as $100*sf^2$ where sf is the service factor of the motor. Many motors have a service factor of 1.15. If a service factor is not listed, use 1.00. The default value of J01 is 132, representing a service factor of 1.15. The sustained current level required for a motor thermal fault is motor rated current * service factor.

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The third parameter that set the motor thermal protection is J00 (***i_sqr_t_wdt***). This is proportional to the thermal time constant of the motor. The scale factor is 1144 per minute. Acceptable ranges are 1 to 28 minutes. The default value of 4,768 (4.17 minutes) is very conservative. If the drive trips on a motor thermal overload and does not appear to be very hot, increase J00.

This thermal protection is most valid for blower cooled or naturally ventilated motors as the amount of cooling is independent of speed. If the motor is fan cooled then i_sqr_t_lim may need to be reduced if the motor is operated at low speeds and high loads for extended periods of time.

Below is a plot of the motor thermal overload trip time with J00 and J01 set at the default values of 4,768 and 132.

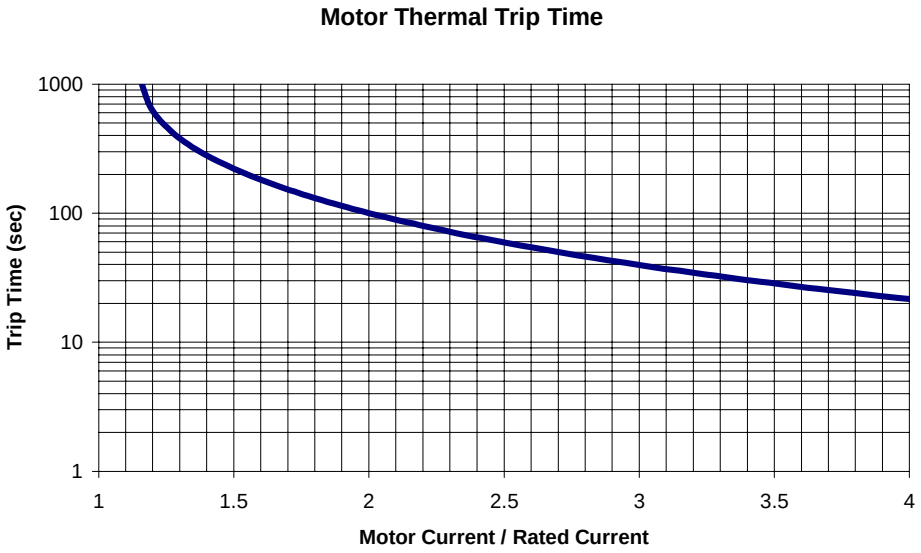


Figure 6-2

Acceleration and deceleration

A Spindleblok has two acceleration and deceleration profiles, linear and optimized spindle. The linear profile will accelerate or decelerate at a constant programmed rate unless the motor cannot produce adequate torque. The acceleration rate is parameter F01 (***accel_rate_dflt***) and the deceleration rate is F02 (***decel_rate_dflt***). The linear profile is selected by clearing bit 7 of parameter C01 (***drive_mode***). It is a good profile for applications that do not operate very deeply into the field-weakening region. The main benefit of the linear profile is that acceleration times are easily predictable.

For applications that operate in the field-weakening region, Spindleblok has a special optimized spindle acceleration and deceleration profile. The curve is based on accelerating an inertial load with constant torque producing current. From zero speed up to the field weakening point, this is a linear acceleration. Above the field weakening point, the rate of acceleration decreases as the field is decreased, reflecting the reduction in torque per amp. This mode is selected by setting bit 7 of parameter C01 (***drive_mode***).

The actual acceleration and deceleration curve is calculated on the fly based on the DC link voltage, the motor parameters, and the acceleration or deceleration parameters. The parameter F01 (***accel rate_dflt***) sets the base acceleration rate and F02 (***decel_rate_dflt***) sets the base deceleration rate used below field weakening.

Accurately predicting the time to accelerate to speeds above base speed is difficult because it is dependent on line voltage and stiffness as well as motor parameters. Typically, if a motor takes one second to accelerate to base speed then it will take 2.5 seconds to accelerate to twice base speed, 5 seconds to accelerate to three times base

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speed, and 8.5 seconds to accelerate to four times base speed. Note that deceleration times for the same setting in F02 (***decel_rate_dflt***) as F01 (***accel_rate_dflt***) usually results in faster deceleration times than acceleration times above base speed because the dc bus voltage is raised during dynamic braking. This allows the Spindleblok to increase the field in the motor, which gives more torque for the same current.

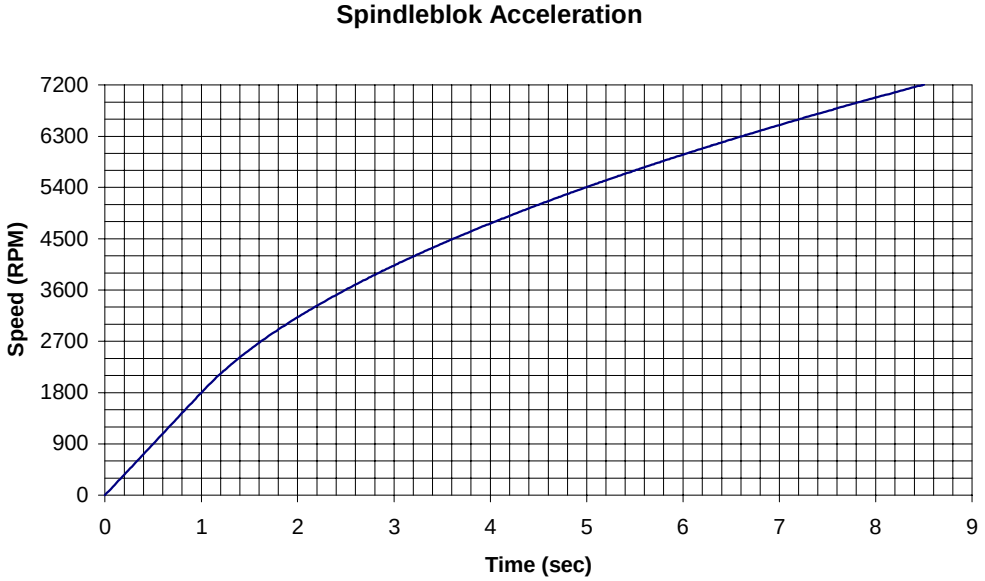


Figure 6-3

A typical acceleration curve is shown above. The motor was programmed to accelerate to base speed (1800 RPM) in one second. The speed command is 7200 RPM. If a linear curve was used, the acceleration time would nearly double for the same maximum current.

Two alternate set of acceleration and deceleration rates exists, parameters F03 (***accel_rate_hi_j***) and F04 (***decel_rate_hi_j***) and parameter F05 (***accel_rate_ol***) and F06 (***decel_rate_ol***). Parameters F03 and F04 replace F01 and F02 when the alternate set of speed regulator gains is selected. This can be done through local I/O or by clearing bit 10 of parameter C01 (***drive_mode***). Parameters F05 and F06 replace F01 and F02 when the drive is in open loop mode (see below).

Max speed

The parameter F00 (max_speed) sets the maximum speed that the drive is allowed to run. Speed commands are limited to a maximum magnitude of this value and if the frequency of the drive ever exceeds to corrosponding synchronous frequency by 15 hz, the drive will fault on overspeed. This also scales the analog input voltage (see the local setpoint section).

Drive Mode

The parameter C01 (***drive_mode***) is bit defined. Setting or clearing specific bits in this

Figure 6-4

parameter changes various modes of the drive.

Note that several of the bits can be affected by digital inputs if the appropriate digital input functions are programmed. These bits are: Bit 4 (sensorless flux vector or open loop mode), bit 5 (enable or disable forward direction), bit 6 (enable or disable reverse direction), and bit 10 (default or alternate speed regulator settings). If a digital input is

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programmed to control these options then the state of the digital input takes precedence over a serial write to that bit of C01 (***drive_mode***). For example, if a digital input is programmed as forward enable and is de-asserted (forward motion is disabled) then you cannot re-enable forward motion by writing to C01.

Dynamic Braking Resistor Setup

The internal control of an external braking shunt resistor is provided in the Spindleblok. There is no internal shunt resistor, therefore without an added shunt resistor, the drive cannot dissipate any braking energy. If the application has sufficient inertia, requires high deceleration, or has over-hauling loads then an external shunt resistor must be added.

Information on braking resistance selection is provided in the SpindleBlok manual.

The braking controller is a proportional PWM regulator. It is setup by two parameters, J09 (***vdc_braking***) and K06 (***kp_brake***). Parameter J09 (***vdc_braking***) sets the DC link voltage at which braking commences. This value must be less than J08 (***vdc_max***), the over-voltage trip point. A braking voltage of 380 volts is recommended for 240-volt class drives, 760 volts is recommended for 480-volt class drives, and 200 volts is recommended for 115-volt class drives. If you change parameter J09, you must cycle the power to drive for the change to take affect.

Parameter K06 (***kp_brake***) is the proportional gain in the braking regulator. The default value of 4096 is recommended but may be reduced if the dc link is not stable during braking.

Software thermal protection for the shunt resistor is also available. It is configured through parameters J0B (***db_pt_wdt***) and J0C (***db_pt_lim***). J0C (***db_pt_lim***) should be set to the power rating in watts of the dynamic brake resistor. Setting this to zero disables thermal protection of the shunt resistor. When no shunt resistor is used, J0C (***db_pt_lim***) should be set to zero to prevent false trips from the protection software.

Parameter J0B (***db_pt_wdt***) sets the thermal time constant of the dynamic brake resistor. The default value of 57 corresponds to thermal time constant of 60 seconds and is fairly conservative. Lower values represent longer time constants, see the “SpindleBlok Drive Parameter Definitions” document for scaling details.

Open Loop Mode

Spindleblok includes an open-loop volts-per-hertz mode. This mode is useful when a feature of the sensorless flux vector control is inappropriate. An example of this is the spindle orient function where smooth motion is required to zero speed. In sensorless flux vector mode, the motor will stop and enter a dc hold mode (dc current in injected to maintain rotor magnetiziation) when the magnitude of the speed command is less than one percent of base speed. Thus, a four-pole, 60 Hz motor will enter dc hold when the speed command is between -18 and 18 RPM. In a spindle orient function, an external controller is commanding the speed based on a spindle position encoder. The dc hold feature would cause a limit cycle during settling.

The precision torque and speed control of the flux vector system is disabled during open loop mode.

A separate set of acceleration rates and analog input speed command scaling is provided for open loop mode. For a spindle orient type application, the open loop acceleration rates should be set very high so that the rate limiter does not add a lag to the system. The external controller should control the acceleration rate. The acceleration rates for open loop mode are parameters F05 (***accel_rate_ol***) and F06 (***decel_rate_ol***).

The analog input scaling should also be set to make best use of the available resolution. The analog input is an 11-bit input for the +/- 10 volt. In sensorless flux vector mode, the

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analog input may be scaled to 10,000 RPM. This gives a resolution of about 10 RPM per bit. This is adequate for the high-speed operation but is rough for a spindle orient where the maximum speed would not exceed 200 RPM. Scaling the open-loop analog input to a max speed of 500 RPM gives a bit resolution of ½ RPM, which gives a very smooth spindle orientation. The scaling of the analog input for open loop mode is set by parameters M1A (***vin_max_spd_ol***) and M1B (***vin_min_spd_ol***).

Tuning the Current Regulators

The current regulators are PD regulators and must be tuned before spinning the motor. The proportional gain is parameter K07 (***kp_i_nom***) and the differential gain is K08 (***kd_i_nom***). Changes to these parameters only take effect when the drive is off.

The best method to tune the current regulators is to observe the current control behavior during standard commissioning. Standard commissioning injects different levels of DC current into the motor. The idea is to increase the gains until the current regulators become unstable, then reduce the gains by a safety margin.

Start by initializing the current regulator gains to default values: K07 (***kp_i_nom***) = 4096 and K08 (***kd_i_nom***) = 2048. Confirm that the run enable is present by reading parameter D19. Bit zero will be set if the drive is enabled to run. Perform a standard commission by writing FFFBh (65,531) to parameter C00 (***drive_command***). Alternatively, you can click the “Commission Drive” button in the “Motor Setup” submenu of the “Utils” menu of SBconfig. The drive will apply stepped DC current to motor for approximately ten seconds.

If the drive faults on an over-current or if the motor squeals at 300-400 Hz then the regulator gains are too high. Reduce parameters K07 and K08 by 50% and repeat the process until commissioning completes smoothly.

If commissioning completes smoothly with an even, stepped, high pitched hum (10 kHz) then increase the current regulator gains, parameters K07 and K08, by 50% and repeat the process until the drive faults on over-current or the motor squeals at 300-400 Hz. Do not set any gain over 32,767.

Note that changes in the current regulator gains will only take affect when the drive is off.

When the boundary between stable and unstable operation of the current regulators is found set the gains at one half this value. For example, if the motor first squeals or trips on over-current when the gains are K07 = 9,216 and K08 = 4,608 then set the tuned gains to K07 = 4,608 and K08 = 2,304.

Setting up the speed regulator

As mentioned above, it is critical to tune the speed regulator before spinning the motor. The speed regulator is relatively easy to tune for spindle applications because it is designed to give the same response at all speeds in spite of the fact that the torque constant changes in the field-weakening region.

The speed regulator is a classic PI regulator with a low pass filter to minimize high frequency noise. Three parameters affect the tuning K00 (***kp_trq_dflt***), K01 (***ki_trq_dflt***), and K02 (***iq_wdt_dflt***). K00 is the proportional gain, K01 is the integral gain, and K02 sets the bandwidth of the low pass filter. K02 also inversely affects the resulting proportional gain. All of these parameters have a range of 1 to 32,767.

An alternate set of these gains exists as parameters K03 (***kp_trq_hi_j***), K04 (***ki_trq_hi_j***), and K05 (***iq_wdt_hi_j***). This set is useful for machines with selectable gear ratios where the resulting reflected inertia varies widely and requires different regulator settings for good performance. The alternate set can be selected by clearing bit 10 of C01 (***drive_mode***) or through the local digital inputs. Note that an alternate set of acceleration and deceleration rates is selected as well.

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The Microsoft Excel spreadsheet “Spindleblok speed regulator.xls” is provided to aid in tuning the speed regulator. It was designed for mechanical systems in which the load inertia and the gear ratio between the motor and load can vary. It is a good tool to come up with initial values for the speed regulator gains. It can also be used to fine-tune. Conversely, the three parameters, K00, K01, and K02 can be adjusted directly to fine-tune the system.

The first step in tuning the speed regulator is to enter the five scaling parameters at the top of the spreadsheet. These are A08 (***ki_imag***), A09 (***kv***), G02 (***rated_speed***), G04 (***rated_freq***), and G1C (***omega_base***).

Next, you must enter the rotor inertia. If this is not known, you can estimate by comparing frame size in the listed table. Note that if your motor is a two-pole motor then use half the value in the table. If your motor is a four or higher pole motor, use the listed value. It is better to underestimate the motor inertia than to overestimate it.

Next enter a range of load inertia, as a fraction of motor inertia. If your inertia does not vary then enter the same value for minimum and maximum. If you do not know the load inertia, estimate it and input a range that brackets your estimate. For example, if you estimate that the load inertia is twice the rotor inertia, you may want to bracket it by entering an inertia range from 1 to 4 times.

Next, enter the range of gear ratios (expressed as motor speed and corresponding spindle speed). If your system has a fixed gear ratio, enter that for both minimum and maximum. If your system has more than two gear ratios, enter the minimum and maximum.

Next, enter the desired closed loop bandwidth. The bandwidth affects how fast the speed regulator can respond to a speed change or reject an external load disturbance. If it is set very low then the system will appear sluggish and unresponsive. If it is too high then the drive may excite resonances in the transmission or machine or the motor may run a bit rough as it responds to noise in our speed estimate. As a start, enter a bandwidth that results in a value of K00 between 2000 and 5000. This usually gives good results. For an initial tuning start with K00 closer to 2000. Note that a lower bandwidth results in a lower K00.

Finally, write the regulator gains (K00 to K02) to the Spindleblok using the set button in SBconfig.

If you want to use both sets of regulator gains, repeat the last four steps for parameters K03, K04, and K05. Note that in each case, default and alternate, you should only enter the load inertia range and gear ratio range that is used for that case.

Try running the drive to an intermediate speed, somewhat below the field weakening point. If the system experiences excessive overshoot then you most likely underestimated the load inertia. If the system chatters or runs rough you have either overestimated the load inertia or have entered a bandwidth that is too high for your system.

Once the system responds in a stable manner, you may be able to further improve response if you initially bracketed your estimated load inertia. Try to narrow the bracket and test the response. For example, if you entered a load inertia range of 1 to 4 times rotor inertia try using a range of 1.4 to 2.8 times. A narrower range of inertias will allow the system to respond faster without rough operation.

You can also optimize the regulator by directly altering parameters K00, K01, and K02 while the drive is running. A good test is to increase the acceleration rate (F01 ***accel_rate_dflt***) to a very high value after the motor has reached the intermediate test speed. Step the speed by a small increment (100 rpm) and monitor the response. If the speed appears to overshoot then either increase K00 (***kp_trq_dflt***) or decrease K01 (***ki_trq_dflt***). If the step seems rough, either increase K02(iq_wdt_dflt) or decrease K00 (kp_trq_dflt). When you change these three parameters, increase them by steps of 50% or decrease them by steps of 33%.

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Auto-tuning

Auto-tuning is a means for the drive the determine some of the motor parameters as well as some internal parameters. There are two levels of auto-tuning: standard and extended. Standard auto-tuning applies various levels of DC excitation to the motor and does not spin it. During standard auto-tuning, the drive determines the motor stator resistance (parameter G0A) and some internal parameters. During extended auto-tuning, the motor will spin and the magnetizing current ratio will be determined (parameter G18).

Standard Auto-tuning

Standard auto-tuning determines the stator resistance of the motor as well as several internal calibration parameters. It is very important that a standard auto-tune is performed on every drive so that the inverter can be calibrated to the wiring and motor. You should perform the standard auto-tune after the motor parameters have been entered. The speed regulator does not need to be tuned before executing a standard auto-tune.

To perform a standard auto-tune, make sure that bit 3 of parameter C01 (drive_mode) is set. Checking the “Disabled” box under “Extended Commission” in the “Drive Mode” menu of SBconfig does this. Then write FFFBh (65,531) to parameter C00 (drive_command). Alternatively, you can click the “Commission Drive” button in the “Motor Setup” submenu of the “Utils” menu of SBconfig.

A standard auto-tune should take about 10 seconds. The drive must be enabled to run for a standard auto-tune to execute.

Extended Auto-tuning

Extended auto-tuning automatically determines the required magnetizing inductance and sets parameter G18 (k_id). The drive will spin the motor to roughly half of rated speed to accomplish this. The motor can be loaded or unloaded although if the motor is loaded, it should be a steady load or the auto-tuning may not converge. The speed regulator must be successfully tuned to perform an extended auto-tune. If you are duplicating one drive to another, with the same make and model of motor then you do not need to execute an extended auto-tune. A standard auto-tune should be executed, though.

To perform an extended auto-tune, clear bit 3 of parameter C01 (***drive_mode***). Checking the “Enabled” box under “Extended Commission” in the “Drive Mode” menu of SBconfig does this. Then write FFFBh (65,531) to parameter C00 (***drive_command***). Alternatively, you can click the “Commission Drive” button in the “Motor Setup” submenu of the “Utils” menu of SBconfig.

If the acceleration is rough or the drive overshoots and does not settle well then the speed regulator needs adjustment.

Extended auto-tune can also be used to determine if the G00 (***rated_volts***) is optimal for the motor and drive. Often, a motor rated for across-the-line operation is designed to work over range of voltages from a low line to high line. Therefore, the listed rated voltage may not be optimal. In this case the rated voltage is typically too high. Conversely, high speed, constant torque spindles often list an operating condition that is not at the field weakening point but is well into the field weakening region. For example, a motor may list a nameplate operating point of 300 Hz, 220 volts, 8.5 amps, and 17,470 RPM. While this is a valid operating point, 220 volts may not be optimal at 300 Hz but may reflect the limitation of available supply voltage. The optimal voltage at 300 Hz may be 280 volts and should entered as such to calculate the best flux command (or volts-per-hz ratio).

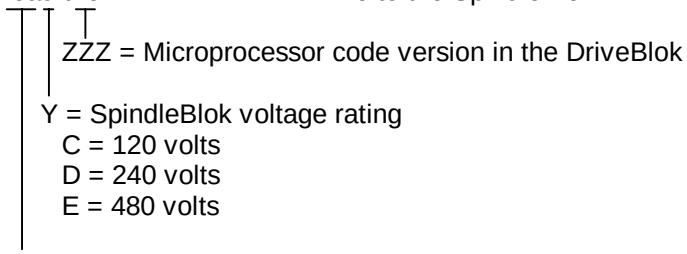
Evidence that the rated voltage (G00 ***rated_volts***) may be too high is an enhanced commissioned value of G18 (***k_id***) that is above 50. To test if this is the case, reduce G00 (***rated_volts***) by 10% and re-commission. If the new value for G18 (***k_id***) is lowered by more than 15% then the new voltage is more optimal. If so, reduce G00 (***rated_volts***) again and repeat the test.

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A similar test can be used to determine if a higher rated voltage is optimal. If increasing the G00 (***rated_volts***) by 10% and commissioning results in G18 (***k_id***) increasing by less than 15% then the higher rated voltage is most likely more optimal.

Restoring a Drive to Factory Defaults

In order to restore a SpindleBlok to it's factory default configuration use the SSI_POD2P program to down load the BBXXYZZZA.DEF file to the SpindleBlok.



Example: For a 5 horsepower 240 volt SpindleBlok running 0109 code version the default configuration file is BB05D109A.DEF.

Figure 6-5

Def File Nomenclature

Step One: Determine Microprocessor Code Version in SpindleBlok

To determine the microprocessor code version in the MTS Systems DriveBlok, SpindleBlok, and IndexBlok products, remove the top cover and note the code version label on the microprocessor. The microprocessor is the socketed integrated circuit to the left of center on the top printed circuit board.

Step Two: Install Pod2P

To setup Pod2P on the computer's hard drive create a directory called Pod2P. Copy the SSI_POD2P.exe program and the 0ZZZ.ver files to this directory. The 0ZZZ.ver files must reside in the same directory on the computer's hard drive as the program file SSI_POD2P.exe (where ZZZ is the microprocessor code version in the SpindleBlok). It is also convenient to have the BBXXYZZZA.DEF file reside in the same directory.

Step Three: Running Pod2P

To run Pod2P open Windows Explorer and navigate to the Pod2P directory and double click the mouse on the SSI_POD2P.exe program file. The first time the SSI_POD2P program is opened two buttons are not available, the SET and SET ALL buttons. To activate this feature, open the SSI_POD2P program and prior to opening a **User List** type ctrl-D (hold the ctrl key and press D), then exit SSI_POD2P. When the SSI_POD2P program is reopened, two new buttons will appear near the top of the window, SET and SET ALL. Note: This feature will not become available if a **User List** is opened prior to typing Ctrl-D.

Step Four: Restoring SpindleBlok to Factory Default Configuration

With the computer interfaced to the SpindleBlok and power applied to the SpindleBlok, open the SSI_POD2P program and select **file** from the top tool bar. Under **file** select **Open User List** and specify the file BBXXYZZZA.DEF. When this file has loaded click the mouse over the SET ALL button. When prompted as to if you really want to do this, select Yes.

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When the down load is complete, disconnect power to the SpindleBlok and verify that the green power LED begins to blink. When power is reapplied the SpindleBlok will be restored to factory default.

How to Duplicate a Drive

See information on www.mtsautomation.com or contact an application engineer.

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7. Setting up Local I/O

The local I/O can be configured to control both the speed setpoint and the starting of the drive. To enable local I/O, bits 8 and 9 of C01 (drive_mode) must be cleared. Clearing bit 8 enables local setpoint control and clearing bit 9 enables local start control. These can be independently set and cleared, clearing bit 8 but setting bit 9 results is local setpoint control and serial start control. Note that if bit 9 of C01 is clear, enabling local start, and a serial stop is received, the drive will automatically switch to serial start control by setting bit 9 of C01. This prevents the local I/O from inadvertently restarting the drive after a serial stop command.

Local Setpoint

The local setpoint can come from two sources, the analog input or preset speeds. Any preset speed that has been setup and is enabled will take precedence over the analog input. To define preset speeds, some of the programmable digital inputs must be programmed as preset bits and the preset speeds must be programmed into parameters M0C through M12. See the section on **Digital Inputs** for more details.

The analog input will control the speed in local setpoint mode if no defined preset speeds are enabled. The analog input can be set as bi-polar (-10 volts to 10 volts) or uni-polar (0 to 10 volts). Setting bit 13 of C01 (***drive_mode***) specifies bi-polar mode, clearing bit 13 of C01 (***drive_mode***) specifies uni-polar mode. Note that any change between uni-polar and bi-polar will not take effect until a power on reset.

The analog input voltage is scaled by parameters M18 (***v_ref_range***) and M19 (***v_ref_offset***), 32,767 is 10 volts, 0 is zero volts. Any voltage reading between M19 (***v_ref_offset***) and M18 (***v_ref_range***) + M19 (***v_ref_offset***) will be scaled linearly between M1C (***vin_min_spd_cl***) and F00 (***max_speed***). Voltage readings above this range will scale to F00 (***max_speed***), voltage readings below this range will scale to M1C (***vin_min_spd_cl***). In open loop mode, parameter M19 (***vin_spd_scl_ol***) is used instead of F00 (***max_speed***) to scale the analog input. Note that M19 cannot be larger than F00 or a parameter fault will occur.

When the analog input is set in bi-polar mode, speed and direction come from the analog input. Positive voltages are forward direction and negative voltages are reverse direction. In uni-polar mode, only the speed comes from the analog input. The direction must be set by either using run-forward or run-reverse digital input or using the forward/reverse digital input. See the section on **Digital Inputs** for more details.

The plot below shows the speed setpoint as a function of analog input voltage with M1C (***vin_min_spd_cl***) set to 0, F00 (***max_speed***) set to 7,200, M19 (***v_ref_offset***) set to 0 and M18 (***v_ref_range***) set to 26,214.

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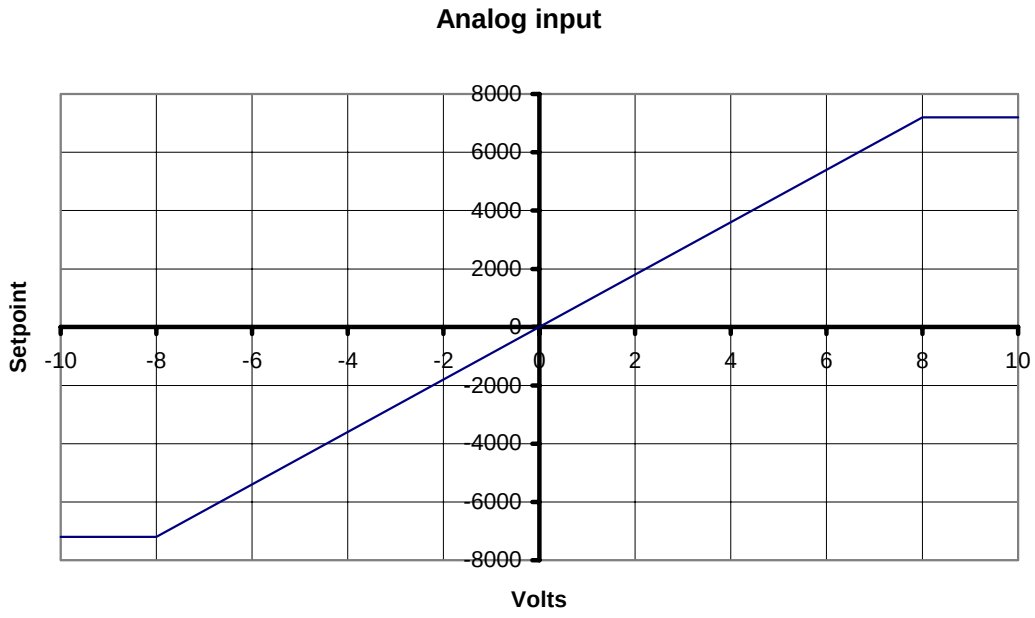


Figure 7-1

The plot below shows the speed setpoint as a function of analog input voltage with M1C (***vin_min_spd_cl***) set to 900, F00 (***max_speed***) set to 3,600, M19 (***v_ref_offset***) set to 3,277 and M18 (***v_ref_range***) set to 26,214.

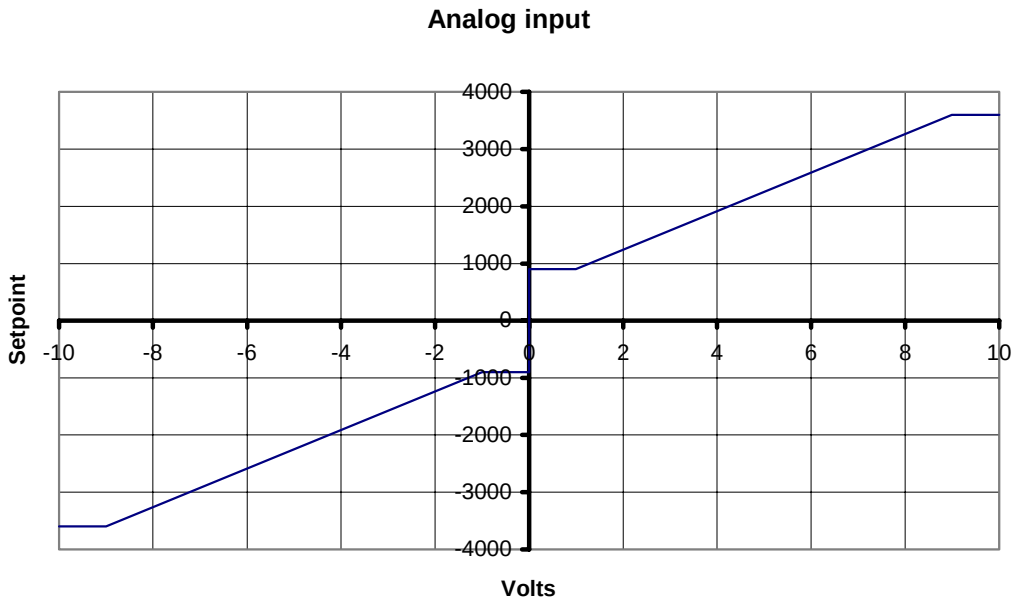


Figure 7-2

Digital Inputs

Spindleblok has eight available digital inputs. Digital input 1 (pin 9) is Run Enable. Digital inputs 2 and 3 (pins 10 and 11) are either Run and Rev or Run Forward and Run Reverse. The choice is made by the state of bit 14 of C01 (***drive_mode***). The functionality of these three pins is described in sections VII and VIII of the "Setup and Control Specification" and should be carefully studied. Digital inputs 4 through 8 (pins 12 through 16) can be programmed as external fault, preset speeds, forward enable, reverse

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enable, default / alternate speed regulator, or open loop. Review section IV of the "Setup and Control document" for descriptions of the available functions. Pins 15 and 16 can optionally be programmed as digital input 7 and 8 or open collector digital output 1 and 2. If these pins are used as inputs then digital output functions 1 and 2 should be programmed as "set high". See the next section to use them as outputs.

The physical state of the digital inputs can be read real time as the lower 8 bits of D18 (***dig_in***). A set bit indicates that the pin is pulled low and a clear bit indicates that the pin is held high. Parameter D19 (***dig_in_z0***) gives the asserted states of the digital inputs in the lower 8 bits. A set bit indicates asserted while a clear bit indicates de-asserted.

Digital Outputs

Spindleblok has four available digital outputs, two isolated relays and two open collector outputs. The two open collector outputs (digital outputs 1 and 2) share pins 15 and 16 with digital inputs 7 and 8. To use these pins as outputs, digital input functions 7 and 8 should be set to the null function. To use these pins as inputs, see the above section, **Digital Inputs**. All digital outputs are programmable as set high, set low, at speed, out of regulation, run, reverse, overload alert, over temperature alert, speed detect low, speed detect high, torque detect low, torque detect high, brake actuate, fault, control mode, and fault code. They can also be programmed to control their state through serial control. Review section V of the "Setup and Control Document" for more thorough descriptions of the available functions.

Analog Outputs

Spindleblok has two available analog outputs. They are 8 bit outputs that are scaled from 0 to 10 volts. They are programmable as current, torque, speed, frequency, output voltage, heatsink temperature, DC link voltage, or serial set value. Two of these, torque and speed, are considered signed variables and the analog output is offset by five volts. For example, zero speed gives 5 volts, positive speed increases from five volts and negative speed decreases from 5 volts. The analog outputs can also be programmed to display other internal dyanamic variables if required. Contact your sales rep for assistance if this is needed.

Programming the I/O

To program the I/O, you must first set the three bits of C01 (***drive_mode***) that set the I/O mode. These are:

	BIT SET	BIT CLEAR
Bit 12	Digital inputs pulled up. • *Drive must be power-on reset, or IO init command must be executed for changes to take affect.*	Digital inputs pulled down. • *Drive must be power-on reset, or IO init command must be executed for changes to take affect.*
Bit 13	Bipolar analog input. The analog input is sampled as a –10 volt to +10 volt input. • *Drive must be power-on reset for changes to take affect.*	Unipolar analog input. Only voltages between 0 and 10 volts are read on the analog input. This range is sampled twice as often as in bipolar mode. • *Drive must be power-on reset for changes to take*

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		affect
Bit 14	Digital input 2 is run and digital input 3 is invert local setpoint (fwd_rev). • *IO init command must be executed for changes to take affect.*	Digital input 2 is run forward and digital input 3 is run reverse. • *IO init command must be executed for changes to take affect.*

Table 7-1

Next, you must program the I/O functions that you want to use. Note that the state of bit 14 of C01 (***drive_mode***) sets the functionality of digital inputs 2 and 3. Digital input 1 is always Run Enable. The digital inputs functions for digital inputs 4 through 8 are programmed into parameters M00 through M04. The list of available functions can be found in the "Setup and Control Specification". Any unused pin should be programmed with the Null Function (value 0). Note that digital output 1 and 2 share the same pin as digital input 7 and 8. If these pins are to be used as outputs then the M03 (***dig_in_7_fcn***) and M04 (***dig_in_8_fcn***) must be set to 0 (Null Function). Conversely, if these pins are to be used as inputs them M06 (***dig_out_1_fcn***) and M07 (***dig_out_2_fcn***) must be set to 0 (Set High).

The digital input polarity should also be set. The lower 8 bits of parameter M05 (***dig_in_polarity***) define the polarity of each of the 8digital inputs. Bit 0 is digital input 1, bit 1 is digital input 2, etc. When the bit is cleared, the input is active when it is pulled low. When the bit is set, the input is active when it is high.

Similarly, the relay and digital output functions and the analog output functions should be programmed. Parameters M06 (***dig_out_1_fcn***) and M07 (***dig_out_2_fcn***) program the open collector digital outputs, M08 (***relay_1_fcn***) and M09 (***relay_2_fcn***) program the relay outputs, and M0A (***analog_out_1_fcn***) and M0B (***analog_out_2_fcn***) program the two analog outputs.

After all of the I/O functions are programmed, you need to initialize the new I/O setup by writing F7FFh (63,487) to parameter C00 (***drive_command***). SBconfig has automated this I/O initialization and it can be accomplished by clicking the "IO Init" button. Note that if your I/O setup required you to change the analog input setup between bi-polar and uni-polar then the change will not take effect until a power on reset.

To finish the I/O setup you must program any preset speeds (parameters M0C through M12) that you will use. Also, if you are using torque detect high / low, speed detect high / low, or out of regulation digital outputs, program the levels in parameters M13 through M17. Refer to the parameter definition table for scaling.

If you are using the analog speed reference, you must program the scale factors, parameters M18 (***v_ref_range***), M19 (***v_ref_offset***), and M1C (***vin_min_spd_cl***). For open loop mode program the maximum speed parameter M1A (***vin_spd_scl_ol***) and the minimum speed parameter M1B (***vin_min_spd_ol***).

The plot below shows the speed setpoint as a function of analog input voltage with M1C (***vin_min_spd_cl***) set to 0, F00 (***max_speed***) set to 7,200, M19 (***v_ref_offset***) set to 0 and M18 (***v_ref_range***) set to 26,214.

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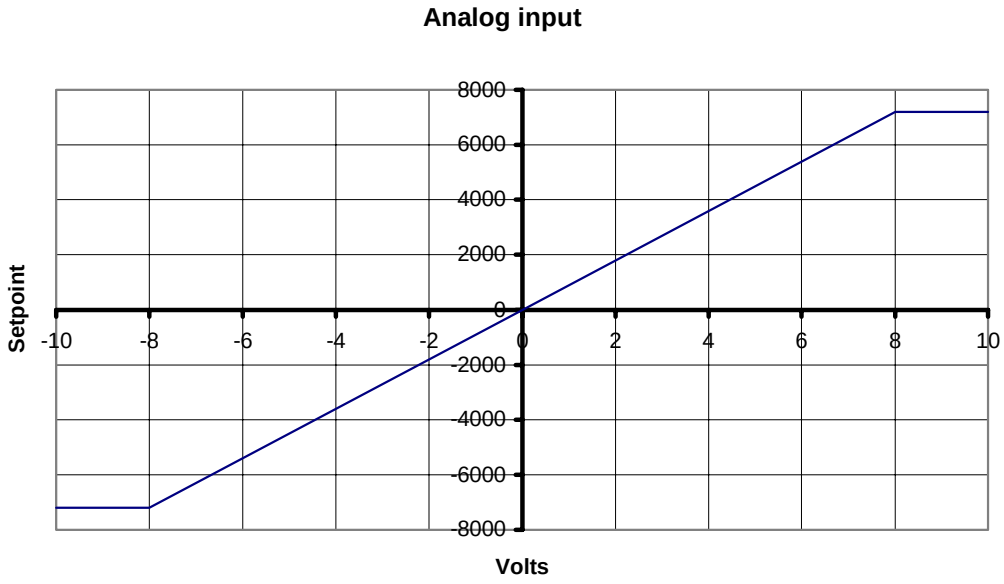


Figure 7-3

To scale the analog outputs, set parameters M1A (***ao_1_scale***) and M1B (***ao_2_scale***). Refer to the Setup and Control Specification for scaling information, depending on the analog output functions you have chosen.

Finally, you should enable the control method you have chosen by setting or clearing bits 8 and 9 of C01 (drive_mode). This can be done through the "DriveMode" menu of SBconfig.

	BIT SET	BIT CLEAR
Bit 8	Serial setpoint control	Local setpoint control
Bit 9	Serial start control	Local start control

Table 7-2

Fault handling

If a fault condition occurs while the Spindleblok is running, the Spindleblok will instantly shut off and annunciate a fault blinking the red fault LED. The number of blinks in the repeated pattern reflects the specific fault. See the document on Extended Fault Codes for more detail on the cause of the fault and corrective actions. If a digital output or relay is programmed with the fault function, this output will also activate. To clear a fault with the local I/O, de-assert Run Enable (digital input 1). Do not restart the drive until the motor has had sufficient time to coast to a stop.

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8.Setting up Serial Control

Setup

To setup the drive for serial control, you must program the baud rate and desired drive address into parameters B00 (drive_address) and B01 (baud_rate). The available drive addresses are '1' – '9' and 'A' – 'Z'. The 35 addresses are available so that a single RS485 master can control multiple drives. Entering the ASCII equivalent into parameter B00 (drive_address) programs the address. It is recommended that addresses other than the default of '1' be used only in multi-drive systems. Any drive with an address other than '1' should be clearly marked! Note that if you use SBconfig to change the drive address, you will need to set the drive address under the "Utils" / "Comm Setup" menu to continue to communicate with the drive.

The available baud rates are 300, 600, 1200, 2400, 4800, 9600, and 19200. These are the only values that should be written to parameter B01 (baud_rate). To make a new baud rate take effect, you need to either cycle power to the drive or perform a serial initialization by FF7Fh (65407) to parameter C00 (drive_command). Note that if you use SBconfig to change the baud rate, you will need to set the baud rate under the "Utils" / "Comm Setup" menu to continue to communicate with the drive.

Finally, you should enable the control method you have chosen by setting or clearing bits 8 and 9 of C01 (drive_mode). This can be done through the "DriveMode" menu of SBconfig.

	BIT SET	BIT CLEAR
Bit 8	Serial setpoint control	Local setpoint control
Bit 9	Serial start control	Local start control

Table 0-1

Control

Typical serial control systems run several parallel processes. Feedback from the drive is monitored on a periodic basis. This consists of reading parameters of interest from the Feedback Page (D00 – D1A). Commonly read parameters are D00 (***drive_state***), D03 (***i_mag***), D06 (***vout***), D09 (***omega_m_dsp***), or D0B (***torque***). Start and stop commands are issued, as needed, by writing to parameter C00 (***drive_command***).

The speed setpoint is written to, as needed, at parameter C02 (***omega_cmd_save***) or parameter C03 (***omega_cmd_save_nv***). The difference between these two parameters is that C03 (***omega_cmd_save_nv***) is saved in both RAM and non-volatile ee-prom. The value written will be stored during power down and retrieved on power up. Parameter C02 (***omega_cmd_save***) is only saved in RAM and will be lost on power down. You should write to C02 (***omega_cmd_save***) if you write the speed command often as the non-volatile ee-prom has only a 100,000 write cycle life. If your control system updates the speed command each time it runs or on a periodic basis, use parameter C02 (***omega_cmd_save***). If you want to initialize the speed command once and not write to it again, use parameter C03 (***omega_cmd_save_nv***).

The Spindleblok will need to have run_enable (digital input 1) on the local I/O asserted to be able to run. This is often used as a mechanical emergency stop. You can also simply jumper pin 9 (digital input 1) to pin 8 (digital ground) to enable the drive. An additional

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option that requires no external parts is the invert the polarity of run_enable (digital input 1) so that it is asserted when it is high by setting bit 0 of M05 (***dig_in_polarity***).

The state of the digital and analog outputs can be controlled through the serial port if your serial control system needs external outputs. Programming the digital output and relay functions (M06 – M09) to a value of 15 (serial control) allows you to set the state of the outputs by writing to parameter D17 (***dig_out_prog***). The analog outputs can be serially controlled in a similar manner. See the Setup and Control document and the drive parameter definition document for details.

If the drive is to be controlled through the serial port, then the loss of serial communications fault should be enabled. This will cause the drive to fault and shut down if no serial message is received within a preset time. Writing a non-zero number to parameter J02 (***comm_timer_max***) enables the loss of serial communications fault. The value sets the time window for the serial communications fault, it is scaled by 52 msec per count. A value of 95 gives a recommended communications time out of 5 seconds.

Fault handling

If a fault condition occurs while the Spindleblok is running, the Spindleblok will instantly shut off and annunciate a fault blinking the red fault LED. The number of blinks in the repeated pattern is the fault number and reflects the specific fault. See the document on "Extended Fault Codes" for more detail. The drive will also respond to any serial read or write with a unique fault response. The fault response includes the fault number. To clear the fault through the serial port, read parameter D01 (***drive_status_save***).

The Spindleblok will also respond to any serial read or write with the fault response (fault code 0FFh) after a power up reset.

It is very important that serial control systems continuously send a serial command to the drive so that any fault will be detected quickly. If the controller does not need to write to any parameters then it should read some feedback parameter.

Extensive fault data is available in the fault cue (parameters E00 – E2D). See the section below on Troubleshooting below and the appendix on Spindleblok Parameters, Page E. For a more complete description of Serial Communications see our application note on our web site at http://www,mtsautomation.com.

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Extended Fault Codes w/ Cause and Remedy

Sat faults

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
10XXh	4096 - 4223	1	Short circuit detected or inverter damaged. The lower seven bits specify which IGBTs detected a problem. Bit 0 – Brake, Bit 1 – CL, Bit 2 – CU, Bit 3 – BL, Bit 4 – BU, Bit 5 – AL, Bit 6 AU	One or more of the inverter IGBT could not turn on or was prevented from turning on by a ground fault or a short circuit. REMOVE POWER FROM THE DRIVE AND ALLOW THE CAP BANK TO DISCHARGE. Disconnect the motor from the drive and check for ground faults with an ohmmeter. Check for phase to phase shorts by confirming that the three phase to phase resistances are equal. You can check for permanent damage on the inverter with a diode checker between the three motor terminals (T1, T2, and T3) and the plus and minus bus (-B and +B). The diodes should block and the forward voltage should be consistent. If no problem is found then the fault may be a nuisance trip. This can be caused by improper grounding or external noise on the power lines or ground. Make sure that the drive and motor are properly grounded. In particular make sure that the motor is grounded to the heatsink and that the ground wire is bundled with the motor leads.

DB overload faults

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
2000h	8192	2	DB Overload	The internal thermal model of the DB resistor indicates that the DB resistor is overheating from excessive braking. If the DB resistor is very hot then either replace it with a higher wattage resistor or decelerate less often. If the DB resistor does not seem very hot then the internal thermal model needs to be modified. Two parameters affect this model. The first is J0C (***db_pt_lim***) which is the rated wattage of the DB resistor. If the resistor is cooled by forced air or has additional heatsinks then a value higher than the published rating can be used. If you set this parameter to zero then thermal protection of the DB resistor is disabled. The second parameter is J0B (***db_pt_wdt***) which is the thermal time constant of the DB resistor. This controls the time that the DB resistor is allowed to dissipate high braking power before tripping. Halving this number doubles the time before a trip. The default value is very conservative.

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Phase over current

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
3000h	12288	3	Phase Overcurrent	The motor current sensors detected excessive current and shut the drive down. If this happened during commissioning or at start, the current regulators may be unstable. Try reducing the current regulator gains by half (parameters K07 ***kp_i_nom*** and K08 ***kd_i_nom***). If this does not solve the problem, make sure that the motor parameters match the motor. Make sure the magnetizing current (G18 ***k_id***) is not too large. It should not be above 60 except in special cases. Try reducing the per-unit-resistance (G17 ***k_rs***) by half and recommissioning. If the overcurrent happened while the motor is loaded, try reducing the load limit (G10 ***load_lim***). If the motor rated current matches the drive rated current then the load limit should not exceed 200%. If the overcurrent happened during field weakening then check the slip limit (G11 slip_lim). Most standard AC motors have a slip limit between 200% and 300%. Special spindle motors may have a limit as high as 450%. Also make sure that the appropriate rated slip is programmed by setting rated speed (G02 ***rated_speed***). If this is a low slip motor then you may need to reduce the rate limits on flux (L04 ***flux_rate_lim_pos*** and L05 ***flux_rate_lim_neg***). Finally experiment with the leakage inductance parameter G06 ***ll_lm*** by increasing or decreasing it by 10.

Not Used

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
4000h	16384	4	Not Used	

DC link undervoltage

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
5000h	20480	5	DC link undervoltage	The voltage sensor has detected a low bus voltage. If the drive is a 240 volt or 480 volt class drive with three phase power within line voltage specification then the most likely explanation is that a momentary input line dropout occurred. If the problem persists, monitor the input line voltage. If the input power is single phase or the drive is a 115 volt class drive then drawing excessive power from the motor may droop the line or cause enough ripple on the DC bus to cause an undervoltage trip. Increasing the DC bus capacitance will reduce the DC bus ripple.

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DC link overvoltage

Fault No (hex)	Fault No (decimal	Fault LED Blink Count	Description	Cause and Remedy
6000h	20480	6	DC link overvoltage	The voltage sensor has detected a high bus voltage. Either the AC line exceeded specification or the inverter regenerated to the DC bus during deceleration or with an overhauling load. An inductive short in the motor to ground can also cause this at low speeds. If the fault occurred during deceleration then make sure that a DB resistor that can dissipate the braking power is installed or reduce the appropriate deceleration rate (F02 ***decel_rate_dflt***, F04 ***decel_rate_hi_j***, or F06 ***decel_rate_ol***). Also confirm that the braking voltage (J09 ***vdc_braking***) is set below the trip voltage (J08 ***vdc_max***). For 230 volt drives, the braking voltage should be at least 40 volts below the trip voltage. For 460 volt drives, the braking voltage should be at lease 80 volts below the trip voltage. The braking voltage should be set higher than any voltage level generated by rectifying the AC input lines. For normal line conditions, the braking voltage should be set to 380 volts for a 230 volt drive and 760 for a 480 volt drive. After setting J09 (***vdc_braking***), a power-on reset must occur for the new value to take effect. The final parameter that affect the dynamic braking is K06 (***kp_brake***), the braking regulator gain. The recommended value is 4096. Increasing the gain will decrease the voltage rise during braking but may also cause rough braking or dc link instability. If the DB resistor and all parameters are correct, confirm that the braking system is working by connecting a DC volt meter (rated for 1000 volts) across the braking resistor. The meter should register zero volts while the drive is not braking and a large voltage when the motor is decelerating (until the drive trips on DC link overvoltage). If the meter always registers zero volts then the braking IGBT is not operating. Contact your sales rep.
6001h	20481	6	Not Used	

Not Used

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
7000h	28672	7	Not Used	
7001H	28673	7	Not Used	

A/D Offset Fault

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
8000h	32768	8	A/D offset out of range	The phase current sensors zero current offsets have drifted excessively from the factory calibrated values. If either of the offsets (I04 ***ib_offset*** and I07 ***ic_offset***) are near zero or above 50,000 then the sensors have

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				failed. In any case, if the fault persists then the contact your sales rep.

Motor Fault

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
9000h	36864	9	Motor did not stop within 10 seconds of commanded stop time.	High inertia or an overhauling load prevented the drive from decelerating at the programmed deceleration rate and load limit. Increase the load limit (G10 ***load_lim***) or decrease the appropriate deceleration rate rate (F02 ***decel_rate_dflt*** or F04 ***decel_rate_hi_j***). If the motor is in field weakening you may want to check the programmed slip limit (G11 ***slip_lim***). If increasing this parameter does not speed up deceleration then the motor may be pulling out and decreasing the slip limit may help.
9001h	36865	9	Motor overspeed	The estimated motor speed exceeded the programmed maximum speed (F00 ***max_speed***). If the commanded speed is near the programmed maximum speed then the overshoot during acceleration or a transient may trip the drive on overspeed. Try re-tuning the speed regulator. First, try decreasing the integral gain by a factor of two (K01 ***ki_trq_dflt*** or K04 ***ki_trq_hi_j***). If this helps then increase the proportional gain by 50% (K00 ***kp_trq_dflt*** or K03 ***kp_trq_hi_j***). If changing the integral gain has no affect then increase both the proportional gain and the low pass filter bandwidth by 50% (K00 ***kp_trq_dflt*** and K02 ***iq_wdt_dflt*** or K03 ***kp_trq_hi_j*** and K05 ***iq_wdt_hi_j***). You can also decrease the acceleration rates (F01 ***accel_rate_dflt*** or F03 ***accel_rate_hi_j***) or increase the max speed (F00 ***max_speed***) to increase the trip margin.
9002h	36866	9	Not Used	
9003h	36867	9	Not Used	
9004h	36868	9	Not Used	
9005h	36869	9	Not Used	

Heat Sink Overtemp

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
A000h	40960	10	Heat sink overtemp	The temperature of the power substrate exceeded the trip limit. Confirm that the heatsink fan (if one exists) operates correctly. If the power substrate temperature (D0A ***heatsink_temp***) is above the fan turn-on temperature (J04 ***fan_on_temp***) then the fan should be operating. If it is not, measure the voltage at the fan terminal to determine if the fan or the power supply is problem. Check if the operating current exceeds the drive specification. This can be read from the data stored in the fault cue. Confirm that the airflow over the heatsink is not obstructed. Measure the ambient temperature while the drive is operating to determine if it is excessive. Finally confirm that the module has good thermal contact

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				with the heatsink by checking the tightness of the module mounting screws and the flatness of the heatsink.

Motor Thermal Overload

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
B000h	45056	**11**	Motor thermal overload	The internal i^2t model of the motor indicates that the motor is near its thermal limit. If the motor appears very hot then you must reduce the load, if not then the internal model should be set to better match the motor. Three parameters affect this protection. The motor rated current (G03 ***i_rated***), the thermal limit (J01 ***i_sqr_t_lim***) and the thermal time constant (J00 ***i_sqr_t_wdt***). The motor rated current should always be the nameplate value. The thermal limit is determined from the service factor, which is often listed on the motor nameplate. Typical values are 1.00 or 1.15. Parameter J01 (***i_sqr_t_lim***) can be calculated as 100 * service factor^2. A higher number can be used for the service factor if the ambient temperature is less than the rated ambient. The default thermal time constant is set conservatively at 250 seconds (***i_sqr_t_wdt*** = 4768). If premature thermal overload trips are occurring, this should be increased.

Communication Loss

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
C000h	49152	12	Communications loss	A loss of serial communications was detected while the drive was operating. This occurs when no valid message is received for a period exceeding the programmed timeout (J02 ***comm_timer_max***). If a drive is controlled locally then J02 (***comm_timer_max***) should be set to zero, which disables the communications loss fault. If the drive is controlled through the serial port then a non-zero value should be used to protect the system if the serial controller locks up or the serial cable opens. Make sure that the programmed timeout is long enough such that garbled messages can be detected and without causing a fault. A few seconds is usually adequate for this.

External Fault

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
D000h	53248	13	External fault	An external input tripped the drive. There are two sources of external faults. A digital input can be defined as an external fault. De-asserting such an

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				input will cause an external fault if the drive is running or is requested to start. Clear the fault and clear the external fault condition. An external fault can also be commanded through the serial interface by writing the value 0FFDFh to paramater C00 (***drive_command***) (bit 5 cleared). Once the external fault condition is cleared, write 0FFEFh to C00 (drive_command) to clear the external fault in the drive.

EEProm Fault

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
E000h	57344	14	Not Used	
E001h	57345	14	Not Used	
E002h	57346	14	Drive could not initiate parameters from the ee-prom.	The ee-prom has been corrupted or has failed. Contact your sales rep.
E003h	57347	14	Wrong FPGA version.	The FPGA on the control card has failed. Contact your sales rep.

Parameter Error

Fault No (hex)	Fault No (decimal)	Fault LED Blink Count	Description	Cause and Remedy
F000h	61440	15	Not Used	
F001h	61441	15	Not Used	
F002h	61442	15	Motor rated speed and frequency indicate a pole count greater than 12.	The motor nameplate model is set up for motors with pole counts of 12 or less. For a 60 Hz motor, the rated speed must be greater than 514 rpm. If your motor has nameplate speed less than 514 rpm, the drive can still run this motor. You will either have to set up the motor using internal parameters (bit 1 of ***drive_mode*** (C01) is cleared) or you can specify an equivalent two-pole motor. To do this, replace ***rated_speed*** (G02) with the nameplate rated speed times the number of pole pairs. To calculate the actual pole pair count, truncate the following to an integer: 60*rated frequency / rated speed. All speed parameters (***omega_cmd_save*** (C02, C03), ***max_speed*** (F00), . . .) must be entered as equivalent two-pole numbers.
F003h	61443	15	Motor nameplate parameters indicate that output power exceeds input power.	There is an error in the motor nameplate data. The maximum possible input power (rated volts * rated current * 1.732) is less than shaft power (horsepower * 745.7). Confirm that entered motor data (***rated_volts*** (G00), ***rated_hp*** (G01), and ***i_rated*** (G02)) matches the motor nameplate. Confirm that scaling is correct.
F004h	61444	15	Motor nameplate parameters indicate that the power factor and/or efficiency must be too	Based on the nameplate data, the motor efficiency or power factor is too low for the motor nameplate model. For a motor greater than one hp, this usually indicates an error in the motor nameplate data.

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			low.	Confirm that entered motor data (***rated_volts*** (G00), ***rated_hp*** (G01), and ***i_rated*** (G02)) matches the motor nameplate. Confirm that scaling is correct. For motors of less than one hp, the data may be correct but the motor may be too inefficient or the power factor too low. To run a motor like this, reduce ***i_rated*** (G02) until the fault goes away. For best starting conditions, set ***k_id*** (G18) in the range of 70 and 90.
F005h	61445	15	Motor rated speed and frequency indicate that the motor rated slip is excessive. slip > max slip (max slip stored in eeprom)	The rated slip of the motor is larger than the motor nameplate model will allow. Confirm that ***rated_speed*** (G02) and ***rated_freq*** (G04) are correct. If they are, increase ***rated_speed*** (G02) until the fault goes away.
F006h	61446	15	Motor could not reach required speed during extended commission.	
F007h	61447	15	Extended commission process resulted in a value for magnetizing reactance that is out of range.	
F008h	61448	15	Not Used	
F009h	61449	15	Not Used	
F00Ah	61450	15	Motor rated speed and frequency indicate that the rated slip is zero.	The entered ***rated_speed*** (G02) is the no-load speed of the motor, not the loaded speed. Enter the loaded speed of the motor. If this is not known, reduce the ***rated_speed*** (G02) by 3%.
F00Bh	61451	15	Max speed too high	The maximum speed is out of range. Reduce ***max_speed*** (F00) to within range. The largest allowable value for ***max_speed*** (F00) is: 2 pole motor 31,861 rpm 4 pole motor 15,930 rpm 6 pole motor 10,620 rpm 8 pole motor 7,965 rpm
F00Ch	61452	15	Max speed used in analog open loop mode is larger than max speed	Parameter M1A (***vin_max_spd_ol***) is larger than ***max_speed*** (F00). Reduce M1A (***vin_max_spd_ol***) until it is less than or equal to ***max_speed*** (F00).
F00Dh	61453	15	Not enabled to spin in either direction during extended commission	Both the forward direction and reverse direction are disabled during extended commission. If digital inputs have been defined as di_forward_enable and di_reverse_enable, make sure that at least one direction is enabled. If the run_forward and run_reverse are defined, make sure that both of these inputs are not active. If the drive is under serial control, make sure that bit 5 (forward enable) or bit 6 (reverse enable) of ***drive_mode*** (C01) is set prior to commissioning.
F00Eh	61454	15	Standard commission process resulted in a value for stator resistance that is out of range.	The commissioned value of stator resistance exceeded the programmed limit. This can happen for several reasons. First, the motor may be disconnected from the drive. Confirm that the motor connections are secure. Second, the motor may have a stator resistance that exceeds the programmed limit. This is common if the motor rated power is more than one frame size less than the drive rated power. If this is the case, increase parameter G14 (***rs_max***) and recommission

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				until the fault goes away. The drawback to this is that performance of a high resistance motor can be poor and general operation rough. Also, if the drive is later used on a larger motor, you may need to reset G14 (***rs_max***) to 3000 and reset the auto-tune parameters by writing 0FEFFh to C00 (***drive_command***). Finally, the stator resistance may be so far off of the value in the drive that the commissioned estimate diverges. First, rest the auto-tune parameters by writing 0FEFFh to C00 (***drive_command***). Next reduce the drive's resistance estimate by halving parameters G17 (***k_rs***) and G0A (***rs***). Re-attempt to commission the motor.
F00Fh	61455	15	Standard commission process resulted in a value for inverter switching correction that is out of range.	The commissioned value of inverter switching correction is out of range. Confirm that the motor connections are secure. Write 0FEFFh to C00 (***drive_command***) to reset the auto-tune parameters. Re-attempt to commission the motor. If this fault persists, contact your sales rep.
F010h	61456	15	Analog closed loop min speed is greater max_speed	Parameter M1C (***vin_min_spd_cl***) is larger than ***max_speed*** (F00). Reduce M1C (***vin_min_spd_cl***) until it is less than or equal to ***max_speed*** (F00).
F011h	61457	15	Analog open loop min speed is greater than analog open loop max speed	Parameter M1B (***vin_min_spd_ol***) is larger than M1A (***vin_max_spd_ol***). Reduce M1B (***vin_min_spd_ol***) until it is less than or equal to M1A (***vin_max_spd_ol***).
F0012h	61458	15	Analog reference voltages are out of range. v_ref_offset + v_ref_range > 32767	The analog reference voltage offset and range exceed 10 volts. In parameter terms, this means that ***v_ref_offset*** (M19) plus ***v_ref_range*** (M18) exceed 32767. Reduce ***v_ref_offset*** (M19) and / or ***v_ref_range*** (M18) until their sum is less than 32767.

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10.Product Dimensions

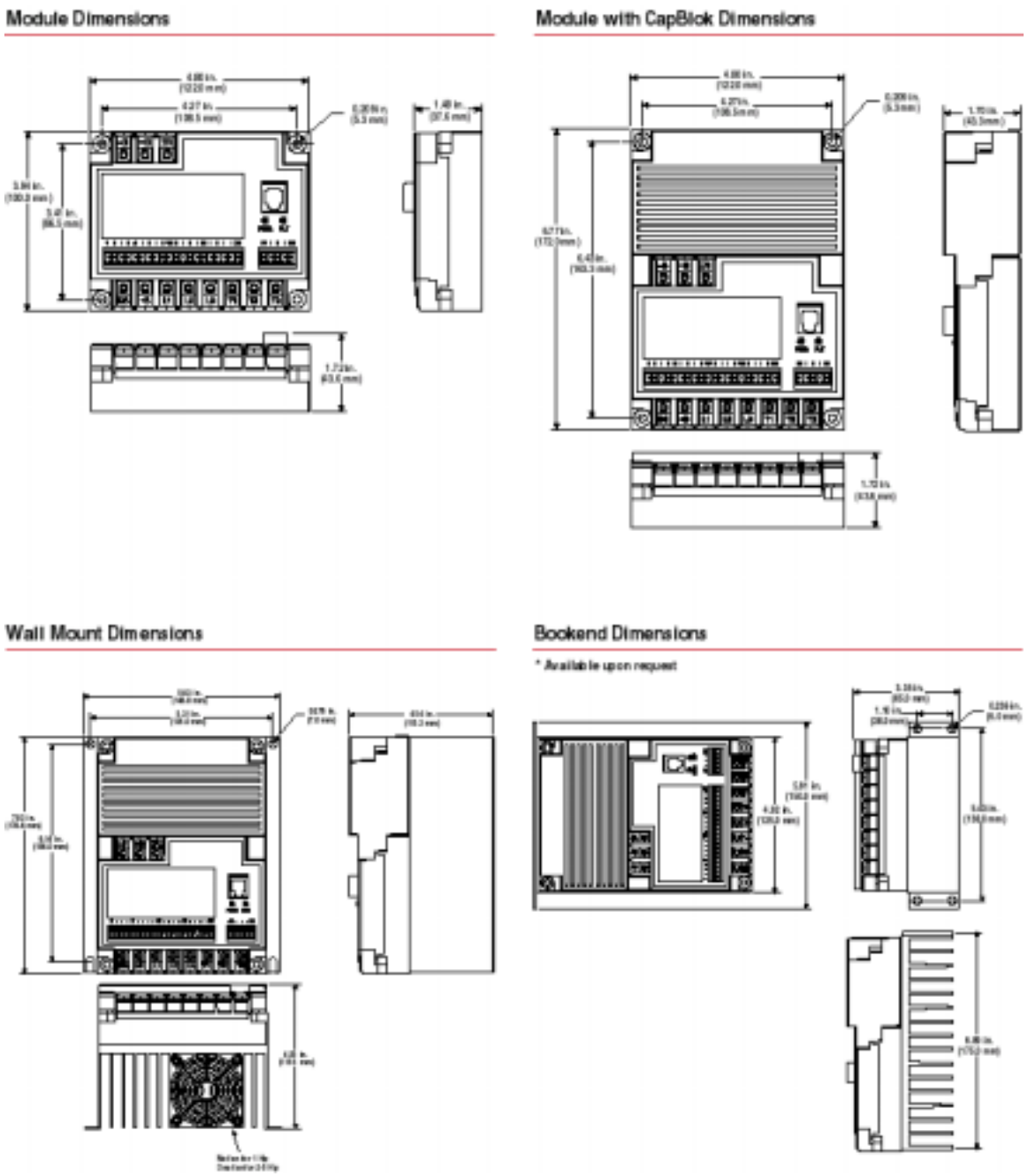


Figure 0-1

Product Dimensions, Series 1000

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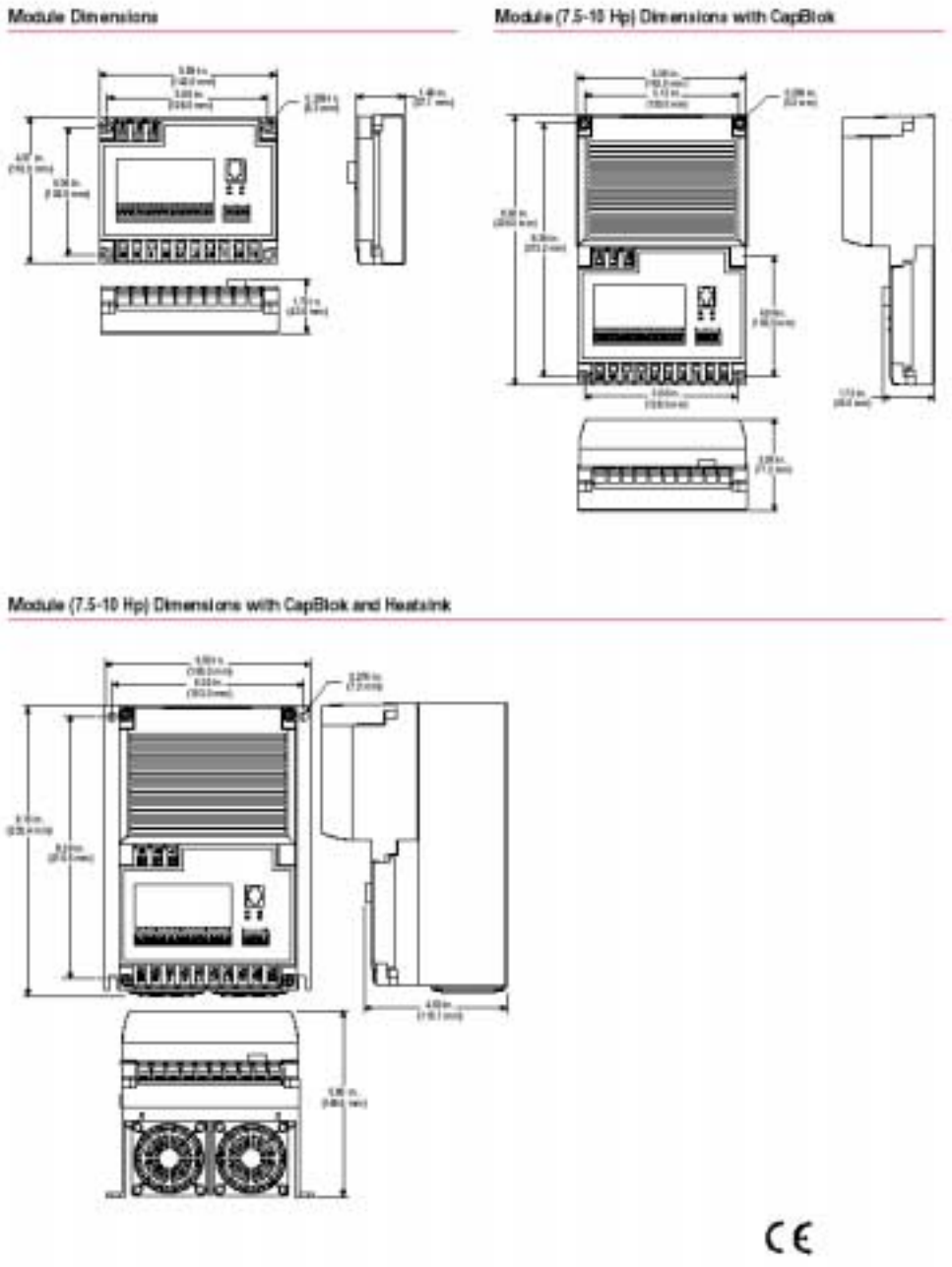
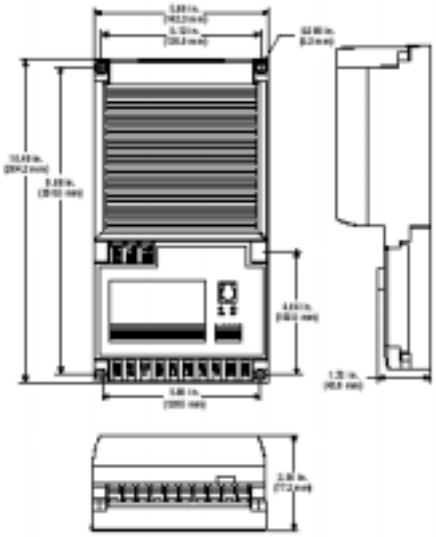


Figure 0-2
Series 2000 Dimensions, 7.5 - 10 Hp

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Module (15-20 Hp) Dimensions with CapBlok



Module (15-20 Hp) Dimensions with CapBlok and Heatsink

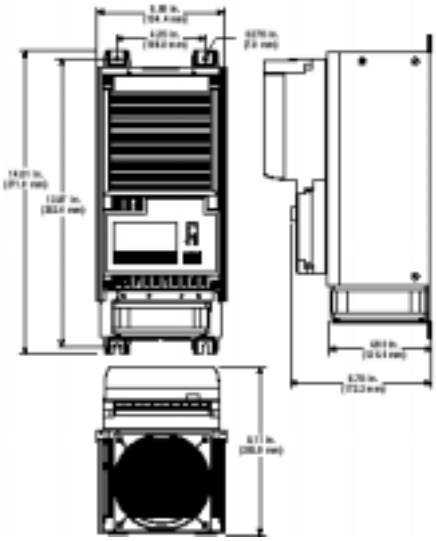


Figure 0-3
Series 2000 Dimensions, 15 - 20 Hp

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Appendix A: Basic System Diagram

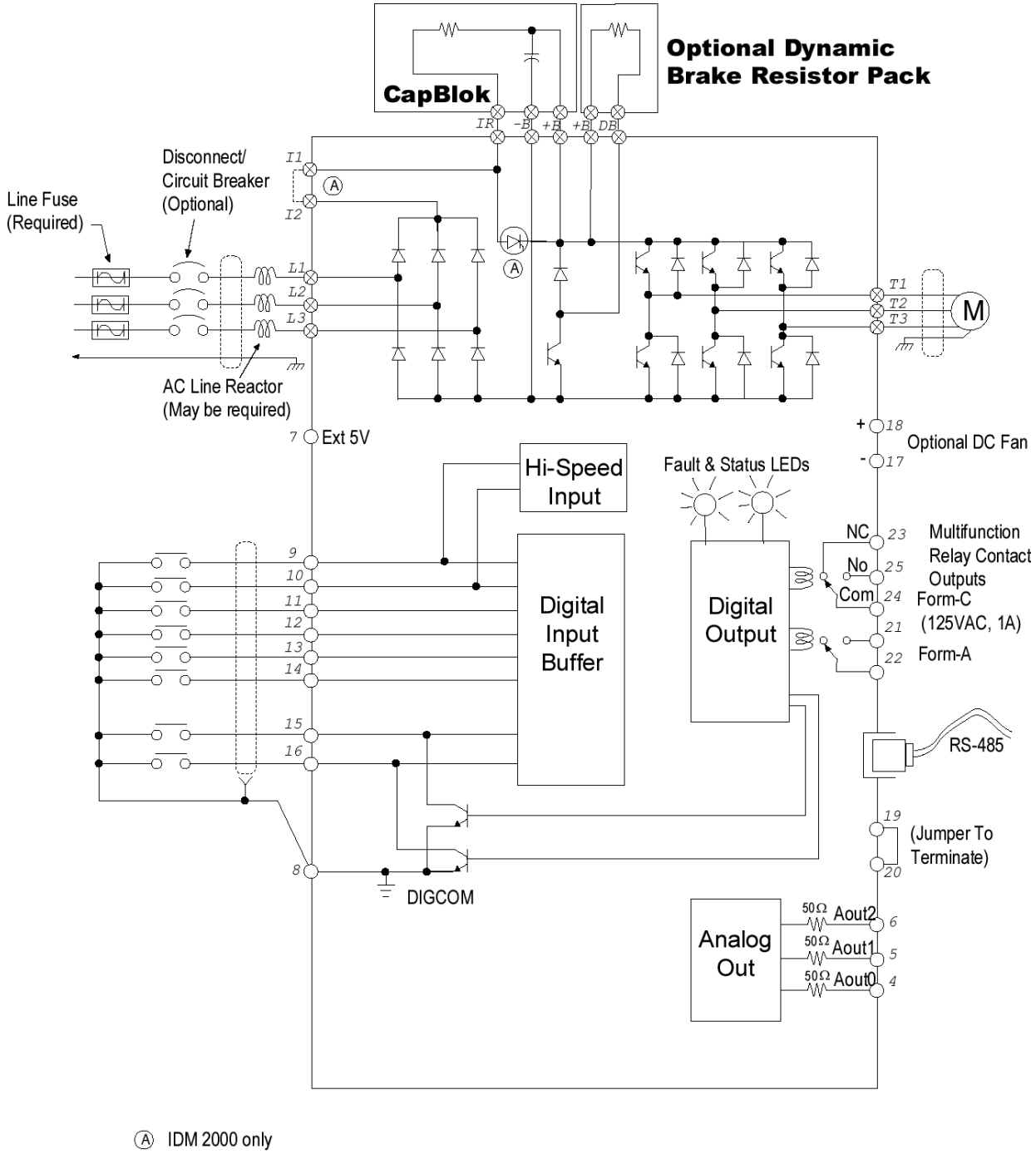


Figure 0-1
Basic System Diagram

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Appendix B: Installation for EMC Directive Compliance

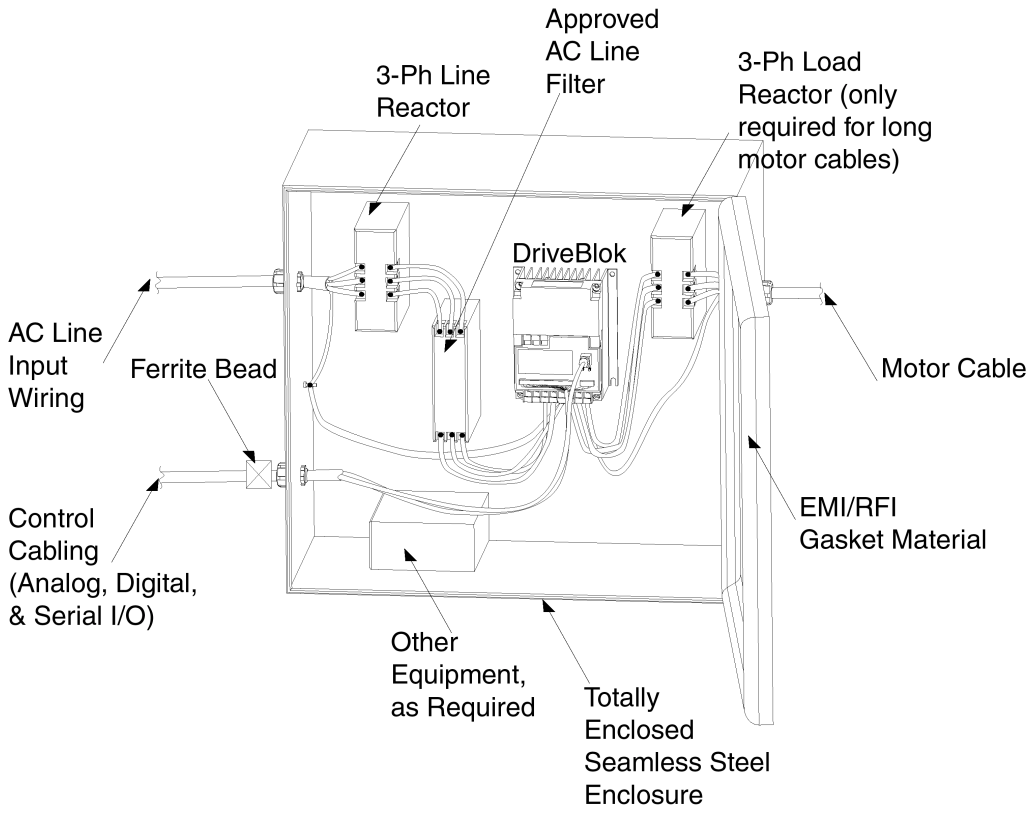


Figure 0-2

Diagram for showing EMC compliance

Outline of Installation Requirements

1. Install the SpindleBlok and EMC components within a totally enclosed seamless steel enclosure. A standard NEMA or IEC enclosure is adequate for this purpose.

2. Run AC Line Input wiring through a rigid or flexible metal-jacketed conduit, as required by applicable Electrical Code. Rigidly couple the conduit to the enclosure with a low impedance electrical connection (removing paint from the steel enclosure surface as required).

3. Run a separate Ground conductor with the 2- or 3-wire AC Line input wires inside the conduit, and bond this separate conductor directly to a Ground Bonding stud on the enclosure surface.

4. Install a 1-ph or 3-ph 1% (minimum) line reactor, as required, in series with the incoming AC Line.

5. Install an appropriately rated 1-ph or 3-ph European Standard-compliant noise filter between the line reactor and the input terminals of the drive. See the table in the Operator's Manual for recommended representative noise filters.

6. Run a separate Ground conductor from the provided Open-Frame Drive Ground bonding screw (or in the case of an IDM module installation from immediately adjacent to the mounted SpindleBlok module) to the enclosure Ground-bonding stud.

7. If required, install a 3-ph 1% (minimum) line reactor in series with the outgoing Motor Cable. This is normally only required for motor cables over 10m (100ft) in length, but should be tested in your application.

8. Use a shielded cable for wiring between the drive and motor (Motor Cable). Run a separate Ground conductor in the Motor Cable, connected directly to the SpindleBlok

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heatsink Ground-bonding screw on one end, and the motor Ground bonding screw in the motor junction box at the motor end. This cable may be run in a rigid conduit, but better EMC suppression is provided by a shielded cable with a braided shield.

9. Clamp a ferrite bead around all analog and digital control I/O and / or serial I/O cables as they exit the enclosure.

It is useful to note that the SpindleBlok has passed all EMC emissions and susceptibility tests outside the enclosure described here, with the sole exception of the ESD directive. If the SpindleBlok is protected from casual contact and therefore ESD susceptibility testing is not required, it should be possible with shielded cables to pass all other EMC Directives outside a sealed secondary enclosure.

Low Voltage Directive

A power electronic system is quite unique in its safety concerns and the methods used to ensure the safety of people, animals, plant and equipment. The applicable Standard for this product family is prEN50178-1995: Electronic Equipment for use in Power Installations. This Standard details the design requirements and verification testing required for power electronic systems, including motor drive products, and we have self-certified compliance to the Low Voltage Directive according to this Standard.

To ensure that your installation is safe, we recommend that the SpindleBlok be installed in the following manner:

- The SpindleBlok and CapBlok come in two voltage classes. The 230V class units achieve full rating at 230VAC ±10% 3-phase 50/60Hz. Operation at 200V must be derated – the drive current rating cannot be increased at 200V and so can deliver less total output power under this condition. The 400V class units carry a dual rating – they are rated to deliver full power at 400VAC ±10% 3-phase 50/60Hz and 480VAC ±10% 3-phase 50/60Hz. This means that you can deliver higher output current at 380 / 400V operation to deliver the same shaft power from an appropriately rated motor. The CE Mark applies to all 230V class applications, but for the 400V class only applications at 380 / 400VAC.
- On an Open-Frame Drive model, connect the heatsink Ground-bonding terminals to Earth as shown in the wiring diagram above. Module customers must bond the Earthing conductor as close to the mounted module as possible so as to provide a return path for currents injected into the IDM module baseplate. Even if EMC compliance is not required, the drive must be bonded to Ground with a suitable conductor rated for continuous current of at least the input current rating of the drive itself. Wire these connections separately – do not daisy chain Ground connections.
- Do not use an Earth leakage circuit breaker as an electric shock protector.
- Install current-limiting fuses on the incoming AC Line power leads to prevent damage to equipment and people in the event of a catastrophic failure of the power electronic circuits.
- While not normally required, it is generally good practice to install a surge suppressor assembly at the input terminals of the drive. These assemblies are available from many sources – recommended assemblies are listed in the Operator's Manual.

The operating rating of the Relay Outputs provided for control I/O is 30V 0.5A for the purpose of a CE compliant installation. UL considers them acceptable for 120VAC 1A, but they are not rated at that voltage according to EN50178.

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Appendix C: Internal Drive Parameters

Group A - Drive Identification

Typographical Conventions:
parameter_name, Drive parameters are listed in bold italic.

No	Name	Scaling	Access	Description
A00	***eeprom_valid***	Valid code = a5a5h	Read Only	Indicates that the EEPROM was initialized with data, and passed verification.
A01	***ee_version***	TBRR T = 0 → Release T = 1 → Beta B = Software Base B = 1 → SSI/Gen 2 B = 2 → SpindleBlok B = 3 → MBARI B = 4 → SpindleBlok RR = Release number in hex.	Read Only	EEPROM Version
A02	***ee_revision***	upper byte is custom setup code (00 → standard factory default setup), lower byte is revision number	Read Only	Reflects the final factory parameter definition file that was downloaded into the drive.
A03	***code_version***	TBRR T = 0 → Release T = 1 → Beta B = Software Base B = 1 → SSI/Gen 2 B = 2 → SpindleBlok B = 3 → MBARI B = 4→ SpindleBlok RR = Release number in hex.	Read Only	Code Version. note that code version and eeprom version must match for the drive to initialize.
A04	***drive_sn_lo***		Read Only	Drive serial number low
A05	***drive_sn_mid***		Read Only	Drive serial number mid
A06	***drive_volts***	Volts	Read Only	Drive voltage rating
A07	***drive_hp***	10*HP	Read Only	Drive horsepower rating
A08	***ki_imag***	Counts per amp	Read Only	KI: Drive nominal current scaling factor
A09	***kv***	Counts per volt	Read Only	KV: Drive volts scale factor
A0A	***drive_kw***	Counts per 1000 radians per sec	Read Only	KW: Drive frequency scale factor

Group B - Serial Communications

No	Name	Scaling	Access	Description
B00	***drive_address***	1-9,A-Z	Read/ Write	The address of this drive used in serial communications. There are 35 possible values.
B01	***baud_rate***	300,600,1200,2400,4800,9600,19200	Read/ Write	Serial communications baud rate. Changes to this parameter only take effect after a reset of the serial communications command is given (see C00, ***drive_command***).

Group C - Drive Command

No	Name	Scaling	Access	Description
C00	***drive_ command***	Bit 0 → Stop request Bit 1 → Start request Bit 2 → Commission request	Read/ Write	This parameter is bit defined. Sending a command to the drive is accomplished by setting this parameter with the

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		Bit 3 → reserved (always write as 1) Bit 4 → Clear External fault Bit 5 → External fault Bit 6 → Clear the fault queue. Bit 7 → Reset serial communications. Bit 8 → Set Factory Default Autotune Parameters Bit 9 → reserved (always write as 1) Bit 10 → reserved (always write as 1) Bit 11 → IO Reset Bit 12 → Calc Motor Bit 13 → reserved (always write as 1) Bit 14 → reserved (always write as 1) Bit 15 → Processor Reset		appropriate bit cleared. The command is acknowledged when the corresponding bit is set. Note that to cause a processor reset, the processor reset bit must be cleared AND all other bits must be set.
C01	***drive_mode***	Bit 0 set → Ramp to stop Bit 0 clr → Coast to stop. Bit 1 set → Calculate motor parameters from nameplate data on start. The calculated parameters are: rs, half_poles, fluxr_cmd_nom, iq_rated, and rr_kw. If the motor has been commissioned, rs will calculate to the commissioned value, otherwise it will be calculated on a per-unit basis. Bit 1 clr → Do not calc motor parms. The parameters rs, half_poles, fluxr_cmd_nom, iq_rated, and rr_kw must be supplied. The parameter rs can be fine-tuned by commissioning. Bit 2 set → Normal communications mode. The check-sum is verified on each message. Bit 2 clr → Ignore check-sum on all serial communications. Bit 3 set → Perform standard commission only on a commission request. The motor will not spin during a standard commission. Bit 3 clr → Perform standard and extended commission on a commission request. The motor will spin during the extended commission. Bit 4 set → Request sensorless flux vector mode. The mode can change from open loop to sensorless flux vector mode only when the drive is off or the frequency is less than 1% of rated frequency. This bit can be controlled by the Open Loop digital input function, which takes precedence over serial writes, if it is assigned Bit 4 clr → Request open loop mode. The	Read/ Write	This parameter is bit defined. Set and clear the appropriate bits to set the drive in the desired mode. This parameter should be changed by performing a read-modify-write so that only the intended bits are changed.

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		mode can change from sensorless flux vector to open loop mode only when the drive is off or in DC hold. Bit 5 set → Forward direction is enabled. This bit can be controlled by the Forward Enable digital input function, which takes precedence over serial writes, if it is assigned. Bit 5 clr → Forward direction is disabled. When forward direction is disabled, any forward speed command (positive speed command) is replaced by a zero speed command. Bit 6 set → Reverse direction is enabled. This bit can be controlled by the Reverse Enable digital input function, which takes precedence over serial writes, if it is assigned. Bit 6 clr → Reverse direction is disabled. When reverse direction is disabled, any reverse speed command (negative speed command) is replaced by a zero speed command. Bit 7 set → Acceleration and deceleration ramps are modified to maintain constant torque current for an inertial load during field weakening. At speeds less than base speed, the acceleration and deceleration ramps are linear and independent of the setting of bit 7. Bit 7 clr → Linear acceleration and deceleration ramps. Bit 8 set → Serial setpoint control. Bit 8 clr → Local setpoint control. Bit 9 set → Serial start control. Bit 9 clr → Local start control. Local start control will switch to serial start control (bit 9 will be set) on a serial stop request or if faults are cleared serially. Bit 10 set → Use default set of speed regulator gains (K00 – K02) and acceleration and deceleration (F01- F02). This bit can be controlled by the Low Inertia / High Inertia digital input function, which takes precedence over serial writes, if it is assigned Bit 10 clr → Use high inertia set of speed regulator gains (K03 – K05) and acceleration and		

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		deceleration (F03- F04). Bit 11 → Reserved, write as 1 Bit 12 set → Pull up digital inputs internally to 5 volts. Bit 12 clr → Pull down digital inputs 1 – 6 internally to ground. Digital inputs 7 and 8 are always pulled up. Bit 13 set → Analog input bi-polar mode. The analog input is sampled as a -10 to +10 volt signal. Bit 13 clr → Analog input uni-polar mode. The analog input is sampled as a 0 to +10 volt signal. Bit 14 set → Run / Fwd-Rev mode. Digital input 2 is run and digital input 3 is fwd-rev (invert local setpoint). Bit 14 clr → Run-Fwd / Run-Rev mode. Digital input 2 is run-fwd and digital input 3 is run-rev. Bit 15 → Reserved, write as 1		
C02	***omega_cmd_ save (RAM only)***	RPM	Read/ Write	Commanded speed for serial setpoint. Stored in RAM only.
C03	***omega_cmd_ save (eeprom and RAM)***	RPM	Read/ Write	Commanded speed for serial setpoint. Stored in RAM and eeprom.

Group D - Drive Feedback

No	Name	Scaling	Access	Description
D00	***drive_state***	Byte 0 → State machine location (0-ffh) Byte 1 → Feedback bit indicating status. **Bit 0 set → Reverse direction** Bit 0 clr → Forward direction Bit 1 – Reserved Bit 2 set → Inverter is running Bit 2 clr → Inverter is off Bit 3 set → Open loop control mode Bit 3 clr → Sensorless flux vector control mode. Bit 4 set → Drive commissioning Bit 4 clr → Drive not commissioning. Bit 5 set → Speed and flux tracking regulators are on. Bit 5 clr → Speed and flux tracking regulators are off. Bit 6 – Reserved Bit 7 – Reserved	Read Only	This parameter consists of 2 bytes. The low byte is the drive control state. The upper byte is used to provide feedback to the user as to the mode that the drive is in.
D01	***drive_status_ save***	Bit 0 clr → System faulted. Always clear when any other bit is clear.	Read Only	When the system is not faulted, this parameter will be read as 0ffffh. Reading this parameter when the drive is faulted will

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		Bit 1 clr → Inverter interrupt sat fault. Bit 2 clr → DB overload. Bit 3 clr → Phase over current. Bit 4 → Reserved. Bit 5 clr → DC Link under voltage. Bit 6 clr → DC Link over voltage. Bit 7 clr → Reserved. Bit 8 clr → A/D offsets out of tolerance. Bit 9 clr → Motor fault. Bit 10 clr → Heat sink overtemp. Bit 11 clr → Motor thermal overload. Bit 12 clr → Communications Fault. Bit 13 clr → External Fault Bit 14 clr → EEProm fault Bit 15 clr → Motor Parameter Fault		clear the fault and allow a restart to be attempted.
D02	***limit_flag***	Bit 0 set → Output voltage on limit, internally cleared Bit 1 set → Output voltage on limit, latched. Bit 2 -15 → Reserved	Read/Write	Bits set in this parameter indicate that the corresponding limit was hit. Only latched bits should be cleared by a serial write. This should only be done when the drive is off.
D03	***i_mag***	I (amps 0 - peak) * ***ki_imag***	Read Only	Output current magnitude, filtered by ***dsp_wdt***
D04	***id***	Id (amps 0 - peak) * ***ki_imag*** / 2	Read Only	d-axis current magnitude, not filtered.
D05	***iq***	Iq (amps 0 - peak) * ***ki_imag*** / 2	Read Only	q-axis current magnitude, not filtered.
D06	***vout***	Motor Volts (volts 0 - peak) * ***kv***	Read Only	Output voltage, filtered by ***dsp_wdt.***
D07	***vdc_dsp***	VDC (volts) * ***kv***	Read Only	DC link voltage, filtered by ***dsp_wdt***
D08	***omega_dsp***	10 * Hz	Read Only	Electrical frequency (unsigned), filtered by ***filt_wdt***.
D09	***omega_m_dsp***	RPM	Read Only	Signed mechanical speed, positive is forward direction, negative is reverse direction, filtered by ***dsp_wdt***.
D0A	***heatsink temp***	0.1 degrees C	Read Only	Heat sink temperature, not filtered
D0B	***torque***	N-m * 100	Read Only	Signed torque, filtered by ***dsp_wdt***
D0C	***power_in***	Watts	Read Only	Input power through the rectifier, filtered by ***dsp_wdt***. This is calculated as inverter output power (vd*id+vq*iq) plus ***losses_on***. Negative values are assumed to go to the braking resistor if it is on.
D0D	***elapsed_lo***	0.01 hours	Read/Write	Incremented every 1/100 hour when the drive is running.
D0E	***elapsed_hrs***	hours	Read/Write	Incremented each time ***elapsed_lo*** reaches 100.
D0F	***fluxr_ff***	Flux (1-n volt-sec) ***kv *omega_base***	Read Only	Present commanded rotor flux.
D10	***db_pt***	DB PT = $P*(1-e^{-t/TC})$	Read Only	Instantaneous dynamic brake resistor power filtered by the resistor's thermal time constant TC. TC is defined by ***db_pt_wdt***. P is the power into the braking resistor. When this value exceeds the rated power of the resistor (***db_pt_lim***), the drive will fault with a DB overload. If ***dp_pt_lim*** is zero, this parameter is not updated.
D11	***invrs_lm***	See ***invrs_lm_nom***	Read Only	Estimated magnetizing reactance
D12	***I_sqr_t***	$100*(I_{ss}/I_{rated})^2$ **I_{ss} is the equivalent thermal steady state current.**	Read Only	Drive thermal loading. Calculated as I^2T, low pass filtered with a time constant of ***i_sqr_t_wdt.***

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D13	***feedback1_ptr***	0-FFFF	Read/Write	A pointer to the memory location. The value in the memory location can be read in ***feedback1_value.***
D14	***feedback2_ ptr***	0-FFFF	Read/Write	A pointer to the memory location. The value in the memory location can be read in ***feedback2_value.***
D15	***feedback1_ value***	0-FFFF	Read Only	The value in the memory location pointed to by ***feedback1_ptr.***
D16	***feedback2_ value***	0-FFFF	Read Only	The value in the memory location pointed to by ***feedback2_ptr.***
D17	***dig_out_prog***	Bit 0 → Digital out 1 state Bit 1 → Digital out 2 state. Bit 2 → Reserved, write as 0. Bit 3 → Reserved, write as 0. Bit 4 → Reserved, write as 0. Bit 5 → Reserved, write as 0. Bit 6 → Relay 1 state. Bit 7 → Relay 2 state. Bit 8 –15 → Reserved, write as 0.	Read/Write	The current value in the digital output register. If one of the programmable digital outputs or relay outputs (M07 – M0A) are programmed for serial control, writing to the appropriate bits sets the desired state. Any other programmed digital output function takes precedence over a serial write.
D18	***dig_in***		Read Only	The current value in the digital input register.
D19	***dig_in_z0***	bit 0 – 7 → assertion state of digital inputs 1 through 8.	Read Only	The current assertion level of the digital inputs. Bit set = asserted, Bit clear = de-asserted.
D1A	***vin_res***	Signed 16 bit word 0 = 0 volts 8001h = -10 volts 7fffh = 10 volts	Read Only	Analog voltage input value.

Group E - Fault Queue

No	Name	Scaling	Access	Description
E00	***fault_cue_full*** ***Note: The variable name is a misnomer. It actually indicates that the cue has rolled over at least once.***	0-1 0 indicates cue not full 1 indicates cue full	Read Only	Zero when no faults have been recorded since the queue was last reset, or the fault cue has not rolled over. Indicates that there are 4 or less faults in the cue. When the fault cue rolls over (from 4 back to 1), this index is set to 1. This indicates that the cue is full. The last fault recorded will be ***last_fault_index.***
E01	***last_fault_ind ex***	0-4 0 indicates no faults. 1 indicates fault 1. 2 indicates fault 2. 3 indicates fault 3. 4 indicates fault 4.	Read Only	Zero when no faults have been recorded since the queue was last reset. If ***fault_cue_full*** is 0, there are 4 or less faults in the cue. If ***fault_cue_full*** is 1, There are 4 faults in the cue. The most recent fault is ***last_fault_index***. The previous fault is ***last_fault_index*** -1, etc…The fault cue is circular, therefore the cue rolls from 1 back to 4, when reading the cue.
E02	***first_fault_stat us***	***drive_status_save***	Read Only	
E03	***first_fault_tim e_lo***	***elapsed_time_lo***	Read Only	
E04	***first_fault_tim e_hi***	***elapsed_time_hi***	Read Only	
E05	***first_fault_ drive_state***	***drive_state***	Read Only	
E06	***first_fault_I***	***i_mag***	Read Only	

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E07	***first_fault_vdc***	***vdc***	Read Only	
E08	***first_fault_speed***	***omega_m***	Read Only	
E09	***first_fault_ext_error***	***first_fault_ext_error***	Read Only	
E0A			Reserved	
E0B	***fault_1_status***	***drive_status_save***	Read Only	
E0C	***fault_1_time_lo***	***elapsed_time_lo***	Read Only	
E0D	***fault_1_time_hi***	***elapsed_time_hi***	Read Only	
E0E	***fault_1_drive_state***	***drive_state***	Read Only	
E0F	***fault_1_i***	***i_mag***	Read Only	
E10	***fault_1_vdc***	***vdc***	Read Only	
E11	***fault_1_speed***	***omega_m***	Read Only	
E12	***fault_1_ext_error***	***fault_1_ext_error***	Read Only	
E13			Reserved	
E14	***fault_2_status***	***drive_status_save***	Read Only	
E15	***fault_2_time_lo***	***elapsed_time_lo***	Read Only	
E16	***fault_2_time_hi***	***elapsed_time_hi***	Read Only	
E17	***fault_2_drive_state***	***drive_state***	Read Only	
E18	***fault_2_I***	***i_mag***	Read Only	
E19	***fault_2_vdc***	***vdc***	Read Only	
E1A	***fault_2_speed***	***omega_m***	Read Only	
E1B	***fault_2_ext_error***	***fault_2_ext_error***	Read Only	
E1C			Reserved	
E1D	***fault_3_status***	***drive_status_save***	Read Only	
E1E	***fault_3_time_lo***	***elapsed_time_lo***	Read Only	
E1F	***fault_3_time_hi***	***elapsed_time_hi***	Read Only	
E20	***fault_3_drive_state***	***drive_state***	Read Only	
E21	***fault_3_I***	***i_mag***	Read Only	
E22	***fault_3_vdc***	***vdc***	Read Only	
E23	***fault_3_speed***	***omega_m***	Read Only	
E24	***fault_3_ext_error***	***fault_3_ext_error***	Read Only	
E25			Reserved	
E26	***fault_4_status***	***drive_status_save***	Read Only	
E27	***fault_4_time_lo***	***elapsed_time_lo***	Read Only	
E28	***fault_4_time_hi***	***elapsed_time_hi***	Read Only	
E29	***fault_4_drive_state***	***drive_state***	Read Only	
E2A	***fault_4_I***	***i_mag***	Read Only	
E2B	***fault_4_vdc***	***vdc***	Read Only	
E2C	***fault_4_speed***	***omega_m***	Read Only	
E2D	***fault_4_ext_error***	***fault_4_ext_error***	Read Only	

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Group F - Drive Parameters

No	Name	Scaling	Access	Description
F00	***max_speed***	RPM	Read/Write Run locked	Maximum allowed commanded speed.
F01	***accel_rate_ dflt***	RPM/sec * poles/2. Ignoring slip frequency, these units are Hz/min. If bit 7 of ***drive_mode*** is set and the motor is in field weakening, the actual acceleration rate will be reduced approximately in proportion to the depth of field weakening to maintain constant acceleration torque current.	Read/Write	Default acceleration profile rate setting, used when bit 10 of ***drive_mode*** is set and bit 3 of high byte of ***drive_state*** is clear. If bit 7 of ***drive_mode*** is set, all acceleration and deceleration profiles are calculated to require a constant torque current (iq) regardless of the depth of field weakening. Therefore, the actual acceleration rate is dependent on the motor flux rating, the motor speed, and the dc bus voltage. If bit 7 of ***drive_mode*** is clear, then all acceleration and deceleration profiles are linear.
F02	***decel_rate_dflt***	See ***accel_rate_dflt***	Read/Write	Default deceleration rate setting, used when bit 10 of ***drive_mode*** is set and bit 3 of high byte of ***drive_state*** is clear.
F03	***accel_rate_hi_j***	See ***accel_rate_dflt***	Read/Write	High inertia acceleration profilerate setting, used when bit 10 of ***drive_mode*** is clear and bit 3 of high byte of ***drive_state*** is clear.
F04	***decel_rate_hi_j***	See ***accel_rate_dflt***	Read/Write	High inertia deceleration profile rate setting, used when bit 10 of ***drive_mode*** is clear and bit 3 of high byte of ***drive_state*** is clear.
F05	***accel_rate_ol***	See ***accel_rate_dflt***	Read/Write	Open loop acceleration profile rate setting, used when bit 3 of high byte of ***drive_state*** is set.
F06	***decel_rate_ol***	See ***accel_rate_dflt***	Read/Write	Open loop deceleration profile rate setting, used when bit 3 of high byte of ***drive_state*** is set.

Group G - Motor Parameters

No	Name	Scaling	Access	Description
G00	***rated_volts***	Motor Name plate voltage (volts)	Read/Write Run Locked	Only required for nameplate mode.
G01	***rated_hp***	100 * HP	Read/Write Run Locked	Only required for nameplate mode.
G02	***rated_speed***	RPM	Read/Write Run Locked	Only required for nameplate mode.
G03	***i_rated***	10 * RMS amps	Read/Write Run Locked	Always required. Used in nameplate mode and to calculate the i^2t limit.
G04	***rated_freq***	Hz	Read/Write Run Locked	Only required for nameplate mode.
G05	***torque_loss_ percent***	% of rated torque iq_rated = (2374/half_poles)*(rated_hp/(rated_speed*torque_loss_%)*((1000+2*ll_lm)/1000)*ki_imag*wb*kv/Fds	Read/Write Run Locked	Mechanical torque loss in motor, as percentage of rated. Used to calculate ***iq_rated*** in nameplate mode. The default value is adequate for most applications and should not be changed.
G06	***ll_lm***	Ll/(Ll+Lm)* 1000	Read/Write Run Locked	Ratio of stator leakage inductance to total stator inductance.
G07	***inductance_***	Maximum of	Read/Write	Maximum allowable value for ***inductance***.

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	max	ω_{base} * ((Lr*Ls – Lm^2) / Lm)* ***drive_kv*/ *ki_i_mag***		This is presently not used and is intended for use when inductance is auto-tuned.
G08	***fluxr_cmd_ nom***	Rated line to neutral flux (0 - peak volt-sec) * ***omega_base*** * ***drive_kv***	Read/Write	This is the commanded rotor flux level. It is calculated in nameplate mode, otherwise it must be provided.
G09	***iq_rated***	Amps (0-pk) * ***ki_i_mag*** * / 2.0	Read/Write	Rated torque-producing current. This is calculated in nameplate mode, otherwise it must be provided. This is used in the load limit and slip limit calculations.
G0A	***rs***	$Rs * \frac{Lr}{Lm} * 2 * omega_base * \frac{drive_kw}{1000} * \frac{drive_kv}{ki_i_mag}$ Rs is line to neutral stator resistance in ohms. Lm is line to neutral stator magnetizing inductance in henrys. Lr is line to neutral rotor total inductance reflected to the stator in henrys. Ls is line to neutral stator total inductance in henrys. Rr is line to neutral rotor resistance reflected to the stator in ohms.	Read/Write	Line to neutral stator resistance. This is determined during a standard auto-tune.
G0B	***rr_kw***	$Rr * \frac{Lr}{Lm} * 2 * omega_base * \frac{drive_kw}{1000} * kv / ki_imag$	Read/Write	Motor rotor resistance (reflected to stator). This is calculated in nameplate mode but must be provided otherwise.
G0C	***invrs_lm_nom***	2^15 * ***ki_imag*** / (***kv*** * Lm * ***omega_base***)	Read Only	Initial estimate of motor magnetizing reactance. Auto-tuned while the drive is operating. The initial estimate is calculated at start, based on ***ki_id***.
G0D	***invrs_lm_max***		Read/Write	Maximum value that ***invrs_lm*** can set by the flux regulator.
G0E	***inductance***		Read/Write	Stator leakage inductance. Auto calculated at start for induction motors based on ***invrs_lm_nom*** and ***ll_lm***.
G0F	***half_poles***		Read/Write	Number of Poles / 2. This is calculated in nameplate mode but must be provided otherwise.
G10	***load_lim***	% of rated iq	Read/Write Run Locked	Iq (torque producing current) limit during motoring and braking as a percent of rated iq. For an induction motor this limit is superseded by ***slip_lim*** when the iq limit requires more slip than ***slip_lim*** allows.
G11	***slip_lim***	% of rated slip	Read/Write Run Locked	This is the maximum allowed slip as a percent of rated slip.
G12	***slip_gain***	percent	Read/Write Run Locked	% gain on slip calculation—used when calculating rotor resistance from nameplate variables.
G13	***krs***		Read/Write	Incremental gain on ***rs*** commissioning.
G14	***rs_max***	Same scaling as ***rs***	Read/Write	Maximum limit for ***rs*** during commissioning.
G15	***rs_gain***	$rs = rs_estimated * \frac{rs_gain}{100}$	Read/Write	Gain on commissioned value of ***rs***. To use exact commissioned value of ***rs***, ***rs_gain*** = 100.
G16	***max_rated_ slip***	10 * %	Read/Write Run Locked	Maximum slip allowed to be entered by the user without generating a motor parameter fault.

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				Example: A setting of 100 corresponds to a maximum of 10% maximum rated slip. Applies only in nameplate mode.
G17	***k_rs***		Read/Write Run Locked	Per unit stator resistance. Set during commissioning by the drive. ***rs*** = (***rated_volts*** ^{2}/ ***rated_hp***)*(***k_rs*** / 100)*(***Kv***/ ***ki_imag***). Applies only in nameplate mode.
G18	***k_id***	0 - 100 %	Read/Write Run Locked	d-axis current as percent of rated current. This is auto tuned during extended commissioning.
G19	***default_k_rs***		Read/Write	k_rs is set to this on the command ***Set Factory Default Autotune***.
G1A	***default_k_id***		Read/Write	k_id is set to this on the command ***Set Factory Default Autotune***.
G1B	***Dc_hold_w_ ratio***	10 * %	Read/Write	Dc Hold mode is entered when the speed command and the speed are below this percentage of ***omega_lo_lim***.
G1C	***Omega_base***	rad/sec	Read/Write Run Locked	Base frequency for flux scaling.

Group H - Braking Parameters

No	Name	Scaling	Access	Description
H00	***dc_inject_time***	DC injection duration (sec) / 0.0524	Read/Write	Duration of DC injection. DC injection is applied when the control system has detected the drive has stopped.

Group I - Current and Voltage Feedback Parameters

No	Name	Scaling	Access	Description
I00	***vdc_gain***	2^16 * ***kv*** / raw_kv default = 32533 (230v) default = 33032 (460v)	Reserved	DC link scale factor, used in calculating *volt_gain.* raw_kv = 130.94 (230v) raw_kv = 65.472 (460v) This is calibrated for each drive.
I01	***offset wdt***		Reserved	Break frequency of low-pass filter on current sensor offset identification controller.
I02	***ib_gain***	Nominal = 26812	Reserved	Gain to calculate current in internal units from raw A/D number. This is calibrated for each drive.
I03	***ib_offset_nom***	Nominal = 26812	Reserved	Initial value for ***ib_offset***. The parameter ***ib_offset*** is set to this value on drive reset. This is calibrated for each drive.
I04	***ib_offset***		Reserved	A/D offset in phase B current. Calculated while drive off, when current should be zero.
I05	***ic_gain***	Nominal = 26812	Reserved	Gain to calculate current in internal units from raw A/D number. This is calibrated for each drive.
I06	***ic_offset_nom***	Nominal = 26812	Reserved	Initial value for ***ic_offset***. The parameter ***ic_offset*** is set to this value on drive reset. This is calibrated for each drive.
I07	***ic_offset***		Reserved	A/D offset in phase C current. Calculated while drive off, when current should be zero.
I08	***offset_err***		Reserved	During drive start, if ***ib_offset*** or ***ic_offset*** differ from ***ib_offset_nom*** or ***ic_offset_nom*** by more than ***offset_err*** then an AD_OFFSET fault occurs.
I09	***i_sqr_wav_33***		Reserved	Lockout correction

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	0_30			
I0A	***i_sqr_wav_30_90***		Reserved	Lockout correction
I0B	***i_sqr_wav_90_150***		Reserved	Lockout correction
I0C	***i_sqr_wav_150_210***		Reserved	Lockout correction
I0D	***i_sqr_wav_210_270***		Reserved	Lockout correction
I0E	***i_sqr_wav_270_330***		Reserved	Lockout correction

Group J - Protection

No	Name	Scaling	Access	Description
J00	***i_sqr_t_wdt***	Tc/T, T = sampling time(52.429 ms) ***i_sqr_t_wdt*** < 32767	Read/Write	I^2T time constant for thermal protection
J01	***i_sqr_t_lim***	$100*(I_{trip}/I_{rated})^2$	Read/Write	I^2T trip point for thermal protection limit The thermal protection is an exponential function (a low pass filter), see ***i_sqr_t*** (D0E). The thermal protection will trip if the drive runs at ***i_sqr_t_lim*** percent of rated current for Tc time (Tc is set in ***i_sqr_t_wdt***).
J02	***comm_timer_max***	0-65535 Time (sec) = ***comm_timer_max*** * 0.052 sec	Read/Write	Communications timeout setting. 0 disables time-out checking.
J03	***password***	0-65535	Read/Write	Allows writes to read-only locations when set to the internal password value. This value set by SSI.
J04	***fan_on_temp***	0.1 degrees C	Read/Write	Fan on temp
J05	***temp_hys***	0.1 degrees C	Read/Write	Hysteresis used in fan control
J06	***heatsink_hot***	0.1 degrees C	Reserved	Over temperature trip point
J07	***vdc_min***	Volts	Read Only	Drive under-voltage trip point. If the DC bus voltage falls below this value, the drive will fault. Changes to this value only take affect after a power on reset.
J08	***vdc_max***	Volts	Read Only	Drive over-voltage trip point. If the DC bus voltage rises above this value, the drive will fault. Changes to this value only take affect after a power on reset.
J09	***vdc_braking***	Volts	Read/Write	Value at which the dc bus is regulated during braking. Changes to this value only take affect after a power on reset.
J0A	***iabc_max***	I (amps) * ***ki_imag***	Reserved	Overcurrent trip point.
J0B	***db_pt_wdt***	2^16 * 0.052 / Tc (sec) Tc = Thermal time constant of DB resistor in seconds. TripTime = -ln((P-DBLim)/P)*Tc P = power into DB If P <= DBLim, TripTime = ∞ If P = 1.582*DBLim, Trip Time = Tc	Read/Write	Time constant for DB protection.
J0C	***db_pt_lim***	Watts	Read/Write	DB resistor power rating. Setting this to zero disables the DB protection.

Group K - Regulator Gains

No	Name	Scaling	Access	Description

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K00	***Kp_trq_dflt***	1 - 32767	Read/Write	Speed controller proportional gain, default mode
K01	***ki_trq_dflt***	1 - 32767	Read/Write	Speed controller integral gain, default mode
K02	***iq_wdt_dflt***	26.214*w(rad/sec)*	Read/Write	The break frequency of the lowpass filter on the speed regulator, default mode
K03	***Kp_trq_hi_j***	1 - 32767	Read/Write	Speed controller proportional gain, high J mode
K04	***ki_trq_hi_j***	1 - 32767	Read/Write	Speed controller integral gain, high J mode
K05	***iq_wdt_hi_j***	26.214*w(rad/sec)*	Read/Write	The break frequency of the lowpass filter on the speed regulator, high J mode
K06	***kp_brake***	1 - 32767	Read/Write	Braking controller proportional gain
K07	***kp_i_nom***	1 - 32767	Read/Write	Current regulator proportional gain. Do not adjust from factory default.
K08	***kd_i_nom***	1 - 32767	Read/Write	Current regulator derivative gain. Typical value should be ½ ***kp_i_nom***. A value of zero turns off the derivative term.
K09	***kpi_omega***	1 - 32767	Read/Write	Flux tracking PLL proportional gain. Do not adjust from factory default.
K0A	***ki_omega***	1 - 32767	Read/Write	Flux tracking PLL integral gain. Do not adjust from factory default.
K0B	***kp_flx***	Nominal values: ***kp_flx*** = 1-3	Read/Write	Flux estimator stabilizing gain (smaller number is more stabilization and lag). Do not adjust from factory default.

Group L - Internal Parameters

No	Name	Scaling	Access	Description
L00	***i_sqr_wave***		Read Only	Lockout correction
L01	***omega_lo_lim***		Reserved	Calculated in ***start_calcs.*** Drive transitions to DC hold mode when ***omega_m*** and commanded speed are less than value ***dc_hold_w_ratio*omega_lo_lim.*** Also, the drive will not come out of DC hold until the commanded speed is above ***dc_hold_w_ratio*omega_lo_lim.***
L02	***filt_wdt***	26.214*w(rad/sec)*	Read/Write	Low pass filter constant in field weakening algorithm.
L03	***check_time***	0.052 second	Read/Write	Delay time used in measuring resistance during commissioning.
L04	***flx_rate_lim_pos***		Read/Write	
L05	***flx_rate_lim_neg***		Read/Write	
L06	***flux_volt_max***		Read/Write	
L07	***commission_starts***		Read/Write	
L08	***commission_angle***		Read/Write	
L09	***losses_on***	Watts	Reserved	Drive internal losses while inverter is on (not including IGBT conduction losses)
L0A	***losses_off***	Watts	Reserved	Drive internal losses while inverter is off
L0B	***dead_time***		Reserved	Write bit 0 as a 1 for SSI drives. Write bits 1-3 as 0's. (read only bits) Write bits 4-7 as needed for dead-time. Write bits 8-15 as 0's Minimum dead-time is 0.1 µ-sec, and increments by 0.2 µ-sec for each integer increment. 0 = 0.1 µ-sec. 1 = 0.3 µ-sec 2 = 0.5 µ-sec, etc…

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				Example. Write: 51H for 1.1 µ-sec dead-time on an SSI drive. 81H for 1.7 µ-sec dead-time on an SSI drive.
L0C	***delta_speed_native***		Read/Write	
L0D	***dsp_wdt***	$\tau \approx 0.002/-\ln(1-wdt/2\text{^}16)$ (Loop executes appr. every 2 m-s.)	Read/Write	Display filter time-constant.
L0E	***fluxr_cmd_inc***		Read/Write	Flux command decrement used when the drive turns off from dc hold to provide a rate limit on current.

Group M - I/O Setup

No	Name	Scaling	Access	Description
M00	***dig_in_4_fcn***		Read/Write	
M01	***dig_in_5_fcn***		Read/Write	
M02	***dig_in_6_fcn***		Read/Write	
M03	***dig_in_7_fcn***		Read/Write	
M04	***dig_in_8_fcn***		Read/Write	
M05	***dig_in_polarity***	BIT 0 = DIN 1 BIT 1 = DIN 2 BIT 2 = DIN 3 BIT 3 = DIN 4 Etc.	Read/Write	Bit defined; When the corresponding bit is set, the digital input is asserted when the input is positive.
M06	***dig_out_1_fcn***	See I/O description document	Read/Write	M09-M0A defines the functions of the digital outputs. DOUT 1 is on the same terminal as DIN 7.
M07	***dig_out_2_fcn***	See I/O description document	Read/Write	DOUT 2 is on the same terminal as DIN 8.
M08	***relay_1_fcn***	See I/O description document	Read/Write	M0B-MOC defines the functions of the relay oututs.
M09	***relay_2_fcn***		Read/Write	
M0A	***analog_ out_1_fcn***	See I/O description document	Read/Write	MOD-MOF defines the functions of the analog outputs.
M0B	***analog_ out_2_fcn***	See I/O description document	Read/Write	
M0C	***preset_ speed_1***	RPM	Read/Write	Preset speeds 1-7 are selected by the digital inputs. (See I/O documentation.)
M0D	***preset_speed_2***	RPM	Read/Write	
M0E	***preset_speed_3***	RPM	Read/Write	
M0F	***preset_speed_4***	RPM	Read/Write	
M10	***preset_speed_5***	RPM	Read/Write	
M11	***preset_speed_6***	RPM	Read/Write	
M12	***preset_speed_7***	RPM	Read/Write	
M13	***speed_detect_ low***	RPM	Read/Write	Threshold value for ***Speed Detect Low*** digital output function. See I/O documentation for details.
M14	***speed_detect_ high***	RPM	Read/Write	Threshold value for ***Speed Detect High*** digital output function. See I/O documentation for details.
M15	***out_of_reg_ parm***	Low byte controls the percentage of time that the speed regulator must be on the limit to assert out of regulation. The scale factor is 5% per count (1 = 5%, 20 = 100%, >= 20 means out of reg will never be asserted). The high byte controls the time until out of regulation is asserted. If the speed regulator is on	Read/Write	

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		the limit 5% of the time more than set by the low byte, the time to out of regulation assertion is 10 msec * high byte value. The trip time decreases proportional to the increase in time that the speed regulator is on the limit.		
M16	***torque_detect_ low***	N-m * 100	Read/Write	Threshold value for ***Torque Detect Low*** digital output function. See I/O documentation for details.
M17	***torque_detect_ high***	N-m * 100	Read/Write	Threshold value for ***Torque Detect High*** digital output function. See I/O documentation for details.
M18	***v_ref_range***	0 = 0 volts, 32767 = 10 volts ***v_ref_range*** + ***v_ref_offset*** must be less than 32768.	Run Locked	***v_ref_offset*** and ***v_ref_range*** define the offset and range for the analog voltage input. Analog voltages with magnitudes less than ***v_ref_offset*** will scale to the minimum speed set by ***vin_min_spd_cl*** or ***vin_min_spd_ol***. Analog voltages with magnitudes between ***v_ref_offset*** and ***v_ref_offset*** + ***v_ref_range*** will scale linearly between the minimum speed and the maximum speed set by ***max_speed*** or ***vin_max_spd_ol***. Analog voltages with magnitudes above ***v_ref_offset*** + ***v_ref_range*** will scale to the maximum speed.
M19	***v_ref_offset***	0 = 0 volts, 32767 = 10 volts ***v_ref_range*** + ***v_ref_offset*** must be less than 32768.	Run Locked	See ***v_ref_range***
M1A	***vin_max_spd_ol***	RPM	Run Locked	Sets the maximum speed that will be commanded by the analog voltage input in open loop mode. See I/O documentation for details.
M1B	***vin_min_spd_ol***	RPM	Run Locked	Sets the minimum speed that will be commanded by the analog voltage input in open loop mode. See I/O documentation for details.
M1C	***vin_min_spd_cl***	RPM	Run Locked	Sets the minimum speed that will be commanded by the analog voltage input in closed loop mode. See I/O documentation for details.
M1D	***Analog out 1 scale***	See I/O documentation	Read/Write	Defines the scaling factor on analog output 1.
M1E	***Analog out 2 scale***	See I/O documentation	Read/Write	Defines the scaling factor on analog output 2.

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Appendix D: Motor Selection Guidelines

Motor Specifications near the minimum BEMF constant and maximum resistance may not meet performance specifications. Selecting a motor which fits in the Optimum (Opt) values provides the BEST performance. For more information, contact our Application Engineering Department MTS Automation recommends the following motor specification to provide the best motor-drive performance. More information on motor selection can be found at http://www.mtsautomation.com.

MTS Automation's Recommended Motor/Drive Combinations

Motor Model #	Drive Model #	Motor Model #	Drive Model #	Motor Model #	Drive Model #	Motor Model #	Drive Model #
MPMI 60B*	1001C	MPMI 140A	1002D	MPMI 420A	1003D	MPMI 900A	2007D
MPMI 60B*	1001C	MPMI 140B	1001D	MPMI 420B	1002D	MPMI 900B	1005D
MPMI 66B*	1001C	MPMI 140C	1003E	MPMI 420C	1003E	MPMI 900C	2007E
MPMI 70B*	1001D	MPMI 140D	1001E	MPMI 420D	1003E	MPMI 900D	1005E
MPMI 71C	1001D	MPMI 141A	1002D	MPMI 421A	1005D	MPMI 901A	
MPMI 72B*	1001D	MPMI 141B	1001D	MPMI 421B	1003D	MPMI 901B	2007D
MPMI 72C	1001D	MPMI 141C	1002E	MPMI 421C	1005E	MPMI 901C	2015E
MPMI 73B*	1001D	MPMI 141D	1001E	MPMI 421D	1003E	MPMI 901D	1005E
MPMI 73C	1001D	MPMI 143A	1003D	MPMI 422A	2001D	MPMI 902A	
MPMI 74B*	1002D	MPMI 143B	1002D	MPMI 422B	1005D	MPMI 902B	2015D
MPMI 74C	1001D	MPMI 143C	1003E	MPMI 422C	2007E	MPMI 902C	2020E
MPMI 80A*	1001D	MPMI 143D	1002E	MPMI 422D	1005E	MPMI 902D	2015E
MPMI 80B	1001D	MPMI 143A	1005D	MPMI 423A	2015D	MPMI 903A	
MPMI 81A*	1001D	MPMI 143B	1002D	MPMI 423B	1005D	MPMI 903B	
MPMI 81B	1001D	MPMI 143C	1005E	MPMI 423C	2015E	MPMI 903C*	2020E
MPMI 82A*	1002D	MPMI 143D	1002E	MPMI 423D	1005E	MPMI 903D	2015E
MPMI 82B	1001D			MPMI 424A	2015D	MPMI 904A	
MPMI 82A	1002D			MPMI 424B	2001D	MPMI 904B	
MPMI 82B	1001D			MPMI 424C	2015E	MPMI 904C	
				MPMI 424D	2007E	MPMI 904D	2020E

/ * May not give optimum performance on low speed high torque applications.
(Contact Application Engineering for Details)

Preferred BEMF Parameter for Rotary Motors

Rotary Motor	For 115VAC and 230VAC Operation		For 460VAC Operation	
	Minimum	Optimum	Minimum	Optimum
2 Pole Motor	10 Vrms/krpm	32 - 80 Vrms/krpm	23 Vrms/krpm	64 - 120 Vrms/krpm
4 Pole Motor	21 Vrms/krpm	64 - 120 Vrms/krpm	42 Vrms/krpm	127 - 240 Vrms/krpm
6 Pole Motor	32 Vrms/krpm	95 - 160 Vrms/krpm	64 Vrms/krpm	191 - 320 Vrms/krpm
8 Pole Motor	42 Vrms/krpm	255 - 240 Vrms/krpm	85 Vrms/krpm	254 - 480 Vrms/krpm

Preferred BEMF Parameter for Linear Motors for IndexBlok Only

Linear Motors	For 115VAC and 230VAC Operation		For 460VAC Operation	
	Minimum	Optimum	Minimum	Optimum
Linear Motors	0.5 6 Vrms/Hz	1.7 - 3.2 Vrms/Hz	1.1 Vrms/Hz	3.4 – 6.4 Vrms/Hz

Recommended Motor Specifications

Model Type	Drive's $I_{max,\ cont.}$ (Arms)	Minimum Motor's I_{max} (Arms)	R_min (l-l ohms)	R_opt (l-l ohms)	R_max (l-l ohms)	L_min (l-l mH)	L_max (l-l mH)
120VAC							
1001C	4.0	1.0	1.2	4.4	18.0	6.5	68.9
1003C	7.2	1.8	0.6	2.3	9.1	3.2	35.0
1005C	10.4	2.6	0.4	1.5	6.1	2.3	25.3
240VAC							
1001D	2.4	0.85	1.2	4.4	18.0	6.5	68.9
1002D	4.8	1.7	0.6	2.3	9.1	3.2	35.0
1003D	6.6	2.4	0.4	1.5	6.1	2.3	25.3
1005D	15.2	3.8	0.2	0.75	3.0	1.4	11.7
2001D	22.0	5.5	0.15	0.56	2.3	1.0	8.7
2010D	26.0	7.0	0.1	0.375	1.5	0.38	5.8
460VAC							
1001E	1.7	0.43	4.8	18.0	72.0	25.0	275.4
1003E	3.4	0.85	2.4	9.0	36.0	13.0	137.8
1003E	4.8	2.4	1.6	6.0	24.0	9.0	91.8
1005E	7.6	1.9	0.8	3.0	12.0	5.8	45.9
2001E	11.0	2.75	0.6	2.25	9.0	4.0	34.4
2010E	14.0	3.5	0.4	1.5	6.0	3.1	23.0
2015E	21.0	5.25	0.2	0.75	3.0	2.3	17.2
2020E	27.0	6.75	0.1	0.4	1.5	1.8	11.5

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Appendix E: Setup and Control Specification

Control Modes

Control modes are setup by setting and clearing bits in drive_mode parameters. All unused bits should be set to one.

drive_mode (C01)

	Bit Set	Bit Clear
Bit 0	Ramp to stop.	Coast to stop mode.
Bit 1	Use motor nameplate data.	Use drive internal motor parameter data.
Bit 2	Normal communication mode.	Ignore checksum.
Bit 3	Normal auto-tune only. • *The motor will not spin during normal auto-tune*	Normal and extended auto-tune.
Bit 4	Sensorless flux vector mode. • *This bit may be set or cleared anytime. The mode will only change, though, when the drive is off or the speed and speed command is below 1% of rated speed.* • *This bit is controlled by the digital input function di_v_per_hz. This digital input function, if used, takes precedence over a serial write to this bit.* • *The mode that the drive is in can be determined by reading bit 3 of drive_state_hi (D00) (clear means sensorless flux vector mode, set means open loop mode) or by using the digital output function do_control_mode.* • *In sensorless flux vector mode, the speed regulator gains, acceleration rate, ad deceleration rate are set by the state of Bit 10 of drive_mode (C01).*	Open loop mode. • *In open loop mode, the speed regulator, flux-tracking regulator, and iq axis current regulator are turned off.* • *In open loop mode, the acceleration rate is set by const_iq_acc_ol (F05) and the deceleration rate is set by const_iq_dec_ol (F06).*
Bit 5	Enable forward direction commands • *The digital input function di_forward_enable or the state of run_reverse digital input controls this bit. The digital inputs, if used, take precedence over a serial write to this bit.*	Disable forward direction commands. All forward speed commands are replaced with a zero speed command.
Bit 6	Enable reverse direction commands • *The digital input function di_reverse_enable or the state of run_forward digital input controls this bit. The digital inputs, if used, take precedence over a serial write to this bit.*	Disable reverse direction commands. All reverse speed commands are replaced with a zero speed command.
Bit 7	Acceleration and deceleration ramps are modified to maintain constant torque current for an inertial load during field weakening. At speeds less than base speed, the acceleration and deceleration ramps are linear and independent of the setting of bit 7. This mode is recommended for applications that operate well into the field weakening range.	Linear acceleration and deceleration ramps.
Bit 8	Serial setpoint control	Local setpoint control
Bit 9	Serial start control	Local start control
Bit 10	Default speed regulator gains and accelerations are used when the drive is in sensorless flux vector mode. • *Speed regulator gains are kp_trq_dflt (K00), ki_trq_dflt (K01), and iq_wdt_dflt (K02).* • *Acceleration rate is const_iq_acc_dflt (F01) and the deceleration rate is const_iq_dec_dflt (F02).* • *This bit is controlled by the digital input function di_lo_j_hi_j. This digital function, if used, takes*	Alternate high J speed regulator gains and accelerations are used when the drive is in sensorless flux vector mode. • *Speed regulator gains are kp_trq_hi_j (K03), ki_trq_hi_j (K04), and iq_wdt_dflt (K05).* • *Acceleration rate is const_iq_acc_hi_j (F03) and the deceleration rate is const_iq_dec_hi_j (F04).*

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	precedence over a serial write to this bit. • *This bit has no effect in open loop mode.*	
Bit 11	N/A	N/A
Bit 12	Digital inputs pulled up. • *Drive must be power-on reset, or IO init command must be executed for changes to take affect.*	Digital inputs pulled down. • *Drive must be power-on reset, or IO init command must be executed for changes to take affect.*
Bit 13	Bipolar analog input. The analog input is sampled as a –10 volt to +10 volt input. • *Drive must be power-on reset for changes to take affect.*	Unipolar analog input. Only voltages between 0 and 10 volts are read on the analog input. This range is sampled twice as often as in bipolar mode. • *Drive must be power-on reset for changes to take affect*
Bit 14	Digital input 2 is run and digital input 3 is invert local setpoint (fwd_rev). • *IO init command must be executed for changes to take affect.*	Digital input 2 is run forward and digital input 3 is run reverse. • *IO init command must be executed for changes to take affect.*
Bit 15	N/A	N/A

Serial Control

Clearing bits in Drive_Command enters serial commands. The serial sub-system will acknowlege the command by re-setting the bits. Any unused bits should be set to one. The bits are defined as follows:

Drive_Command (C00)

	Bit Set
Bit 0	Stop Request • *The drive will stop regardless of mode (serial or local control)* • *If the drive is in local start mode (bit 9 of drive_mode (C01) is clear), the drive will revert to serial start mode (bit 9 of drive_mode (C01) will be set) when any serial stop request is received.*
Bit 1	Start Request • *The drive will start if the drive is in serial start mode (bit 9 of drive_mode (C01) is set), run-enable is asserted.*
Bit 2	Auto tune Request • *The drive will auto tune if the drive is in serial start mode (bit 9 of drive_mode (C01) is set), run-enable is asserted, and the drive is not running.* • *A standard or extended auto tune will be performed based on the state of bit 3 of drive_mode (C01).*
Bit 3	N/A • *Always write as a one*
Bit 4	Clear external fault • *This will not override a external fault set by an asserted external fault digital input.*
Bit 5	Set external fault
Bit 6	Clear the fault cue
Bit 7	Reset the serial communications system • *Changes to drive address or baud rate take effect only on a serial communications reset or a power up reset.*
Bit 8	Reset auto-tune parameters to factory default
Bit 9	N/A • *Always write as a one*
Bit 10	N/A • *Always write as a one*
Bit 11	Initialize the I/O setup • *Changes to i/o functions take effect only on an I/O reset or a power up reset*
Bit 12	Perform motor parameter calculation • *Calculates motor parameters from nameplate data.* • *The drive must not be running for a motor parameter calculation to occur.* • *Motor parameter calculation occurs automatically on each start.*
Bit 13	N/A • *Always write as a one*
Bit 14	N/A

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	• *Always write as a one*
Bit 15	Reset processor • *Drive_Command = 07FFFh resets the processor.*

Omega_cmd_save (C02 and C03)

Writing to omega_cmd_save at either parameter address C02 or C03 sets the serial speed setpoint. The scaling is in RPM. Writing to address C02 writes to only the RAM copy of the serial speed setpoint – changes will not be saved after a power on reset. Writing to address C03 writes to both the RAM copy and the non-volatile copy of the serial speed setpoint – the last write will be remembered after a power on reset. It is recommended that if the control process requires frequent writes to the serial speed setpoint then parameter C02 should be used because the non-volatile memory has a limited write life of 100,000 cycles.

Analog Input Function

The analog input sets the speed command when local setpoint control is set (bit 8 of drive_mode (C01) clear), a preset speed is not selected, and the commanded direction is not disabled. Bit 13 of drive_mode (C01) controls whether the analog input is treated as bi-polar (-10 to 10 volts) or uni-polar (0 to 10 volts).

In closed loop mode, the analog input is scaled such that positive v_ref_offset (M19) volts is vin_min_spd_cl (M1C) RPM in the forward direction, positive v_ref_offset (M18) plus v_ref_range (M18) is max_speed (F00) in the forward direction. Positive analog inputs less than v_ref_offset (M19) are scaled to vin_min_spd_cl (M1C) RPM in the forward direction and positive voltages over v_ref_offset (M19) plus v_ref_range (M18) are scaled to max_speed (F00) RPM. Equivalent negative voltages are scaled to equivalent speeds in the reverse direction. The local speed command will be inverted if digital input 3 is asserted. In this case, positive v_ref_offset (M19) plus v_ref_range (M18) is max_speed (F00) in the reverse direction and negative v_ref_offset (M19) plus v_ref_range (M18) is max speed (F00) in the forward direction. Typically, this is used only in unipolar mode to change motor direction.

In open loop mode, vin_max_spd_ol (M1A) is substituted for max_speed (F00) and vin_min_spd_ol (M1B) is substituted for vin_min_spd_cl (M1C).

Digital Input Functions

Notes

1. Digital input pins 9-14 (DIN1-6) may be pulled up or down, depending on the setting of the pull-up/pull-down mode bit (drive_mode (C01), Bit12). Changes to this mode bit will not take affect until the next power-on reset, or execution of IO init command.
2. The polarity of each digital input may be set individually. The setting of each of the lower 8 bits of dig_in_polarity (M05) corresponds to the polarity of a digital input. Bit 0 applies to digital input 0, Bit 1 applies to digital input 1, etc. If the bit is set (= 1), the polarity is positive acting. Positive polarity means that the input is asserted if the input is high. If the bit is clear (= 0) the polarity is reversed; the input is asserted if the input is low.
3. Digital input pin 9 (DIN1) is run_enable. Run_enable must be asserted for the drive to start and run. If the drive is in local start mode and not faulted, asserting run_enable while Run, Run Forward, or Run Reverse are in the asserted state, the drive will start. If run_enable is transitioned to the de-asserted state while the drive is running, the drive will stop using the current stop mode (ramp or coast). Transitioning run_enable to the de-asserted state while the drive is faulted will clear the fault.
4. Digital input pins 10 (DIN2) and 11 (DIN3) can be set to two choices. They are either Run and Invert Local Setpoint or Run Forward and Run Reverse. The selection is determined by the state of bit 14 of drive_mode (see section 1A).

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- Run only has an effect in local start mode. If the drive is in local start mode, not faulted, not running and run and run_enable are asserted the drive will start. De-asserting run causes no action.
- Invert Local Setpoint only has an effect in local setpoint mode. If it is asserted the local setpoint is inverted, forward speed commands become reverse speed commands and reverse speed commands become forward speed commands. It is typically used as a Forward / Reverse switch when the analog input is in unipolar mode or the presets are all set to forward. Invert Local Setpoint has no effect when it is in the de-asserted state.
- Asserting Run Forward will disable reverse direction (clear bit 6 of drive_mode (C01)) and; if the drive is in local start mode, not faulted, and run_enable is asserted; will start the drive. De-asserting Run Forward will stop the drive if the drive is in local start mode and Run Reverse is also de-asserted. De-asserting Run Forward will also enable reverse direction (set bit 6 of drive_mode (C01)) unless another digital input is disabling reverse direction. If Run Forward is asserted when the speed command is in the reverse direction, the drive can run but at zero speed.
- Asserting Run Reverse will disable forward direction (clear bit 5 of drive_mode (C01)) and; if the drive is in local start mode, not faulted, and run_enable is asserted; will start the drive. De-asserting Run Reverse will stop the drive if the drive is in local start mode and Run Forward is also de-asserted. De-asserting Run Reverse will also enable forward direction (set bit 5 of drive_mode (C01)) unless another digital input is disabling forward direction. Asserting Run Reverse also inverts the local setpoint. If Run Reverse is asserted when the speed command is in the forward direction (after the inversion), the drive can run but at zero speed.

5. Digital input pins12-16 (DIN4-8) are programmable with any of the functions listed in IV. B. Any single function can only be assigned to one pin.

6. Digital I/O Pins 15 and 16 are programmable as inputs or outputs. For these pins to be used as inputs, the output functions must be set to Set High (function #0). These pins are always pulled up.

Digital Input Functions (M00 - M04)

M00-M04 Value	Function Description
0	***Null Function*** Use this function when an input / output pin is to be used as an output or to disable an input pin.
1	***External Fault*** The drive is in the external fault condition when the external fault input is de-asserted. The external fault condition is cleared on the transition of the external fault input to asserted. If the drive is running, or when an attempt is made to start the drive when the drive is in the external fault condition, the drive will trip (enter fault mode).
2	***Preset Speed Bit 0*** The drive may be setup with 0-7 preset speeds. The preset speeds are selected by binary defined inputs, preset speed bit 0, 1, and 2. Bit 2 Bit 1 Bit 0 Setpoint 0 0 0 Analog input 0 0 1 Preset speed 1 0 1 0 Preset speed 2 0 1 1 Preset speed 3 1 0 0 Preset speed 4 1 0 1 Preset speed 5 1 1 0 Preset speed 6 1 1 1 Preset speed 7
3	***Preset Speed Bit 1*** See above…
4	***Preset Speed Bit 2*** See above…
5	***Forward Enable***

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	Asserting forward enable, enables forward direction speed set-points (sets bit 5 of drive_mode (C01)) unless run_reverse is asserted, disabling forward direction. De-asserting forward enable, disables forward direction speed set-points (clears bit 5 of drive_mode (C01)). When forward is disabled and the active set-point commands a forward direction, the actual set-point is set to zero.
6	***Reverse Enable*** Asserting reverse enable, enables reverse direction speed set-points (sets bit 6 of drive_mode (C01)) unless run_forward is asserted, disabling reverse direction. De-asserting reverse enable, disables reverse direction speed set-points (clears bit 6 of drive_mode (C01)). When reverse is disabled and the active set-point commands a reverse direction, the actual set-point is set to zero.
7	***Low Inertia / High Inertia*** Asserting this input clears bit 10 of drive_mode (C01). De-asserting it sets bit 10 of drive_mode (C01). When bit 10 of drive_mode (C01) is set, and the drive is in sensorless flux vector mode, the speed regulator gains are kp_trq_dflt (K00), ki_trq_dflt (K01), and iq_wdt_dflt (K02). The acceleration rate is set by const_iq_acc_dflt (F01) and the deceleration rate is set by const_iq_dec_dflt (F02). When bit 10 of drive_mode (C01) is clear and the drive is in sensorless flux vector mode, the speed regulator gains are kp_trq_hi_j (K03), ki_trq_hi_j (K04), and iq_wdt_hi_j (K05). The acceleration rate is set by const_iq_acc_hi_j (F03) and the deceleration rate is set by const_iq_dec_hi_j (F04).
8	***Open Loop*** Asserting this input clears bit 4 of drive_mode (C01). This is a request for open loop mode. The drive will only switch from sensorless flux vector mode to open loop mode if the drive is off or in dc hold. De-asserting it sets bit 4 of drive_mode (C01). This is a request for sensorless flux vector mode. The drive will only switch from open loop mode to sensorless flux vector mode if the drive is off or the frequency is less than 1% of rated frequency.
>8	***Null Function***

Digital Output And Relay Functions

Notes

1. The following Functions may be used for the digital output pins 15 and 16, the relay outputs.
2. Digital I/O Pins 15 and 16 may be programmed to be digital outputs by setting the digital outputs function parameters to any of the values in the following table. Digital Output 1 and Digital input 7 use the same pin. Digital Output 2 and Digital input 8 use the same pin. If a pin is being used as a digital output, it should not be used as a digital input from an external source.
3. When digital outputs are asserted, the digital output pins are pulled low.

M06-M09 Value	Function Description
0	Set High Sets the output high. (Considered de-asserted). Use this function when an input / output pin is to be used as an input.
1	Set Low Sets the output low. (Considered asserted)
2	At Speed Asserted when drive is in sensorless flux vector mode, running, motor speed is within delta_speed_native (L0C) / half_poles (G0F) of speed set-point, and the drive is not out of regulation.
3	Out of Regulation Asserted when the drive is in sensorless flux vector mode, running, and the speed regulator is consistently on the limit. The fraction of time that the speed regulator must be on the limit is controlled by out_of_reg_parm (M15).
4	***Run*** Asserted any time the drive output devices are active.
5	***Reverse***

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	Asserted when the drive is running in the reverse direction.
6	***Overload Alert*** Asserted when the I^2T accumulator, I_sqr_t (d12), exceeds 100.
7	***Over Temperature Alert*** Asserted when the substrate temperature rises to within temp_hyst (J05) degrees of the heatsink_hot (J06) trip level. De-asserted when the substrate temperature falls to heatsink_hot (J06) – 2*temp_hyst (J05). Heatsink_hot (J06) and temp_hyst (J05) are scaled in 0.1 degrees C.
8	***Speed Detect Low*** Asserted when the absolute value of speed is below speed_detect_low (M13). De-asserted when the speed exceeds speed_detect_low (M13) by one percent of max_speed (F00).
9	***Speed Detect High*** Asserted when the absolute value of speed is above speed_detect_high (M14). De-asserted when the speed drops below speed_detect_high (m14 by one percent of max_speed (F00).
10	***Torque Detect Low*** Asserted when the torque magnitude is below torque_detect_low (M16). De-asserted when the torque exceeds torque_detect_low (M16) by 0.5 nm..
11	***Torque Detect High*** Asserted when the torque magnitude is above torque_detect_high (M17). De-asserted when the torque drops below torque_detect_high (M17) by 0.5 nm..
12	***Brake Actuate*** Asserted when an external brake should be released. De-asserted when an external brake should be applied.
13	***Fault_xrst*** Asserted when the drive is faulted, except when the fault is the reset fault. De-asserted when the fault is cleared.
14	***Control mode*** Asserted when the drive is in open loop mode, de-asserted when the drive is in sensorless flux vector mode.
15	***Serial control*** The digital output is not automatically driven but can be set or cleared by writing to the appropriate bit in the dig_out_prog (D17). Bit 0 is DO1, bit 1 is DO2, bit 6 is Relay 1, and bit 7 is Relay 2.
16	***Fault code blink*** Fault code pattern asserted during a fault. The output is asserted for one second then it is toggled off and on 1 to 16 times depending on the fault. The pattern is repeated as long as the drive is in fault mode.
>16	***Set High***

Analog Output Functions

Notes

User must define the scale of analog outputs. The scaling of analog outputs is defined by parameters AO_1_SCALE (M1D), AO_2_SCALE (M1E). The range of the AO_X_SCALE parameters defines the 10 volt output range of the analog output. For unsigned outputs (current magnituge, frequency, output voltage, heat sink temperature, and DC link voltage) values from 0 to A0_X_SCALE map from 0 to 10 volts. For signed outputs (torque, speed, and feedback values) values from –A0_X_SCALE / 2 to +A0_X_SCALE map from 0 to 10 volts with a value of zero giving 5 volts.

M0A-M0B Value	Function Description
0	***Null Function***
1	***Current*** Current (0 - peak) scaled to ao_x_scale. 0 amps gives zero volts. (Ao_x_scale / ki_imag (A08)) amps gives 10 volts
2	***Torque*** -(ao_x_scale / 200) nt-m gives 0 volts, 0 nt-m gives 5 volts, (ao_x_scale / 200) nt-m gives 10 volts,

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3	***Speed*** -(ao_x_scale / 2) RPM gives 0 volts, 0 RPM gives 5 volts, (ao_x_scale / 2) RPM gives 10 volts.
4	***Frequency*** 0 Hz gives 0 volts, (ao_x_scale / 10) Hz gives 10 volts.
5	***Vout*** 0 volts (l-n peak) gives 0 volts, (ao_x_scale / kv (A09)) volts (l-n peak) gives 10 volts. To convert output volts from l-n to l-l multiply by 1.732.
6	***Heat sink temperature*** 0 deg C gives 0 volts, (ao_x_scale / 10) deg C gives 10 volts.
7	***DC Link Voltage*** 0 volts gives 0 volts, (ao_x_scale / kv (A09)) volts gives 10 volts.
8	***Feedback Pointer 1*** Feedback value 1 (D15) = -ao_x_scale/2 gives 0 volts, feedback value 1 (D15) = 0 gives 5 volts, feedback value 1 (D15) = ao_x_scale / 2 gives 10 volts.
9	***Feedback Pointer 2*** Feedback value 2 (D16) = -ao_x_scale/2 gives 0 volts, feedback value 2 (D16) = 0 gives 5 volts, feedback value 2 (D16) = ao_x_scale / 2 gives 10 volts.
10	***Serial Set Level*** ao_x_scale = 0 to 256 gives 0 to 10 volts. Ao_x_scale values greater than 256 give 10 volts.
>10	***Null Function***

General Notes

Fault Handling

Faults may be cleared by any of the following actions:

Reading parameter D01 (drive_status_save) via the serial interface. If faults are cleared through the serial interface and the drive is in local start mode (bit 9 of drive_mode (C01) is cleared) the drive will revert to serial start mode (bit 9 of drive_mode (C01) will be set). This prevents the drive from restarting on a serial clear when both run and run_enable are asserted

Disabling the drive by de-asserting the run-enable input.

In Local start mode, power-on reset faults are cleared by any valid start command.

Disabling forward or reverse direction

Either clearing bits 5 or 6 of drive_mode (C01) or defining and de-asserting a forward or reverse enable digital input or asserting run_rev or run_fwd can disable forward or reverse direction. Digital input forward or reverse enable and run_fwd and run_rev take precedence over serial writes to bits 5 or 6 of drive_mode (C01). If digital inputs conflict over whether a direction is enabled or disabled, disabled takes precedent. An example of this is to define assert a reverse enable digital input and have run forward asserted. The run forward disables reverse which overrides the reverse enable digital input. The state of any digital input forward or reverse enable is reflected in bits 5 and 6 of drive_mode (C01) but is not recorded in the non-volatile memory.

Speed Set-point

Speed set-point is a signed input. Positive values mean forward direction and negative values mean reverse direction. On the analog input, positive voltage means forward direction and negative voltage means reverse direction. If the direction commanded is disabled (bits 5 or 6 of drive_mode (C01) cleared) then the speed set-point is set to zero. If invert local setpoint is active (DIN3 is asserted) then, on the analog input, positive voltage means reverse direction and negative voltage means forward direction and, for preset speeds, positive values mean reverse direction and negative values means forward direction.

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The speed setpoint can come from three sources: serial, local presets, or local analog. If serial setpoint mode is enabled (bit 8 of drive_mode (C01) is set) then the setpoint source is the serial command. If local setpoint mode is enabled (bit 8 of drive_mode (C01) is clear) then local presets take precedence over the local analog input. If no preset digital inputs are defined or all defined preset digital inputs are de-asserted then the setpoint comes from the analog input when local setpoint mode is enabled. If any of the preset digital inputs are asserted then the associated preset speed is the setpoint when local setpoint mode is enabled. If a preset speed parameter is changed while that preset is active then the setpoint will change immediately.

Serial Start

If the drive is in serial start mode, the run-enable input must be asserted for a start to occur. If a serial start command is received when run-enable is de-asserted, the command is acknowledged but no action is taken.

If a serial start command is received when the drive is in local start mode, the command is acknowledged but no action is taken.

When a serial stop is received, the drive is stopped regardless of the start mode. In addition serial start mode is activated (bit 9 of drive_mode (C01) is set), regardless of whether the drive is running or not.

Local Start

Local start mode will automatically change to serial start mode when a serial stop is received or faults are cleared serially. This prevents a start from a local setup state caused by a serial command.

If the drive is in local start mode and is not faulted, run_enable and run operate as follows:

Run_enable	Run	Chg To	Run_enable	Run	Resulting Action
0	0	⇨	0	1	no action, drive stopped
0	0	⇨	1	0	no action, drive stopped
0	1	⇨	0	0	no action, drive stopped
0	1	⇨	1	1	drive starts
1	0	⇨	0	0	drive stops if running
1	0	⇨	1	1	drive starts if not running
1	1	⇨	0	1	drive stops
1	1	⇨	1	0	no action, drive running

If the drive is in local start mode, not faulted, and run-enable and run are asserted on power up, the drive will start.

If the drive is not faulted, and run-enable and run are asserted when the drive mode is switched from serial start to local start, the drive will start.

If the drive is in local start mode and is not faulted, run_enable (RE), run_fwd (RF), and run_rev (RR) operate as follows:

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Run_enable	Run_Rev	Run_Rev	Chg To	Run_enable	Run_Rev	Run_Rev	Resulting Action
0	0	0	⇨	0	0	1	no action, drive stopped
0	0	0	⇨	0	1	0	no action, drive stopped
0	0	0	⇨	1	0	0	no action, drive stopped
0	0	1	⇨	0	0	0	no action, drive stopped
0	0	1	⇨	0	1	1	no action, drive stopped
0	0	1	⇨	1	0	1	drive starts reverse
0	1	0	⇨	0	1	1	no action, drive stopped
0	1	0	⇨	0	0	0	no action, drive stopped
0	1	0	⇨	1	1	0	drive starts forward
0	1	1	⇨	0	1	0	no action, drive stopped
0	1	1	⇨	0	0	1	no action, drive stopped
0	1	1	⇨	1	1	1	drive starts, speed set to zero
1	0	0	⇨	1	0	1	drive starts reverse
1	0	0	⇨	1	1	0	drive starts forward
1	0	0	⇨	0	0	0	no action, drive stopped
1	0	1	⇨	1	0	0	drive stops
1	0	1	⇨	1	1	1	drive running, speed set to zero
1	0	1	⇨	0	0	1	drive stops
1	1	0	⇨	1	1	1	drive running, speed set to zero
1	1	0	⇨	1	0	0	drive stops
1	1	0	⇨	0	1	0	drive stops
1	1	1	⇨	1	1	0	drive running forward
1	1	1	⇨	1	0	1	drive running reverse
1	1	1	⇨	0	1	1	drive stops

If the drive is in local start mode, not faulted, and run_enable, and run_fwd or run_rev are asserted on power up, the drive will start.

If the drive is not faulted, and run_enable, and run_fwd or run_rev are asserted when the drive mode is switched from serial start to local start, the drive will start.

Common Control methods

Serial Control

Set bits 8 (serial setpoint), 9 (serial start), and 14 (run / fwd/rev) of drive_mode (C01). Assert run_enable (DIN 1) all the time. Start and stop the drive by writing to drive_command (C00). Set the speed command by writing to omega_cmd_save (C02). Set comm_timer_max (J02) to a non-zero value to enable loss of serial communications fault. A value of 96 represents a 5-second timeout, and is recommended.

Local Control, two-wire mode, bi-directional analog input

Clear bits 8 (local setpoint) and 9 (local start) of drive_mode (C01). Set bits 13 (bi-polar analog input) and 14 (run / fwd/rev) of drive_mode (C01). Set comm_timer_max (J02) to zero to disable the loss of serial communications fault. Permanently assert Run (DIN 2) and de-assert Invert Local Setpoint (DIN 3). Start and stop the drive by asserting and de-asserting run_enable (DIN 1). Apply –10 to 10 volts to the analog input to set speed and direction. If preset speeds are also desired, define DIN4 – DIN9 as preset speed bits as appropriate. Program the Preset_Speed_X (M0C – M12) parameters with signed speed values. Asserting any preset speed bits will set the speed command to the associated Preset_Speed_X (M0C – M12) value. The analog input will be used for the speed command when no preset speed bits are asserted.

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Local Control, two-wire mode, uni-polar analog input

Clear bits 8 (local setpoint), 9 (local start), and 13 (uni-polar analog input) of drive_mode (C01). Set bit 14 (run / fwd/rev) of drive_mode (C01). Set comm_timer_max (J02) to zero to disable the loss of serial communications fault. Permanently assert Run (DIN 2). Start and stop the drive by asserting and de-asserting run_enable (DIN 1). Apply 0 to 10 volts to the analog input to set speed. De-assert fwd/rev (DIN 3) for forward direction, assert fwd/rev (DIN 3) for reverse direction. If preset speeds are also desired, define DIN4 – DIN9 as preset speed bits as appropriate. Program the Preset_Speed_X (M0C – M12) parameters with unsigned (positive) speed values. Asserting any preset speed bits will set the speed command to the associated Preset_Speed_X (M0C – M12) value. The direction will be determined by the state of fwd/rev (DIN 3). The analog input will be used for the speed command when no preset speed bits are asserted.

Local Control, three-wire mode, bi-directional analog input

Clear bits 8 (local setpoint) and 9 (local start) of drive_mode (C01). Set bits 13 (bi-polar analog input) and 14 (run / fwd-rev) of drive_mode (C01). Set comm_timer_max (J02) to zero to disable the loss of serial communications fault. Permanently de-assert Invert Local Setpoint (DIN 3). Nominally set run_enable (DIN 1) to the asserted state and run (DIN 2) to the de-asserted state. Start the drive by a pulse on run (DIN2) (assert – de-assert). Stop the drive by a pulse on run_enable (DIN 1) (de-assert – assert). Apply –10 to 10 volts to the analog input to set speed and direction. If preset speeds are also desired, define DIN4 – DIN9 as preset speed bits as appropriate. Program the Preset_Speed_X (M0C – M12) parameters with signed speed values. Asserting any preset speed bits will set the speed command to the associated Preset_Speed_X (M0C – M12) value. The analog input will be used for the speed command when no preset speed bits are asserted.

Local Control, three-wire mode, uni-polar analog input

Clear bits 8 (local setpoint), 9 (local start), and 13 (uni-polar analog input) of drive_mode (C01). Set bit 14 (run / fwd-rev) of drive_mode (C01). Set comm_timer_max (J02) to zero to disable the loss of serial communications fault. Nominally set run_enable (DIN 1) to the asserted state and run (DIN 2) to the de-asserted state. Start the drive by a pulse on run (DIN2) (assert – de-assert). Stop the drive by a pulse on run_enable (DIN 1) (de-assert – assert). Apply 0 to 10 volts to the analog input to set speed. De-assert fwd/rev (DIN 3) for forward direction, assert fwd/rev (DIN 3) for reverse direction. If preset speeds are also desired, define DIN4 – DIN9 as preset speed bits as appropriate. Program the Preset_Speed_X (M0C – M12) parameters with unsigned (positive) speed values. Asserting any preset speed bits will set the speed command to the associated Preset_Speed_X (M0C – M12) value. The direction will be determined by the state of fwd/rev (DIN 3). The analog input will be used for the speed command when no preset speed bits are asserted.

Local Control, run forward – run reverse

Clear bits 8 (local setpoint), 9 (local start), 13 (uni-polar analog input), and 14 (run fwd / run rev) of drive_mode (C01). Set comm_timer_max (J02) to zero to disable the loss of serial communications fault. Nominally set run_enable (DIN 1) to the asserted state and run-fwd (DIN 2) and run-rev (DIN 3) to the de-asserted state. Start the drive in the forward direction by asserting run-fwd (DIN2). Stop the drive by de-asserting run-fwd (DIN 2). Start the drive in the reverse direction by asserting run-rev (DIN 3). Stop the drive by de-asserting run-rev (DIN 3). If run-enable (DIN 1) is de-asserted while the drive is running, the drive will stop. If run-enable is re-asserted while run-fwd (DIN 2) or run-rev (DIN 3) is in the asserted state, the drive will start and run in the appropriate direction. If run-enable (DIN 1), run-fwd (DIN 2), and run-rev (DIN 3) are all in the asserted state, the drive will run at zero speed regardless of the speed setpoint. In this state, if run-fwd (DIN 2) or run-rev (DIN 3) is de-asserted, the drive will accelerate to the speed setpoint in the appropriate direction. Apply 0 to 10 volts to the analog input to set speed. If preset speeds are also desired, define DIN4 – DIN9 as preset speed bits as appropriate. Program the Preset_Speed_X (M0C – M12) parameters with unsigned (positive) speed values. Asserting any preset speed bits will set the speed command to the associated

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Preset_Speed_X (M0C – M12) value. The analog input will be used for the speed command when no preset speed bits are asserted.

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Appendix F: Serial Communications Protocol

MTS Systems DriveBlok, SpindleBlok, and IndexBlok products include a serial port to allow communications access to the drive. This port is primarily used to configure drive parameters to match the requirements of motor and load. This port can also be used to provide real-time access to feedback, monitoring and motor control. Serial communication for control can greatly reduce wiring otherwise needed for analog speed references, discrete I/O to stop and start the drive, etc. Drive commands are addressable to allow a single host computer to control up to 35 drives. This document provides reference materials and descriptions of the software techniques required for serial communications.

Scope

The guidelines in this document apply to all MTS Systems DriveBlok, SpindleBlok, and IndexBlok products

General

MTS Systems DriveBlok, SpindleBlok, and IndexBlok products contain a large number of configuration, operation and monitoring parameters. Access to the drive microprocessor to read or write these parameters is accomplished via a serial communication port. All serial communications to the drive must be initiated and controlled by a host computer. The host can be as simple as an embedded-controller based keypad or as complex as programmable logic controller (PLC) or personal computer. An optional MTS Systems keypad is available or the customer can create their own host computer system.

All messages include a drive address to allow as many as 35 drives to be linked to a single network. Each drive is assigned a unique address on the net and the host computer is responsible for initiating and coordinating all network traffic.

Communications Protocol Description

The serial port supports baud rates up to 19.2k with 8-bit data length, 1 stop bit and no parity. The host computer acts as the master and initiates all communications. The host can either read a parameter value from a drive or write a parameter back to the drive. A drive will only transmit to the network in response to a command addressed to it from the host. While the host can read the value of any parameter, some drive parameters are not write accessible. The typical transmission is as follows:

- The host transmits a command to the network with the address of the drive for which the command is intended.
- The host then waits for the addressed drive to receive the command and respond to the host.
- When the addressed drive receives a command it will carry out the command and respond to the host. If the command could not be executed, the drive will transmit an error response to the host.
- If no response is received after a limited period of time, the host should repeat the message. If no response is received after a limited number of attempts, the host should indicate that a transmission error has occurred.
- If a proper response is received, the host should wait briefly before transmitting another message to the network.

Message Structure

All messages consist of simple, ASCII character text strings. Strings do not contain any non-printable characters. These strings always begin with a single character to indicate the type of message:

Host

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Write	'&'	Write data to a drive parameter
Read	'$'	Read data from a drive parameter

Drive

Acknowledge	'#'	Acknowledge the host that the data has been entered
Response	'%'	Respond to the host with the data requested
Command Error	'?'	Drive has detected a communications error
Fault and Reset	'!'	Drive has had a fault or reset condition

The second character in a message string is always the address of the drive. MTS Systems drives support up to 35 addresses so the single character address in any message string ranges from 1-9, A-Z (upper case). The host can also send a broadcast message to all drives by addressing the command to '0'. All drives will act on this command **but no response messages will be generated**.

The next set of characters depends on the type of message and whether the message is sent by the host or is a response from a drive. This will be explained in greater detail below.

The next to last character in every message string is a single hexadecimal checksum value. This checksum helps ensure that messages corrupted in any way during transmission are rejected by all drives on the network. The checksum must be calculated by the host computer using a specific algorithm and the checksum character derived from that algorithm inserted into the command string. Any drive receiving a message that appears to be addressed for it will perform exactly the same algorithm and verify that the checksum character is identical. If the checksums do not match, the drive will return an error message to the host. Finally, each message string is terminated with a carriage return character.

Host Commands

After the message type and drive address characters, all Read/Write commands from the host next contain the three character parameter number. The first of these three characters is a letter, A-M, which indicates the type or "group" the parameter belongs to. The next two characters represent the hexadecimal number for that parameter within the group. Drive parameter definitions may change from one drive microprocessor code version to another. The drive parameter definition list for a specific code version is available from MTS Systems Application Engineering Group.

Read

A Read command will direct the drive to return the value stored in the parameter indicated. Any drive parameter may be read. Note that a broadcast message (drive address 0) would not be useful since none of the drives will respond.

Read commands are seven characters long and are of the format: $WPXXZ<CR>

$	=	Read
W	=	Drive address (1-9,A-Z)
P	=	Parameter type
XX	=	Parameter number
Z	=	Checksum
<CR>	=	Carriage Return

Write

A Write command will then include the four character hexadecimal value to be stored in the parameter. Do not write to any parameter clearly marked as 'Not Defined' or 'Reserved' in the drive parameter definition list. Attempting to write to a read-only parameter will generate a Command Error message from the drive. Certain parameters are "locked" when the drive is running. The host program should refrain from trying to write to a locked parameter. Attempting to write to a locked parameter will generate a Command Error message from the drive.

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Write commands are eleven characters long and are of the format: &WPXXYYYYZ<CR>

&	=	Write
W	=	Drive address (1-9,A-Z)
P	=	Parameter type
XX	=	Parameter number
YYYY	=	Data to be written to parameter
Z	=	Checksum
<CR>	=	Carriage Return

Drive Responses

The drive addressed will always respond to host commands. When commanded to return the contents of a parameter by a Read command, the drive will reply with a Response message. When responding to a Write command, the addressed drive responds with an Acknowledge message. If a drive can not execute the command or the checksum of the command does not match, the drive will respond with a Command Error message. Finally, a drive that has faulted or reset will ignore commands from the host until the host device clears the fault. Each time the host sends a command to the drive, it will respond with a Fault and Reset message.

Acknowledge

An Acknowledge message is sent after the drive has received a Write command and has successfully written to the parameter.

Acknowledge messages are only four characters long and are of the format: #XZ<CR>

#	=	Acknowledge
X	=	Drive address (1-9, A-Z)
Z	=	Checksum
<CR>	=	Carriage Return

Response

A Response message is sent after the drive has received a Read command and the message contains the data stored in the parameter.

Response messages are eleven characters long and are of the format: %WPXXYYYYZ<CR>

%	=	Response
X	=	Drive address (1-9, A-Z)
P	=	Parameter type
XX	=	Parameter number
YYYY	=	Data contained in parameter
Z	=	Checksum
<CR>	=	Carriage Return

Command Error

Command Error messages are sent whenever a drive has received a command on which it can not act. Command Error messages contain an error code to indicate to the host why the drive could not act on the command.

Command Error messages are five characters long and are of the format: ?XYZ<CR>

?	=	Command Error
X	=	Drive address (1-9, A-Z)
Y	=	Error Code
Z	=	Checksum
<CR>	=	Carriage Return

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Code	Description	Comment
1	Bad Checksum	The checksums do not match
2	Bad Hex Character	Character received was not in the range 0-F
3	Write to Read-Only	Host attempted to write to a read-only parameter
4	Input Buffer Overrun	Host message too long for input buffer
5	Command Undefined	First character in host message not '&' or '$'
6	Write to Locked	Host tried to write to parameter locked while running
7	Parameter Type	Parameter type not in the range A-M
8	Parameter Number	Parameter number beyond end of table

Fault and Reset

A Fault and Reset message is sent in response to any host command after the drive has faulted or reset. When commanded by the host, the drive will respond with this message and will not act on any commands until the drive receives a Read command of parameter D01. This command will clear this mode. The message contains a two-character code to indicate the type of problem.

Fault and Reset messages are six characters long and are of the format: !XYYZ<CR>

!	=	Fault and Reset
X	=	Drive Address (1-9, A-Z)
YY	=	Index of fault in hex (See code list)
Z	=	Checksum
<CR>	=	Carriage Return

Code	Description	Comment	Note
01	Inverter interrupt sat fault	Saturation fault	
02	DB overload	Drive overload	DriveBlok Only
03	Phase overcurrent	Phase current too high	
04	Single phase input detected	Only one phase present at input	DriveBlok Only
05	DC link undervoltage	DC link voltage too low	
06	DC link overvoltage	DC link voltage too high	
07	Base driver fault	Internal power supply out of range	DriveBlok Only
08	A/D offsets out of tolerance	Internal A/D convertor problem	
09	Motor fault	Motor fault has occurred	
0A	Heat sink temperature too high	Heat sink temperature too high	
0B	Motor thermal overload	Motor temperature too high	
0C	Communications fault	Communications fault has occurred	
0D	External fault	A fault external to the drive has occurred	
0E	EEPROM fault	An error has occurred in the EEPROM	
0F	Motor parameter fault	Parameter fault	
FF	Drive reset	Drive has been reset	

Checksum Calculation

The checksum character is a vital part of every message. The checksum is used to ensure that messages inadvertently altered by network interference or data corruption are detected. The checksum is generated by using an algorithm that performs a set combination of Boolean logic on the string to be transmitted. The result of this algorithm is a character always inserted in the next to last character of the message string.

When a message is received, the message contents are validated by comparing the checksum included in the message by the sender with the checksum calculated by the receiver using exactly the same algorithm. If the checksum character in a command string from the host does not match, an Error Response is generated by the drive. If the

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checksum character in a response string from a drive does not match, the host should repeat the command.

The checksum is calculated as follows:

1. Perform an 8-bit logical ADD of the hex values of every character in the string to be transmitted EXCEPT THE CHECKSUM AND CARRIAGE RETURN.
2. Take the result of the step above and logically AND it with 7Fh. This will strip the last bit, setting it to zero, from the results of the ADD and limit the checksum to the first 128 ASCII characters.
3. Take the result of step 2 and logically OR it 40h. This will force bit 6 to 1 and limit the checksum to one of the printable characters.
4. Look up the result of step 3 in a standard ASCII table and insert that character in the checksum position of the message string.

Checksum Example

The host wants to Write the value 0A34h to parameter A21 of drive 1. This results in the string: '&1A210A34'. The ASCII code for each character is:

Character	Code
&	26h
1	31h
A	41h
2	32h
1	31h
0	30h
A	41h
3	33h
4	34h

Thus the hex string equivalent is 263141323130413334h.

1. Logical 8-bit (Modulus) ADD of every character in the string = D3h.
2. Logical AND of D3h with 7Fh = 53h (equivalent to setting bit seven to 0)
3. Logical OR of 53h with 40h = 53h (equivalent to setting bit six to 1)
4. Look up 53h in an ASCII table = 'S' (upper case)

After the host appends the carriage return character, the message '&1A211A34S<CR>' is then transmitted to the drive. Note that this is the ASCII string representation of this message. The actual hex values transmitted to the drive are: 2631413231304133345330Dh.

When the drive receives this message, before it acts on the command or responds to it, the drive will strip the checksum and <CR> from the string and perform exactly the same Boolean calculation. The result of the calculation is compared to the checksum received. If they are the same, the drive continues processing the rest of the message and responds appropriately. If the checksum does not match, the drive responds with a Command Error message.

Here's an example of the checksum calculation in C:

```
unsigned char CalculateChecksum (unsigned char * data, unsigned char count)
{
  unsigned char cks = 0;

  while (count)
```


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```
  {
    cks += *data;
    data++;
    count--;
  }
  cks &= 0x7F;
  cks |= 0x40;
  return(cks);
}
```


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