Application Technique

Allen-Bradley

Vertical Load and Holding Brake Management

Bulletin Numbers 2198, 2094, 2097, VPL, VPC, MPL, MPM

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This publication provides an in-depth discussion on how to apply Kinetix® drives in vertical load applications and how the servo motor holding-brake option can be used to help prevent a load from falling. Kinetix motion control applications are featured with Kinetix integrated motion on EtherNet/IP™ servo drives (Kinetix 5500, Kinetix 5700, Kinetix 6500, and Kinetix 350) and Kinetix VP and MP-Series™ servo motors.

Summary of Changes

This publication contains new and updated information as indicated in the following table.

Topic	Page
Added Kinetix 5700 Safe Monitor and STO Safety Functions.	41
Updated text for Phase-loss detection attributes that were previously referred to as torque proving attributes.	53

Important User Information

Read this document and the documents listed in the additional resources section about installation, configuration, and operation of this equipment before you install, configure, operate, or maintain this product. Users are required to familiarize themselves with installation and wiring instructions in addition to requirements of all applicable codes, laws, and standards.

Activities including installation, adjustments, putting into service, use, assembly, disassembly, and maintenance are required to be carried out by suitably trained personnel in accordance with applicable code of practice.

If this equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

In no event will Rockwell Automation, Inc. be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or liability for actual use based on the examples and diagrams.

No patent liability is assumed by Rockwell Automation, Inc. with respect to use of information, circuits, equipment, or software described in this manual.

Throughout this manual, when necessary, we use notes to make you aware of safety considerations.

	WARNING: Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.
	ATTENTION: Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequence.
IMPORTANT	Identifies information that is critical for successful application and understanding of the product.

Labels may also be on or inside the equipment to provide specific precautions.

	SHOCK HAZARD: Labels may be on or inside the equipment, for example, a drive or motor, to alert people that dangerous voltage may be present.
	BURN HAZARD: Labels may be on or inside the equipment, for example, a drive or motor, to alert people that surfaces may reach dangerous temperatures.
	ARC FLASH HAZARD: Labels may be on or inside the equipment, for example, a motor control center, to alert people to potential Arc Flash. Arc Flash will cause severe injury or death. Wear proper Personal Protective Equipment (PPE). Follow ALL Regulatory requirements for safe work practices and for Personal Protective Equipment (PPE).

Vertical and Horizontal Loads

In this publication, a vertical load is classified as a load that stores potential energy either by gravity or spring effect. In this type of load, Kinetix servo motors must hold part (counterbalanced load) or all (not counterbalanced) of the load even when the motor is not moving, but still powered by the drive.

- Typical vertical loads are elevator and crane applications. But, any load on any inclined plane that can be in motion due to stored potential energy is considered a vertical load in this publication.
- Vertical loads require a holding brake to keep the load stationary while the drive is disabled.

In this publication, a horizontal load is classified as a load that does not store potential energy (either by gravity or spring effect) when the drive is disabled.

- Some horizontal applications can require a holding brake just to keep the load stationary while the drive is disabled.

Holding Brakes

Holding brakes are a factory-only option for Kinetix servo motors. The holding brake is a separate mechanism located on the back of the motor and designed to hold the motor shaft stationary while the drive is disabled. The maximum torque that the holding brake can hold is called the holding torque. In general, the rated holding torque is designed to be higher than the motor continuous stall torque. You must determine whether the motor holding-torque value is sufficient to hold the vertical load. The holding torque specification is specified at the motor shaft.

Refer to Holding Brake Specifications on page 8 for Kinetix VP (Bulletin VPL and VPC) and MP-Series (Bulletin MPL and MPM) servo motor holding torque values and other holding brake specifications.

Holding brakes are released when 24V DC is applied to the brake coil. Voltage and polarity supplied to the brake must be as specified in the drive user manual for proper brake performance. Kinetix Integrated Motion on EtherNet/IP drives use solid-state relays to control the holding brakes. These relays can be cycled a limited number of times within a certain time period (duty cycle). For example, Kinetix 5500 and Kinetix 5700 drives can be reliably cycled 10 times per minute. Refer to Additional Resources on page 58 for the user manual of your Kinetix drive for more information on holding-brake duty cycles.

ATTENTION: Holding brakes are not designed to stop a rotating motor shaft. The recommended method to stop motor shaft rotation is to command the drive to decelerate the motor to zero speed (via logic or by removing the drive enable input), and engage the brake after the motor has reached zero speed. If the drive main input power fails, causing brake power to be removed, the brakes can withstand infrequent use as a stopping brake. However, use of these holding brakes as stopping brakes creates rotational mechanical backlash that is potentially damaging to the system, increases brake pad wear, and reduces brake life. The brakes are not designed nor are they intended to be used as a safety device or to stop the motor rotation.

A 24V DC power source is required to disengage (release) the brake. This 24V DC source can be provided either from an external power supply or from the drive. The holding brake coil needs a certain amount of current to release the holding brake. If that required current is less than the 24V DC current provided by the drive, the drive can be used to power the brake coil and release the holding brake. If the current required to release the holding brake is larger than the current the drive can provide, an external relay (coil and contact) and a user-supplied 24V DC source is required to energize the brake circuit and release the holding brake.

Protect the brake relay against voltage that builds up on the relay terminals. This voltage can damage the relay when actuating the brake. If this brake relay is a dry-contact relay, electrical arcing can occur. If this brake relay is a solid-state relay, the voltage can rise to values that can damage the relay, although arcing doesn't occur. The brake relay can be protected by clamping this voltage to safe levels with a metal oxide varistor (MOV) or a diode. For drives that use a dry-contact brake relay, a customer-supplied MOV or diode is recommended to be installed in parallel to the brake coil to protect the brake relay. Kinetix integrated motion on EtherNet/IP drives use a solid-state brake relay and most have a built-in MOV device included as part of the brake circuit that is used to clamp inductive energy upon brake engagement. For drives with a built-in MOV device, external suppression is not required. Refer to Additional Resources on page 58 for the user manual of your Kinetix drive to determine if your drive includes a suppression device.

Holding brakes have a small backlash associated with them. Backlash is introduced upon actuation when the spline mechanism engages the motor. For example, brake backlash for VPL-A0631 motors is 30 arc minutes, which equates to 0.001389 motor rotations. If this extrapolates to an excessive amount of movement for the application, alternative methods for holding the load must be used.

Design Considerations

This section contains information about the physical properties of the holding brake and best practices to properly design, install, and electrically apply the holding brake. The topics in this section are summarized as part of Vertical Axis Quick Reference/Checklist on page 48. When you have a good understanding of these concepts and best practices, use the checklist to make sure you've applied all them all in your vertical axis application.

Mechanical Advantage

Transmission systems provide the advantage of holding all or part of the load while the drive is disabled. Thus, the mechanical advantage of gear ratios can be leveraged whenever possible with a vertical load. By using gear ratios, which prevent back-driving the load through the transmission system (for example, a gearbox) the load is mechanically held in place once the servo drive is disabled. For lower gear ratios, the transmission system is not always able to hold the load in place when the drive is disabled, causing the load to move downward slowly (at a slower than free-fall speed).

Safety Brake and Alternative Sources for Braking

Kinetix servo-motor holding brakes are not designed as safety devices. A brake that is used as a safety device is different. By definition, a safety brake renders the axis it is attached to, safe. Safety brakes are a special class of brakes. They are specifically designed in accordance with numerous accepted industry standards. They have built-in redundancies, special preventive maintenance needs, and usually they have specific means of inspection.

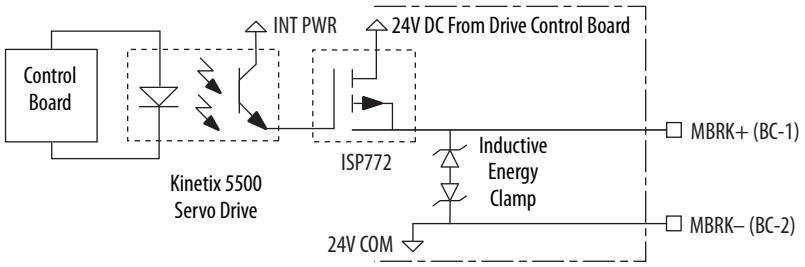
The machine risk assessment determines whether an additional safety stopping-brake or safety holding-brake is required. Servo motor brakes are designed for holding only. If any of these brakes are applied while the motor and the mechanical load have too much stored mechanical energy, the brakes can shear and cause irreparable damage to the brake; and when the brake is compromised, the load can slip. The additional safety brakes can be designed either to stop the load (for example, elevator emergency brakes) or simply provide another channel of holding. Typically, stopping brakes are attached directly to the load and its travel mechanism, while holding brakes are most economically applied on the motor housing. The risk assessment must be the final determinant of the addition, location, and type of brakes.

External Relays

The brake connector (MBRK+ and MBRK-) in a Kinetix drive is connected to a solid-state relay device inside the drive that is used to energize the brake coil. This process of energizing the brake coil requires a certain amount of current. In some cases, for example, where a large servo motor is used with a smaller drive and the holding brake current exceeds the amount of current that the drive is capable of providing, an external relay is required between the drive and the brake coil.

TIP Typically, the Kinetix 5500, Kinetix 5700, and Kinetix 6500 drive families **do not** require an external relay. This is because the current output is sufficient to drive any properly-sized servo motor. This is also true when used with other Kinetix drive products.

Kinetix 5500 Motor Brake Circuit



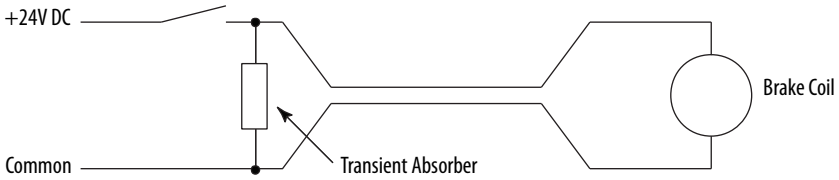
When the brake-coil current requirement does not exceed the drive brake-circuit capability, no external relay is required. However, if the drive brake-circuit capability is exceeded, an external relay is required to satisfy the higher current demand and a suppression device in parallel to the brake coil is recommended.

- Example of MOV suppressor is Bulletin 199-MSMV1
- Example of interpose relay is Bulletin 700-HA32Z24

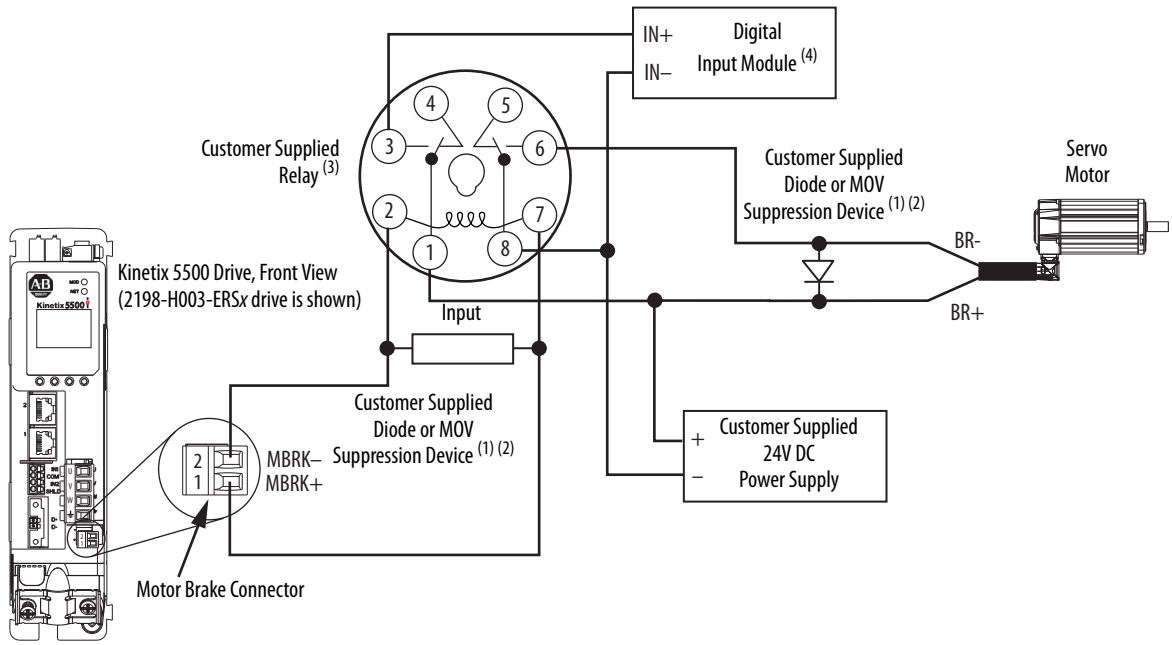
Refer to Additional Resources on page 58 for the user manual of your Kinetix drive for specific brake-relay wiring information.

The wiring used for an external relay used to switch 24V DC loads is considered a potential electrical noise source and can be considered a 'dirty' device inside the electrical panel. See the System Design for the Control of Electrical Noise Reference Manual, publication GMC-RM001, for more information on clean and dirty wireways.

External Transient Absorber (MOV) With the Brake Coil



Kinetix 5500 Drive with External N.O. (normally open) Relay and Holding Brake



(1) Suppression device not required for Kinetix 5500 and Kinetix 5700 servo drives.
(2) Example of MOV suppressor is Bulletin 199-MSMV1.
(3) Example of interpose relay is Bulletin 700-HA32Z24.
(4) This input is the physical state of the holding brake. When wired to a 24V input card, this input can be used as a monitoring function to permit or inhibit motion using controller logic (optional).

24V DC Requirements and Brake Current

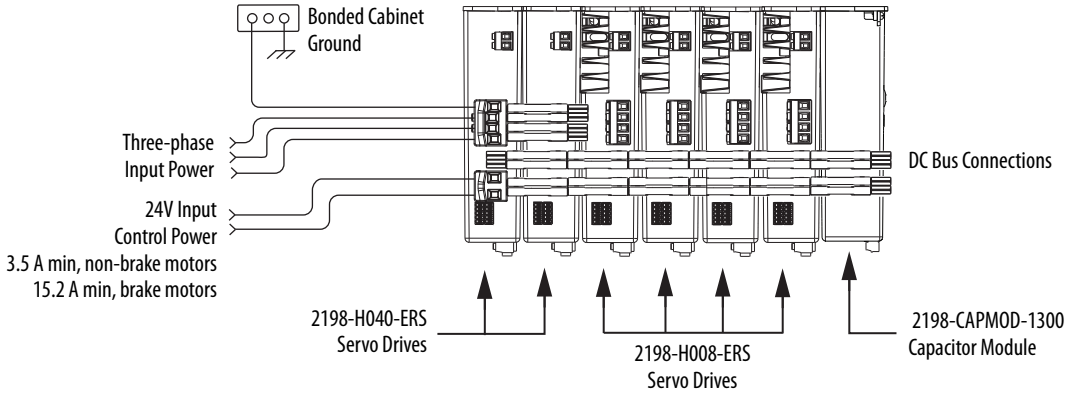
The holding brakes on Kinetix servo motors are 24V DC devices. For the Kinetix 5500 and Kinetix 5700 drive families, the 24V DC (customer supplied) power supply that is used to control brake power is the same 24V DC power supply that is used by the drive's logic control board. This means that the 24V DC power supply must be capable of supplying the drive system control boards and the sum of the axes' holding brake 24V DC current requirements. If this power supply does not have enough current to energize the holding brakes (and the drive system control boards), the brake operation can be intermittent. The example on page 7 shows the logic supply current and brake current that can be used by a typical Kinetix 5500 drive system. With the Kinetix 5500 drives, 2.0 A is the maximum current rating for the brake circuit. This means that if a holding brake requires more than 2.0 A to energize, an external relay is required. Refer to Holding Brake Specifications on page 8 for Kinetix servo motor holding-brake current requirements. By using these tables, you can determine an exact value for the required brake current.

IMPORTANT If using the 24V DC shared-bus connection system to distribute control input power to a cluster of drive modules, current from the 24V shared-bus system must not exceed 40 A. If the 24V DC control power output (both logic power and brake power) exceeds 40 A, you must add another input wiring connector. To do this, you can insert another 2198-TCON-24VDCIN36 or 2198T-W25K-P-IN input wiring connector at any point in your drive cluster. See the Kinetix 5700 Servo Drives User Manual, publication 2198-UM002, for more information on 24V DC shared-bus connections.

Kinetix 5500 System Current Demand Example

In this example, the Kinetix 5500 drive system includes two 2198-H040-ERS drives, four 2198-H008-ERS drives, and one capacitor module.

Shared AC/DC Hybrid Configuration



Kinetix 5500 System Current Demand Calculations

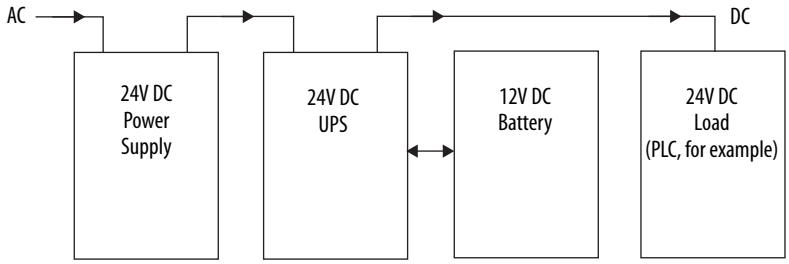
Kinetix 5500 Module Cat. No.	Qty	24V Current (non-brake motors) A_{DC}	24V Current (2 A brake motors) A_{DC}	24V Inrush Current (1) A
2198-H008-ERS*x*	4	0.4 x 4 = 1.6	2.4 x 4 = 9.6	2 x 4 = 8
2198-H040-ERS*x*	2	0.8 x 2 = 1.6	2.8 x 2 = 5.6	3 x 2 = 6
2198-CAPMOD-1300	1	0.3 x 1 = 0.3	N/A	2 x 1 = 2
Total current demand		3.5	15.2	16

(1) Inrush current duration is less than 30 ms.

Loss of Control Power

If 24V DC control power (also called logic power) is removed from the drive, the holding brake engages when the drive faults. If power to the brake is removed, the brake also engages. In some cases it is vital for control power to be maintained to keep the drive communicating with the controller and other devices. An alternative power source for logic power and/or brake power can be an uninterruptable power supply (UPS). In the case where the current draw (and therefore kVA size) for the drives and the holding brakes becomes prohibitive from a cost standpoint, consider using an alternate 24V DC power supply for logic power and the UPS for the brakes. In this case, the brakes engage when the drive faults. To determine the size required for the UPS, you can use the example on page 7 as a reference to obtain the current requirements for the drive and/or brakes, depending on how the UPS is used (logic power only, brakes only, or both). An alternative to the traditional AC powered UPS (Bulletin 1609, for example) is shown below. When using the 1606-XLS240-UPS module, a 24V DC supply is already present. The UPS module provides a means to receive 24V DC from this power supply and maintain power through a power loss condition using a 12V DC battery. The battery (up to 40 Ah) is used during power loss and generates 24V DC output (through the UPS module) that can power the logic supply or just the holding brakes.

Block Diagram Showing a Typical 1606 UPS Module as a UPS Function



Because there is a known lifespan limitation with commercially available UPS devices, any UPS device will require regular maintenance. An alternative to the UPS device is a capacitor bank, however, that adds significant engineering effort and a device that is not easily replaced. We recommend that you use the UPS device instead of a custom engineered solution.

Holding Brake Specifications

Motor brake specifications for all Allen-Bradley® motor families appear in the Kinetix Rotary Motion Specifications Technical Data, publication KNX-TD001. Several of the tables are also shown here for your convenience. If any discrepancies exist between the technical data and this publication, publication KNX-TD001 takes precedence.

When using the Kinetix drive internal brake circuit for MP-Series (Bulletin MPL) motors, use the MOV sub-column (under the Brake Response Time column) for the relevant engage time. If using an external relay circuit with a diode as transient suppression, use the Diode sub-column.

MP-Series Low Inertia Motor Brake Specifications

Motor Cat. No.	Backlash, max (brake engaged) arc minutes	Holding Torque N•m (lb•in)	Coil Current at 24V DC A	Brake Response Time			Brake Rotor Inertia kg-m^2 (lb•in•s^2)	Brake Motor Weight, approx kg (lb)
				Release ms	Engage (by using external arc suppression device)			
					MOV ms	**Diode** ms		
MPL-A/B1510V	0	0.9 (8.0)	0.43…0.53	23	9	18	0.0000099 (0.000088)	1.2 (2.6)
MPL-A/B1520U							0.000015 (0.00013)	1.4 (3.1)
MPL-A/B1530U							0.000026 (0.00023)	1.8 (3.9)
MPL-A/B210V		4.5 (40)	0.46…0.56	58	20	42	0.000033 (0.00029)	1.8 (4.0)
MPL-A/B220T							0.000057 (0.00050)	2.4 (5.4)
MPL-A/B230P							0.000082 (0.00073)	3.0 (6.7)
MPL-A/B310	45	4.18 (37)	0.45…0.55	50	20	110	0.000057 (0.00050)	3.7 (8)
MPL-A/B320							0.000092 (0.00081)	4.6 (10)
MPL-A/B330							0.00013 (0.0011)	5.6 (12.4)
MPL-A/B420	37	10.2 (90)	0.576…0.704	110	25	160	0.00030 (0.0027)	6.0 (13.2)
MPL-A/B430							0.00042 (0.0038)	7.3 (16)
MPL-A/B4530							0.00044 (0.0039)	9.1 (20)
MPL-A/B4540							0.00056 (0.0050)	11.0 (24)
MPL-A/B4560							0.00084 (0.0072)	15.1 (33.2)
MPL-A/B520	25	28.3 (250)	1.05…1.28	70	50	250	0.000897 (0.0079)	12.38 (27.25)
MPL-A/B540							0.00157 (0.0139)	17.6 (38.75)
MPL-A/B560							0.00227 (0.020)	22.8 (50.1)
MPL-B580							0.0030 (0.026)	29.0 (63.8)
MPL-B640	25	70.0 (619)	1.91…2.19	200	120	900	0.00438 (0.03863)	37.27 (82.0)
MPL-B660							0.00628 (0.0555)	42.95 (94.5)
MPL-B680							0.0079 (0.0698)	50.8 (112.0)
MPL-B860		106.0 (938)	2.05…2.50	250	200	1000	0.0177 (0.1570)	72.7 (160)
MPL-B880							0.0232 (0.205)	87.7 (193)
MPL-B960		153.0 (1350)	3.85…4.70	300	200	1200	0.0290 (0.256)	89.5 (197)
MPL-B980							0.0378 (0.334)	116.5 (256)

When using the Kinetix drive internal brake circuit for MP-Series (Bulletin MPM) motors, use the MOV sub-column (under Brake Response Time column) for the relevant engage time. If using an external relay circuit with a diode as transient suppression, use the Diode sub-column.

MP-Series Medium Inertia Motor Brake Specifications

Motor Cat. No.	Backlash, max (brake engaged) arc minutes	Holding Torque N•m (lb•in)	Coil Current at 24V DC A	Brake Response Time			Brake Rotor Inertia kg-m^2 (lb•in•s^2)	Brake Motor Weight, approx kg (lb)
				Release ms	Engage (by using external arc suppression device)			
					MOV ms	Diode ms		
MPM-A/B1151	45	4.18 (37)	0.45…0.55	50	20	110	0.00065 (0.00575)	5.2 (11.4)
MPM-A/B1152							0.00077 (0.00681)	6.9 (15.2)
MPM-A/B1153							0.00089 (0.00788)	8.1 (17.8)
MPM-A/B1302	48	10.2 (90)	0.576…0.704	110	25	160	0.000983 (0.00870)	8.6 (19.0)
MPM-A/B1304							0.001223 (0.01082)	11.7 (25.7)
MPM-A/B1651	25	28.3 (250)	1.05…1.28	70	50	250	0.006605 (0.05846)	17.9 (39.5)
MPM-A/B1652							0.007265 (0.06430)	23.2 (51.1)
MPM-A/B1653							0.008025 (0.07103)	28.2 (62.1)
MPM-A/B2152	25	70 (619)	1.84…2.25	200	120	900	0.02059 (0.18224)	43.8 (96.5)
MPM-A/B2153							0.02254 (0.19949)	53.6 (115.8)
MPM-A/B2154							0.02449 (0.21675)	61.6 (135.7)

Kinetix VP Continuous Duty Motor Brake Specifications

Motor Cat. No.	Backlash, max (brake engaged) arc minutes	Holding Torque N•m (lb•in)	Coil Current at 24V DC A	Brake Response Time		Brake Rotor Inertia kg-m^2 (lb•in•s^2)	Brake Motor Weight, approx kg (lb)
				Release ms	Engage (1) ms		
VPC-B1652	30	35.0 (310)	1.01…1.70	50	200	0.00299 (0.026)	23.3 (51.4)
VPC-B1653						0.00421 (0.037)	28.9 (63.7)
VPC-B1654						0.00543 (0.048)	34.3 (75.7)
VPC-B2153		72 (637)	1.73…3.00	200	300	0.0108 (0.09)	52.7 (116.1)
VPC-B2154						0.0141 (0.12)	60.7 (133.7)
VPC-B2155						0.0174 (0.15)	69.8 (153.8)
VPC-B2156						0.0205 (0.18)	77.7 (171.3)
VPC-B3002		200 (1770)	2.35…3.90	300	1000	0.0290 (0.25)	102.9 (226.8)
VPC-B3003						0.0412 (0.36)	117.1 (258.1)
VPC-B3004						0.0539 (0.47)	138.1 (304.5)

(1) By using diode and zener diode as arc suppression device in external control circuit.

Kinetix VP Low Inertia Motor Brake Specifications

Motor Cat. No.	Backlash, max (brake engaged) arc minutes	Holding Torque N•m (lb•in)	Coil Current at 24V DC A	Brake Response Time		Brake Rotor Inertia kg-m^2 (lb•in•s^2)	Brake Motor Weight, approx kg (lb)
				Release ms	Engage (1) ms		
VPL-A/B0631	30	1.50 (13)	0.297…0.363	38	25	0.0000118 (0.00010)	1.36 (3.0)
VPL-A/B0632						0.0000194 (0.00017)	1.70 (3.74)
VPL-A/B0633						0.0000271 (0.00024)	2.02 (4.45)
VPL-A/B0751		3.0 (27)	0.567…0.693	66	42	0.0000182 (0.00016)	2.06 (4.54)
VPL-A/B0752						0.0000297 (0.00026)	2.62 (5.77)
VPL-A/B0753						0.0000412 (0.00036)	3.18 (7.0)
VPL-A/B1001	30	4.18 (37)	0.45…0.55	90	65	0.000059 (0.00052)	3.26 (7.19)
VPL-A/B1002						0.000093 (0.00082)	4.20 (9.24)
VPL-A/B1003						0.000135(0.0012)	5.08 (11.19)
VPL-A/B1152		6.55 (58)	0.621…0.759	90	95	0.000289 (0.0025)	5.30 (11.67)
VPL-A/B1153						0.000409 (0.0036)	6.88 (15.15)
VPL-A/B1303		14.10 (125)	0.738…0.902	125	120	0.000433 (0.0038)	8.64 (19.03)
VPL-A/B1304						0.000553 (0.0049)	10.21 (22.48)
VPL-A/B1306						0.000813 (0.0072)	13.32 (29.33)
VPL-B1651		32.0 (283)	1.053…1.287	140	120	0.000845 (0.0075)	17.15 (37.78)
VPL-B1652						0.00153 (0.013)	19.65 (43.32)
VPL-B1653						0.00219 (0.019)	22.51 (49.58)
VPL-B1654						0.00295 (0.026)	27.50 (60.63)

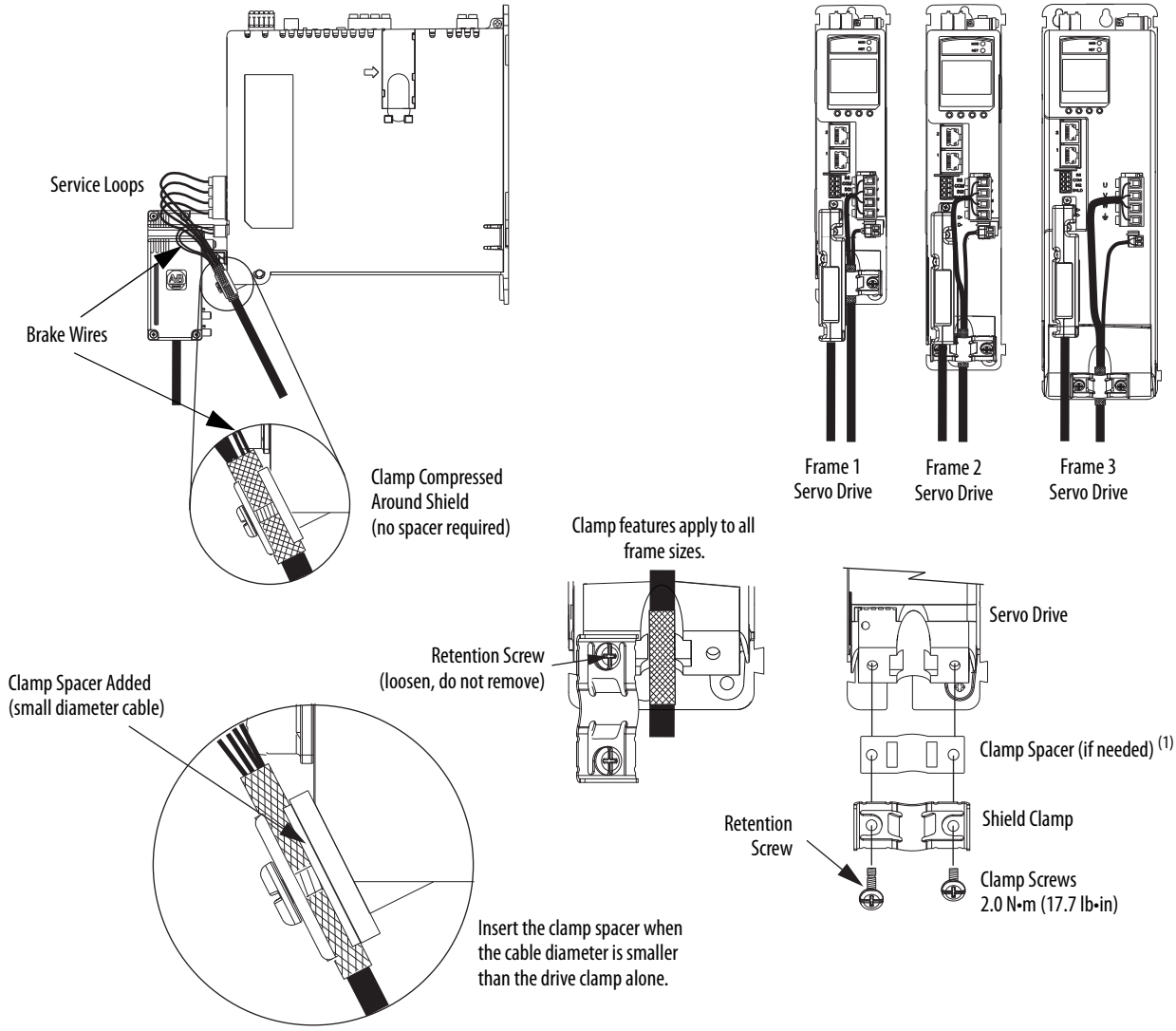
(1) By using diode and zener diode as arc suppression device in external control circuit.

Wire the Holding Brake

The Allen-Bradley Bulletin 2090 power/brake cable includes two flying-lead motor brake conductors that attach to the motor brake connector (MBRK+ and MBRK–) on the drive end and a premolded connector to the motor. Refer to your Kinetix drive user manual for information on how to shield, connect, route, and ground the brake connections. Because the brake relay is a potential source of noise, it is important to follow the individual drive procedure to reduce noise and avoid improper brake operation.

Refer to Additional Resources on page 58 for the user manual of your Kinetix drive and the proper connection drawing.

Kinetix 5500 Cable Clamp Attachment



(1) This clamp spacer applies to only Kinetix 5500 drives and is included with the Hiperface-to-DSL feedback converter kit, catalog number 2198-H2DCK.

Vertical Axis Application Guidelines

This section provides guidance on how to avoid a falling vertical load by configuring the axis for use in a vertical application. The topics in this section are summarized as part of Vertical Axis Quick Reference/Checklist on page 48. When you have a good understanding of these concepts and best practices, use the checklist to make sure you've applied all them all in your vertical axis application.

Automatic Brake Control Configuration

The servo-motor holding brake is engaged automatically on certain trigger conditions. It is also possible to manually trigger the holding brake to perform maintenance on the axis and/or machine. There are common parameters to configure for each axis that uses the holding brake. All of the brake operation settings that are described in this section are configured in the Studio 5000 Logix Designer® application. See Actions Configured in the Logix Designer Application on page 17, for more information on Stop Categories.

For each one of the automatic brake actuation triggers, there are common parameters that can be used. Their use depends on the trigger condition. They are described here and the timing diagrams on page 19, page 20, and page 21 show you when these common parameters are used.

IMPORTANT The Axis Properties of a Kinetix drive in the Studio 5000 Logix Designer application can control automatic brake-output actuation. Do not use any contacts in series with the holding brake circuit (with the exception of the optional external relay shown on page 6). Contacts in series could bypass the automatic operation of the brake circuit and prevent the brake from operating correctly.

Stopping Torque

When disabling or aborting an axis, the stopping torque value determines the maximum amount of torque that is used to stop the motor when the relevant action is invoked. This is set either via Axis Properties>Parameter List or via an SSV instruction. The stopping torque value must not exceed the torque limit set for the axis. When setting this value, consider the mechanics maximum torque value and do not exceed it. Stopping torque is used as part of the Stop Category 1 or Stop Category 2 sequence.

IMPORTANT The Stopping Torque parameter is not used for Stop Category 0 (Disable & Coast) or Safe Torque Off (STO).

Usage	Access	Data Type	Default	Minimum Value	Maximum Value	Semantics of Values
Required - C	SSV	REAL	100 FD	0	10^3 FD	% Motor Rated

Stopping Time Limit

When disabling or aborting an axis, the stopping time limit value determines the maximum amount of time that the drive has to reach zero speed. The resulting action from setting the Stopping Time Limit parameter depends on the trigger condition. This is set either via the Axis Properties>Parameter List or via an SSV instruction.

IMPORTANT The Stopping Time Limit parameter is not used for Stop Category 0 (Disable & Coast) or Safe Torque Off (STO).

Usage	Access	Data Type	Default	Minimum Value	Maximum Value	Semantics of Values
Optional - D	SSV	REAL	1 FD	0	10^3 FD	Seconds

Stopping Time Limit is used as part of the Stop Category 1 or Stop Category 2 sequence. Action taken by the drive, once the time limit is reached, depends on the Stop category. For a Stop Category 1, the drive continues to apply holding torque while engaging the brake. For a Stop Category 2, the drive continues to apply holding torque, but does not engage the brake. See Mechanical Brake Engage Delay for details on the disable sequence.

You can apply Stopping Torque to bring the motor to a successful stop before the device is disabled and all current is removed from the motor.

Mechanical Brake Engage Delay

The Mechanical Brake Engage Delay parameter is the amount of time that the drive's power structure remains enabled after the axis has been commanded to zero speed before disabling the power structure. The motor decelerates to a stop, the brake output actuates, and this delay provides time for the brake to engage. See the timing diagrams, beginning on page 19, for clarification on when this delay time is used. The time to engage the holding brake is given in Holding Brake Specifications beginning on page 8, depending on the type of motor. Use this time as a minimum time value in the Logix Designer application Axis Properties.

IMPORTANT The Mechanical Brake Engage Delay parameter is not used for Stop Category 0 (Disable & Coast) or Safe Torque Off (STO).

Usage	Access	Data Type	Default	Minimum Value	Maximum Value	Semantics of Values
Optional - D	SSV	REAL	0	0	10^3	Seconds

If supported, a brake proving operation is included in the Stop Category 1 sequence prior to disabling the power structure.

Mechanical Brake Release Delay

The Mechanical Brake Release Delay parameter is the amount of time after the drive is enabled but before the drive is able to follow a command. During this delay, no commanded motion is permitted as the drive is physically releasing the holding brake. See the timing diagrams, beginning on page 19, for clarification of when this delay time is used. The estimated time to release the holding brake is given in Holding Brake Specifications beginning on page 8, depending on the type of motor. Use this time as a minimum time value in the Logix Designer application Axis Properties.

Usage	Access	Data Type	Default	Minimum Value	Maximum Value	Semantics of Values
Optional - D	SSV	REAL	0	0	10^3	Seconds

If supported, a torque proving operation is included in this sequence prior to releasing the brake.

Coasting Time Limit

The Coasting Time Limit parameter is the amount of time before the brake engages on a Stop Category 0 (Disable & Coast) condition. See the timing diagrams, beginning on page 19, for clarification of when this delay time is used. This parameter applies to only Kinetix 5500 and Kinetix 5700 drive families.

In the Studio 5000 Logix Designer application, version 26 and earlier, Coasting Time Limit is not available. Stopping Time Limit was used with a Stop Category 0 (Disable & Coast) in a similar manner as Coasting Time Limit (the exception was that Safe Torque Off did not use Stopping Time Limit in this condition).

IMPORTANT The Coasting Time Limit parameter is used for only Stop Category 0 (Disable & Coast) or Safe Torque Off (STO).

IMPORTANT The Coasting Time Limit parameter is not used in a vertical application. Set this delay parameter to 0.

The Coasting Time Limit parameter is useful in horizontal applications where:

- There can be a hard limit of time that needs to be observed before the holding brake **must** be engaged. The actual amount of time that it takes for a load to reach zero speed can be large depending on the load and its inertia. Coasting Time Limit provides some flexibility for determining when to engage the holding brake. Repeated use in a horizontal application, without this delay, can damage the brake.
- A Safe Torque Off (STO) is initiated, its Stopping mode is Disable & Coast, and the coasting time delay provides for a time delay, after the STO request, so that the axis can come to a complete stop before the holding brake is engaged.

Usage	Access	Data Type	Default	Minimum Value	Maximum Value	Semantics of Values
Optional - D	SSV	REAL	0	0	10^3	Seconds

Zero Speed

This parameter applies to Kinetix 5500 and Kinetix 5700 drives. The Zero Speed parameter is available with the Logix Designer application, version 26 and later, and lets you manually set the zero-speed condition that is used by the Logix Designer application to indicate the motor is at zero speed. This value is used to determine when the holding brake is applied in Stop Category 0 and Stop Category 1 and is a percentage of the motor rated speed. Once the motor speed is less than the zero speed value, a timer starts timing (Zero Speed Time) which, upon expiring, is meant to indicate a true zero-speed condition of the motor.

If this value is not supported by your drive or your Logix Designer application, the drive uses a motor Zero Speed that is generally 1% of motor rated speed.

Usage	Access	Data Type	Default	Minimum Value	Maximum Value	Semantics of Values
Optional - D	SSV	REAL	0	0	∞	% Motor Rated

ATTENTION: Be extremely cautious when setting the Zero Speed parameter. It is a critical setting that determines when the holding brake is applied. If this value is set incorrectly, the brake can engage prematurely and damage the motor.

Axis speed in the above description is based on the velocity feedback signal, or in the case of Frequency Control drives, axis speed is based on the velocity reference signal.

Zero Speed Time

The Zero Speed Time parameter is available with the Logix Designer application, version 26 and later, and represents the amount of time that the motor needs to remain below Zero Speed threshold to indicate a true Zero Speed condition. This parameter is used with Category 0 and Category 1 stops in conjunction with the Zero Speed parameter.

IMPORTANT Be extremely cautious when setting the Zero Speed Time parameter. It is a critical setting that determines when the holding brake is applied. If this value is set incorrectly, the brake can engage prematurely and damage the motor.

Usage	Access	Data Type	Default	Minimum Value	Maximum Value	Semantics of Values
Optional - D	SSV	REAL	0	0	10^3	Seconds

If this parameter is not supported, the amount of time needed to satisfy the zero speed criteria is left to the vendor's discretion and is typically immediate (0).

Proving Configuration

This attribute enables the operation of the drive's torque proving and brake proving functions that work together with Mechanical Brake Control. See Torque Prove/Brake Tests on page 51 for more information on how torque and brake proving works.

Usage	Access	Data Type	Default	Minimum Value	Maximum Value	Semantics of Values
Optional - D	SSV	USINT	0	–	–	0 = Disabled 1 = Enabled 2…255: Reserved

Vertical Load Control

With this value, the drive specifies motor control behavior for vertical load applications. When Enabled is selected, the drive attempts, whenever possible, to avoid applying Category 0 stop actions in response to Major Fault conditions. The drive can specify other aspects of its behavior to best handle vertical loads. See Vertical Load Control Feature on page 49 for additional information on this setting

Usage	Access	Data Type	Default	Minimum Value	Maximum Value	Semantics of Values
Optional - FPV	GSV/SSV	USINT	0	–	–	0 = Disabled 1 = Enabled 2…255: Reserved

Actions Configured in the Logix Designer Application

The topics in this section are summarized as part of Vertical Axis Quick Reference/Checklist on page 48. When you have a good understanding of these concepts and best practices, use the checklist to make sure you've applied all them all in your vertical axis application.

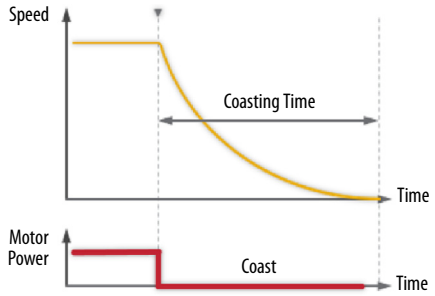
With Kinetix integrated motion on EtherNet/IP drives the drive attempts to use the settings in Axis Properties>Actions category of the Logix Designer application to control the behavior of the drive. Stopping categories are relevant to horizontal and vertical axes with or without holding brakes. The different conditions that are applicable to the holding brake, stopping category, and vertical axis are described in Triggers for Automatic Brake Control (non Exception) on page 22 and Triggers for Automatic Brake Control (Exception) on page 25.

Stopping Categories for Vertical Applications

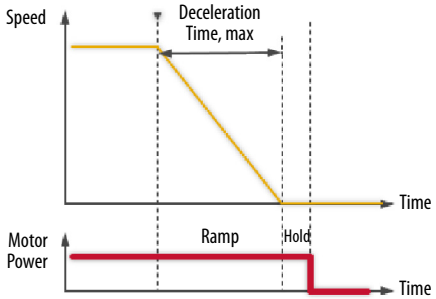
Stop Category Type (1)	Stopping Action Type (Kinetix definition)	Description of Operation
Stop Category 0	Disable & Coast	Drive immediately disables the inverter power structure.
Stop Category 1	Current Decel & Disable	Motor is decelerated (trigger condition determines the rate of deceleration) to zero speed and power structure is disabled.
Stop Category 2	Current Decel & Hold	Motor is decelerated (trigger condition determines the rate of deceleration) to zero speed and power structure remains enabled.

(1) The stopping actions that are applicable to a vertical axis align with IEC-60204-1 stop categories.

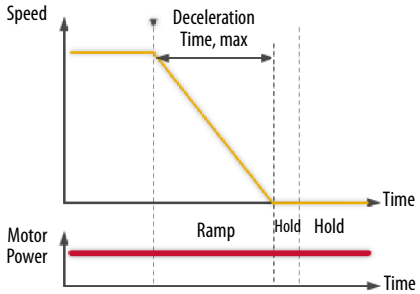
Stop Category 0



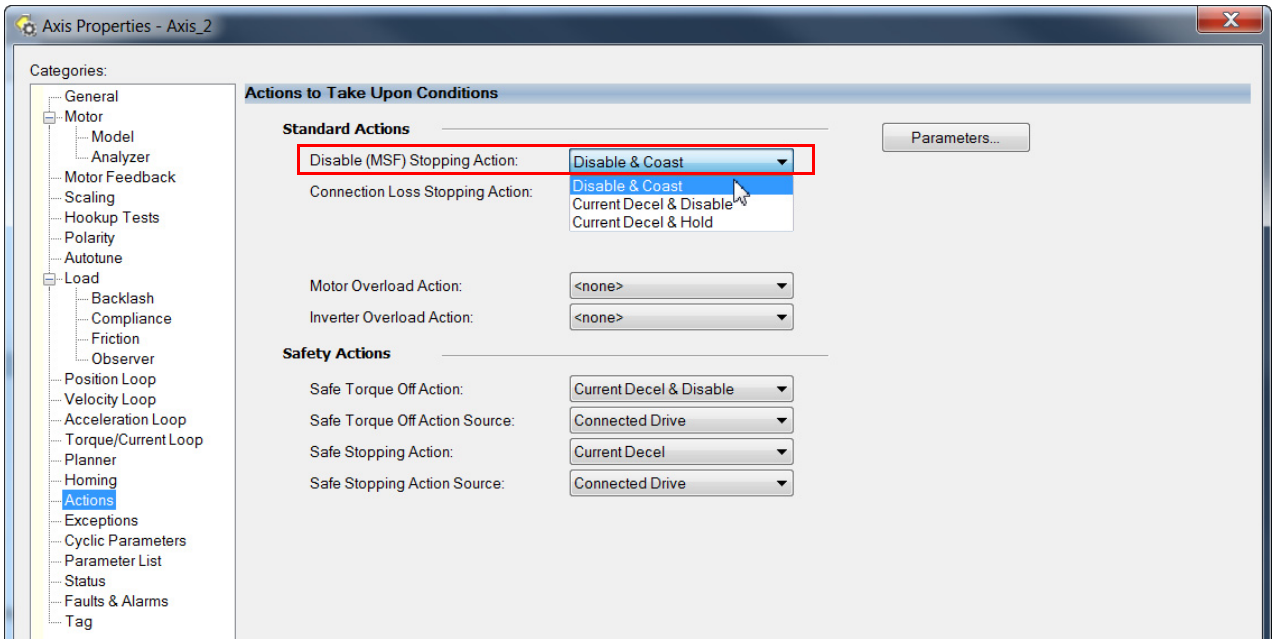
Stop Category 1



Stop Category 2



Axis Properties>Actions Category (Disable & Coast)



TIP Studio 5000 Logix Designer, version 32 and later, has separate categories for Actions and Exceptions. With Logix Designer, version 31 and earlier, Exceptions are part of the Actions category.

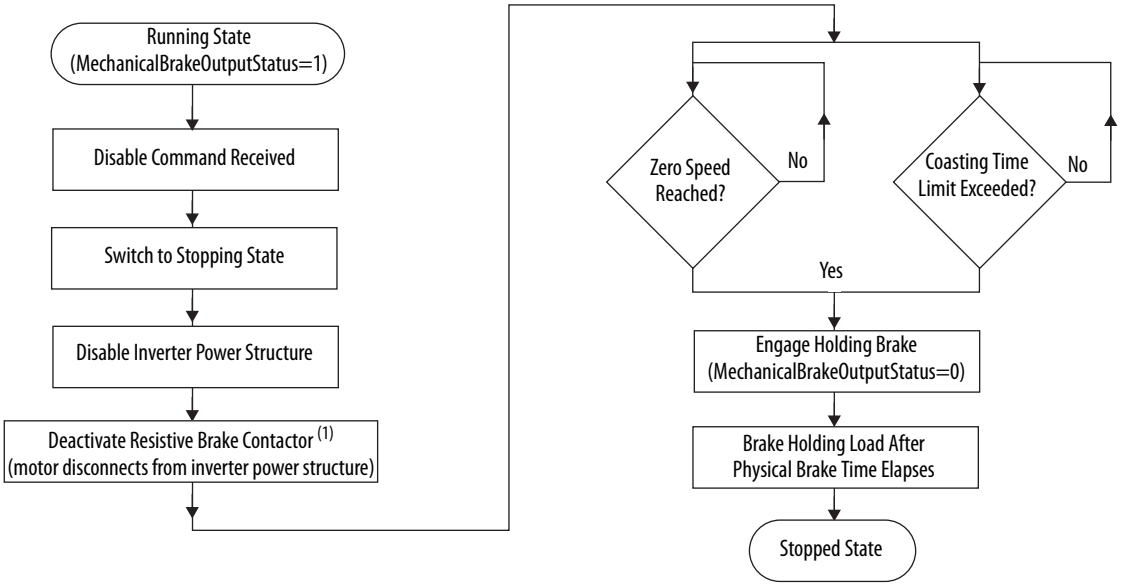
IMPORTANT The Kinetix 5500, Kinetix 5700, and Kinetix 6500 drive firmware overrides the Stopping Action set in the Actions and Exceptions list to protect the drive in case of failure or predictive failure. The use of these Exceptions by the drive are described Triggers for Automatic Brake Control (Exception) on page 25.

IMPORTANT Kinetix 5700 drives (catalog numbers 2198-*xxxx*-ERS4 and 2198-*xxxx*-ERS3/B, firmware 9.001 or later) have enhancements for vertical load control. Refer to Vertical Load Control Feature on page 49 for more information on these enhancements and to see if they apply to your application.

Stop Category 0 Sequence

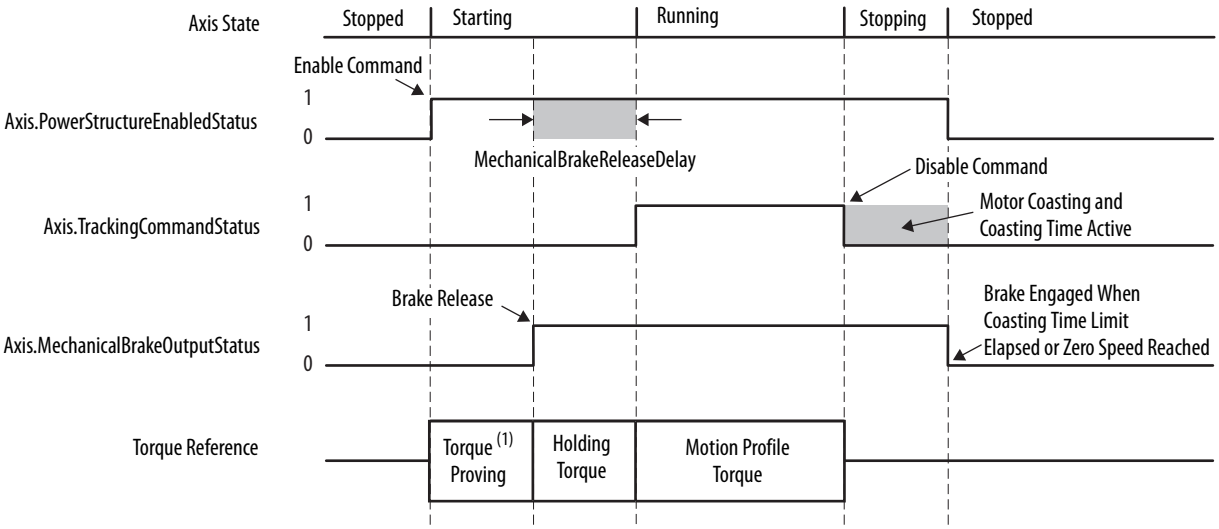
Refer to the Integrated Motion on the EtherNet/IP Network Reference Manual, publication MOTION-RM003, for more information on the Stop Category 0 stop sequence flowchart.

Stop Sequence Flowchart: Stop Category 0 (Disable & Coast)



(1) Resistive brake contactor applies to Kinetix 6500 drives only.

Timing Diagram: Stop Category 0



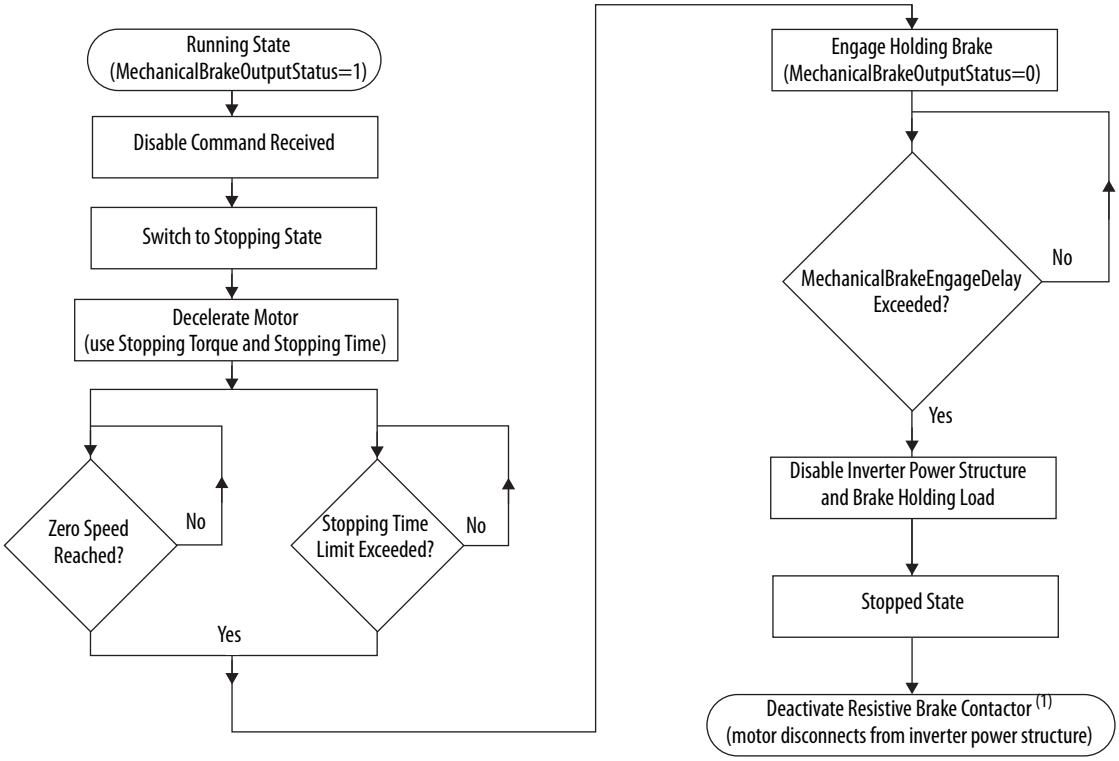
(1) Includes optional brake test.

IMPORTANT In Stop Category 0 (Disable & Coast) or Safe Torque Off demand, if Coasting Time Limit is used, the vertical load drops an amount proportional to the size of Coasting Time Limit and/or zero speed being achieved in the motor. Because a vertical load never encounters zero speed in this condition, Coasting Time Limit is not used in a vertical application. Set this value equal to zero.

Stop Category 1 Sequence

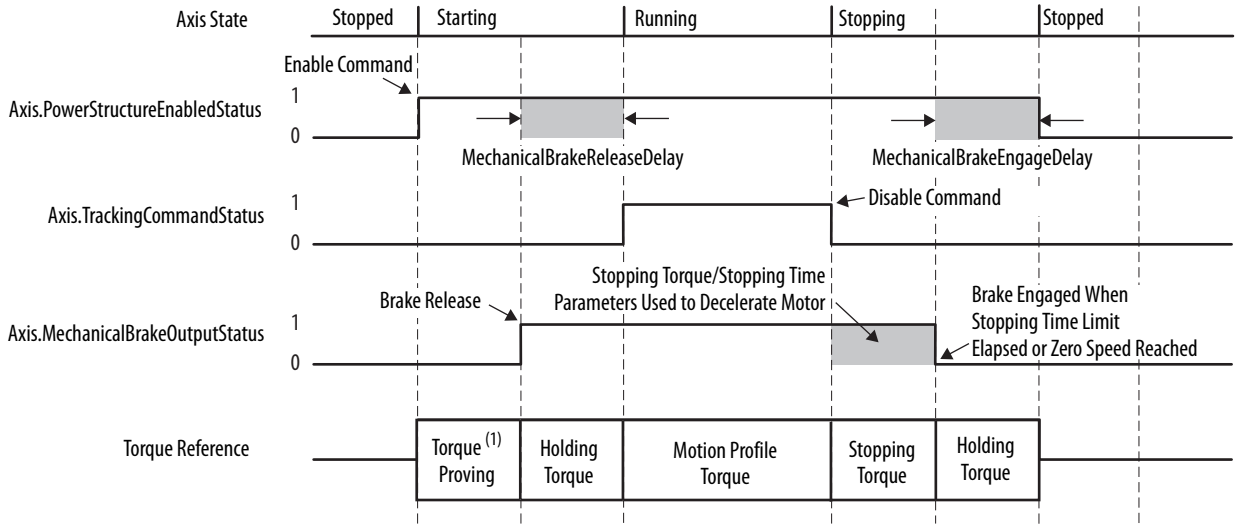
Refer to the Integrated Motion on the EtherNet/IP Network Reference Manual, publication MOTION-RM003, for more information on the Stop Category 1 stop sequence flowchart.

Stop Sequence Flowchart: Stop Category 1 (Current Decel & Disable)



(1) Resistive brake contactor applies to Kinetix 6500 drives only.

Timing Diagram: Stop Category 1



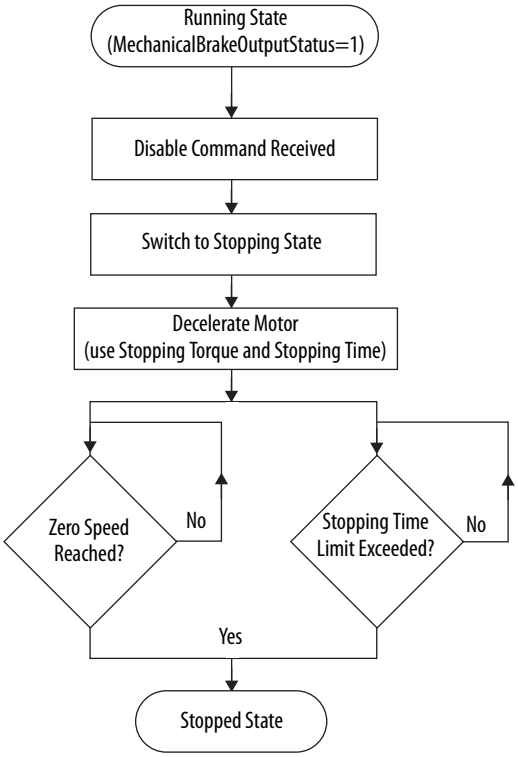
(1) Includes optional brake test.

If the Stopping Torque is small and the motor does not reach zero speed before the Stopping Time expires, the Torque Limit Positive/Negative values are used to drive the motor to zero speed quickly after the Stopping Time expires.

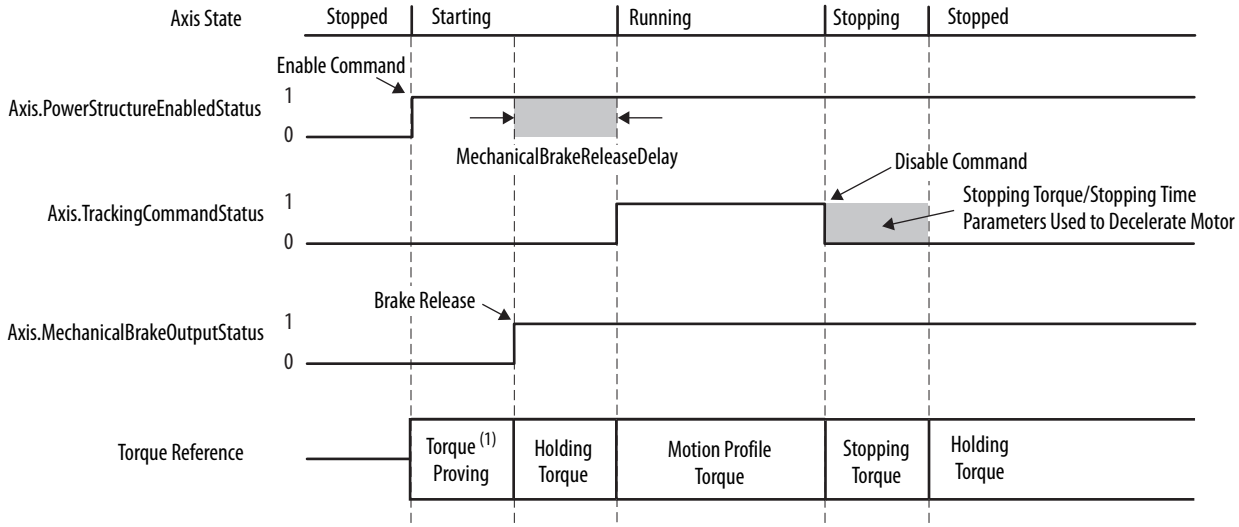
Stop Category 2 Sequence

Refer to the Integrated Motion on the EtherNet/IP Network Reference Manual, publication MOTION-RM003, for more information on the Stop Category 2 stop sequence flowchart.

Stop Sequence Flowchart: Stop Category 2 (Current Decel & Hold)



Timing Diagram: Stop Category 2



(1) Includes optional brake test.

With the Stop Category 2 stopping action, the axis is placed into STOPPED state with power still applied to the drive. After the axis is placed into this STOPPED state, consider that to command motion on this axis, the axis must be 'enabled', which places the axis in RUNNING state.

- If the axis is faulted, issue an MAFR (Fault Reset) command, followed by an MSF and MSO command, to take the axis back to RUNNING state
- If the axis is not faulted, issue an MSF command, followed by an MSO command, to take the axis back to RUNNING state

Depending on the Kinetix drive and the fault severity, the axis status can resume RUNNING or STOPPED state after a fault occurs and is cleared. If the fault is a MAJOR fault (see Triggers for Automatic Brake Control (Exception) on page 25) the fault must be cleared, the axis must be shutdown (MASD), if it's not already in Shutdown state, and reset using an MASR instruction. When the Axis is Shutdown after this Fault condition is active, the MASD (Axis Shutdown) is used to disable the axis and energize the holding brake. An MASR (Axis Shutdown Reset) is used to reset the axis and it is now STOPPED and ready to be enabled (MSO). No brake delays are used with an MASD. If the fault is not a MAJOR fault, the axis is not always able to resume a RUNNING condition when the fault is cleared. When the axis is in RUNNING state, motion can be resumed.

Triggers for Automatic Brake Control (non Exception)

This section explains the triggers for automatic brake actuation when a fault (exception) is not active. The holding brake is actuated with the controller/drive behaviors described in this section.

MSO/MAH/MSF Instructions and Disable (MSF) Stopping Action

You can use MSO (Motion Servo On), MAH (Motion Axis Home-active only) and MSF (Motion Servo Off) instructions to enable and disable a drive, respectively, from the controller logic program or Motion Direct Commands.

The MSO (or active MAH) instruction is part of the Motion Instruction library within the Logix Designer application. Both instructions enable the drive. MSO (or active MAH for homing) use MechanicalBrakeReleaseDelay when releasing the brake. This delay time needs to be defined longer than the mechanical release time of the brake to avoid momentary load drops while enabling the drive. The drive is enabled before the brake is released. For stop sequence flowcharts and timing diagrams refer to page 19.

The MSF instruction impacts vertical applications because it controls the engagement of the holding brake. The Action that the drive takes when encountering an MSF (either in logic or by Motion Direct Commands) follows the selection made in Axis Properties>Actions>Disable (MSF) Stopping Action.

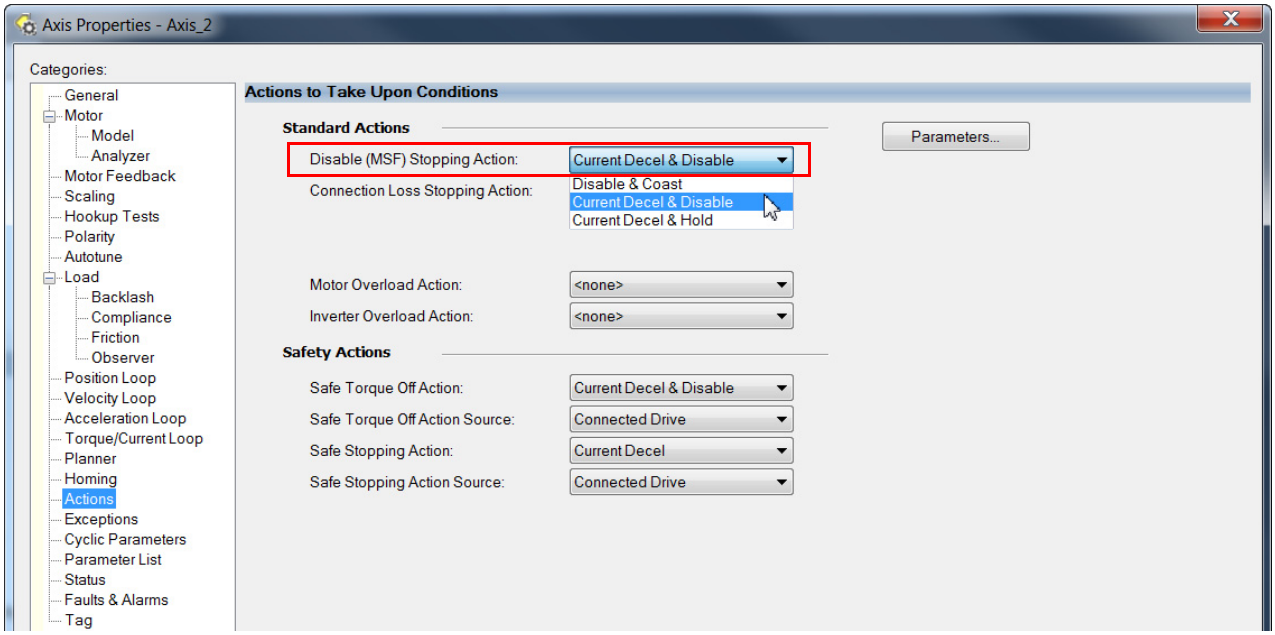
If the Disable (MSF) Stopping Action is not Disable & Coast, Stopping Torque and Stopping Time values are used to decelerate the motor to zero speed.

TIP In the Logix Designer application, version 29 and earlier, Disable (MSF) Stopping Action is named Stopping Action.

IMPORTANT The selection made for Disable (MSF) Stopping Action does not always reflect the actual brake operation if there is an active exception (fault) condition. The actions of the drive are the best available stopping action to provide the most control of the motor and to protect itself. For example, if Current Decel & Disable is used, but the drive exception condition can't tolerate Current Decel & Disable, it uses Disable & Coast. These conditions are described in Triggers for Automatic Brake Control (Exception) on page 25.

IMPORTANT Avoid the Disable & Coast Action where possible for a vertical axis. Current Decel & Disable or Current Decel & Hold are preferred because in these modes the motor decelerates to a stop (zero speed) before the holding brake is applied.

Axis Properties>Actions Category (MSF instruction)

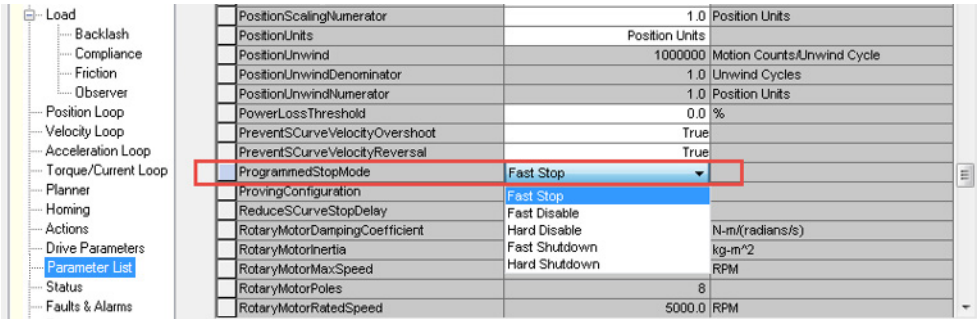


Motion Instruction Library>MSF Instruction

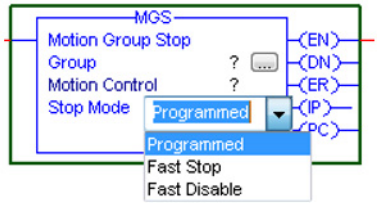
MGS and Controller Mode Change

MGS (Motion Group Stop) instructions are part of the Motion Instruction library within the Logix Designer application and issued from the controller logic program or Motion Direct Command. MGS, when Stop Mode is configured for Programmed, is linked to the ProgrammedStopMode inside Axis Properties>Parameter List category.

Axis Properties>Parameter List Category (ProgrammedStopMode)



Motion Instruction Library>MGS Instruction



The ProgrammedStopMode attribute value determines how a specific axis stops when the Logix 5000™ controller undergoes a critical controller mode change or when an explicit MGS (Motion Group Stop) instruction executes when Stop Mode is set to Programmed.

Controller mode change is when the controller switches from Run mode to Program mode and vice versa. There are currently four modes defined for the Logix 5000 controller (standard controller or GuardLogix® controller): Program Mode, Run Mode, Test Mode, and Faulted Mode. Any mode change into or out of Program mode (prog->run, prog->test, run->prog and test->prog) initiates a programmed stop for every axis owned by that processor. For axes running in Velocity, Torque, or Frequency Control mode (Frequency Control mode is available with only integrated motion on the EtherNet/IP network), if an axis ProgrammedStopMode is set to Fast Stop, when a controller mode change is done, this axis is disabled.

There is a time-out period of 60 seconds applied to the Programmed Stop process, after which the mode change occurs even if motion on one or more axes has not stopped. Each individual axis can have its own ProgrammedStopMode configuration independent of other axes. Five methods of stopping a given axis are currently supported.

The MGS instruction also uses the same 60 second time-out as it also holds off mode change until active messages either complete or time-out. Axes running in Velocity, Torque, or Frequency Control mode, when ProgrammedStopMode is set to Fast Stop, the axis is disabled when a controller mode change occurs.

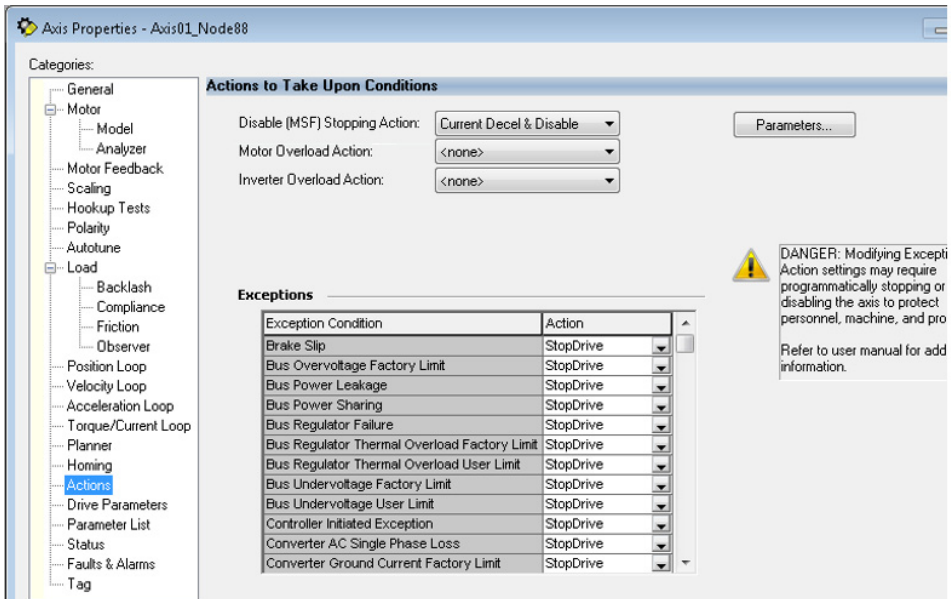
ProgrammedStopMode

ProgrammedStopMode Settings	Description
Fast Stop	When the ProgrammedStopMode attribute is configured for Fast Stop, the axis is decelerated to a stop by using the current configured value for Maximum Deceleration (from the Planner category of Axis Properties). Axis remains enabled after the axis motion has stopped.
Fast Disable	When the ProgrammedStopMode attribute is configured for Fast Disable, the axis is decelerated to a stop by using the value for Maximum Deceleration (in the Planner Category of Axis Properties). Once the motor has decelerated to a stop, the axis is disabled, and the holding brake output is set. MechanicalBrakeEngageDelay is observed in this mode.
Hard Disable	When configured for Hard Disable, the axis uses Stopping Torque to decelerate the motor to a stop. Once the motor has decelerated to a stop, the axis is disabled, and the holding brake output is set. MechanicalBrakeEngageDelay is observed in this mode.
Fast Shutdown	When configured for Fast Shutdown, the axis is decelerated similar to Fast Stop, but once the axis motion is stopped, the axis is placed in the Shutdown state, the axis is disabled, and the holding brake output is set. Recovering from the Shutdown state requires execution of one of the axis or group Shutdown Reset instructions (MASR or MGSR). The MechanicalBrakeEngageDelay is not observed in this mode.
Hard Shutdown	When configured for Hard Shutdown, the axis is immediately placed in the Shutdown state, the axis is disabled, and the holding brake output is set. If the axis was moving, unless the drive is configured to provide some form of dynamic braking, the result is a Disable & Coast stop action (not recommended for vertical axes). The MechanicalBrakeEngageDelay is not observed in this mode. Recovering from the Shutdown state requires execution of one of the axis or group Shutdown Reset instructions (MASR or MGSR).

Triggers for Automatic Brake Control (Exception)

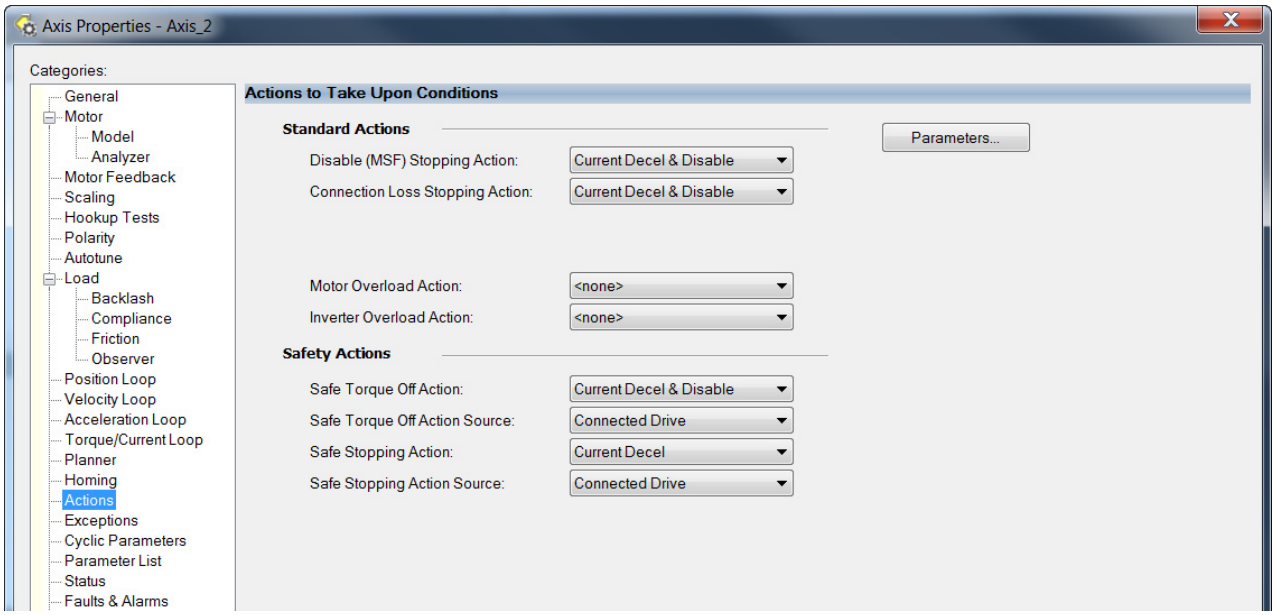
This section explains the triggers for automatic brake actuation when a fault (exception) is active. The programmable exceptions are located in the Actions category of Axis Properties.

Axis Properties>Actions Category (Exception Condition - Logix Designer, version 30 and earlier)



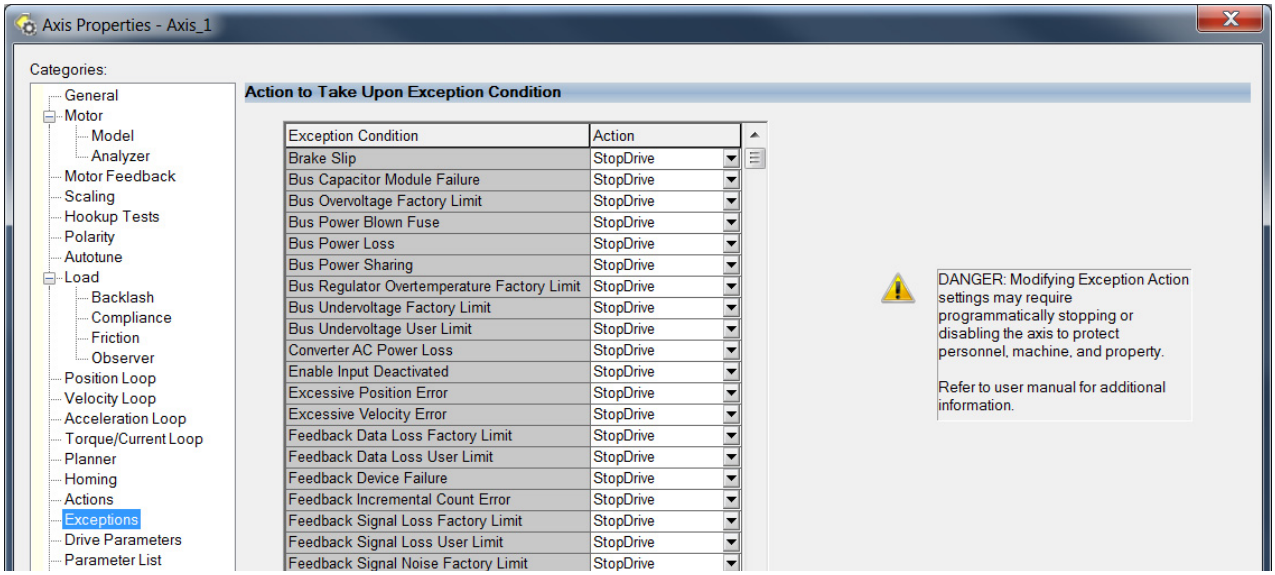
TIP The Actions category in Logix Designer, version 30 and earlier, also includes Exceptions. In Logix Designer, version 31 and later, Actions and Exceptions are separate categories. The Actions available vary depending on the drive being configured. This example applies to Kinetix 5700 drives (catalog numbers 2198-*xxxx*-ERS4 and 2198-*xxxx*-ERS3/B) firmware 9.001 or later.

Axis Properties>Actions Category (Logix Designer, version 31 and later)



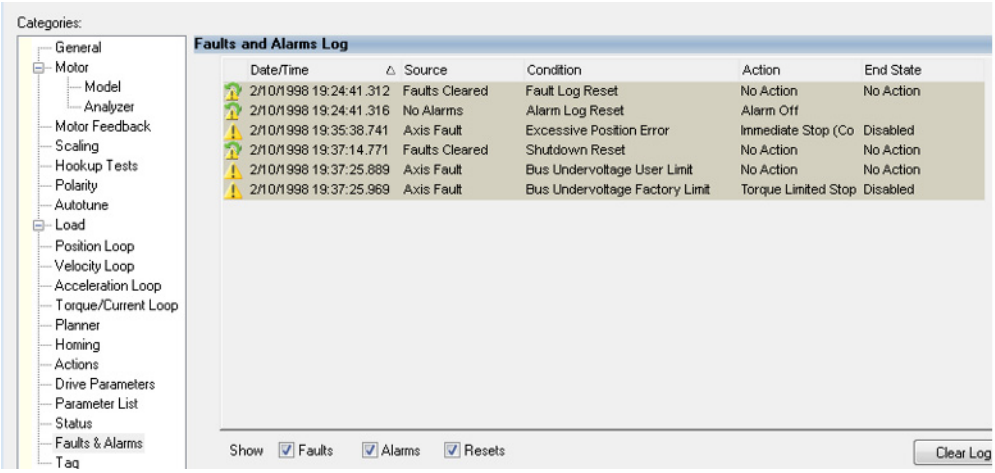
Exception attributes define the conditions under which a corresponding exception action is generated during axis operation that has the potential of generating either a fault or alarm. They are typically associated with temperature, current, and voltage conditions of the device that are continuous in nature.

Axis Properties>Exceptions Category (Logix Designer, version 31 and later)



It is important to determine the sequence of events (what fault occurs when) when considering faults, and how that fault was programmed inside the Actions category. This helps understand what type of action the brake will use. Use a trend in the Logix Designer application to determine the timing of the fault/exception condition. As an alternative, the Axis Properties>Faults & Alarms category shows the last fault (this is the active fault), its time stamp, and the Action taken. Kinetix integrated motion on EtherNet/IP drives support web-page based fault logs. These fault logs are used in the case where communication loss causes the Logix Designer application Alarm Log not to register a fault.

Axis Properties>Faults & Alarms Log



Kinetix drives are designed to provide the best available stopping action to provide the most control of the motor and protection of itself. Because of this, not every drive supports every stopping action. Additionally, you can change the behavior of the trigger condition (exception condition) to fit your application.

Factory Limits (FL) for exceptions are firmware settings in the drive, not configurable, and typically result in a major fault condition. User Limits (UL) for exceptions are configurable and are typically used to generate a minor fault or alarm condition. For this reason, the user limits are generally set inside (or within) the corresponding factory limits. The triggering of a user limit exception does not preclude triggering of the corresponding factory limit exception; the two exception trigger conditions are totally independent of one another.

Drive Exception Conditions

Kinetix drives support exception conditions for these actions. These are drive-level exceptions that are used to better define the resulting fault and how it is acted upon when triggered.

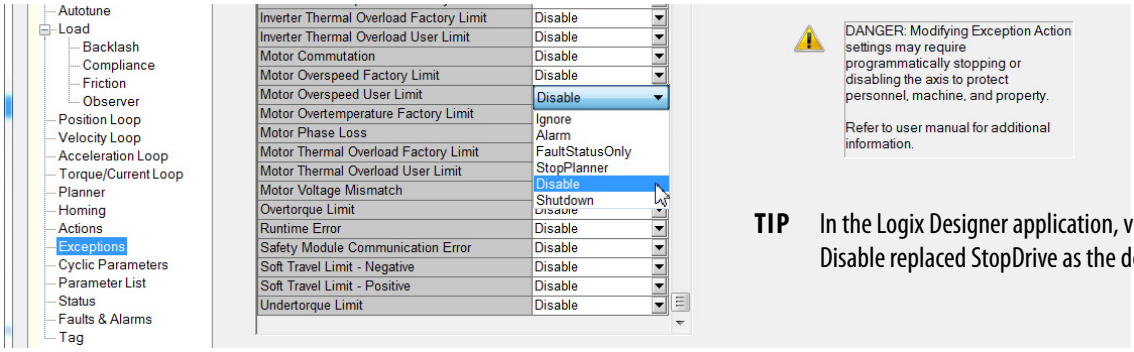
Drive Exception Action Definitions

Exception Action	Drive Exception Condition Definition
Ignore	The drive completely ignores the exception condition. However, for some exceptions that are fundamental to the operation of the planner, Ignore is not an available option.
Alarm	The drive sets the associated bit in the Motion Alarm Status word, but does not otherwise affect axis behavior. Like Ignore, if the exception is so fundamental to the drive, Alarm is not an available option. When an exception action is set to Alarm, the Alarm goes away by itself when the exception condition has cleared.
Minor Fault	The drive latches the exception condition but the drive does not execute any exception action.
Major Fault	The drive latches the exception condition and executes the configured exception action.

Logix Designer Exception Conditions

These exception actions are configured in the Logix Designer application under the Axis Properties>Actions category. The Logix Designer exceptions are mapped to the drive exceptions shown in the table above.

Location of the Logix Exception Conditions



TIP In the Logix Designer application, version 32 and later, Disable replaced StopDrive as the default Action.

Controller Exception Action Definitions

Exception Action	Logix Designer Exception Condition Definition
Ignore	The controller completely ignores the exception condition. However, for some exceptions that are fundamental to the operation of the planner, Ignore is not an available option.
Alarm	The controller sets the associated bit in the Motion Alarm Status word, but does not otherwise affect axis behavior. Like Ignore, if the exception is so fundamental to the drive, Alarm is not an available option. When an exception action is set to Alarm, the Alarm goes away by itself when the exceptional condition has cleared.
FaultStatusOnly	Like Alarm, Fault Status Only instructs the controller to set the associated bit in the Motion Fault Status word, but does not otherwise affect axis behavior. However, unlike Alarm an explicit Fault Reset is required to clear the fault once the exceptional condition has cleared. Like Ignore and Alarm, if the exception is so fundamental to the drive, Fault Status Only is not an available option
StopPlanner	The controller sets the associated bit in the Motion Fault Status word and instructs the Motion Planner to perform a controlled stop of all planned motion at the configured maximum deceleration rate. An explicit Fault Reset is required to clear the fault once the exception condition has cleared. If the exception is so fundamental to the drive, Stop Planner is not an available option
StopDrive (v31 and earlier) Disable (v32 and later)	When the exception occurs, the associated bit in the Fault Status word is set and the axis comes to a stop by using the stopping action defined by the drive for the particular exception that occurred. The stopping method comes from the drive firmware that is shown in the drive behavior troubleshooting tables in the drive user manual. **IMPORTANT:** The drive overrides the MSF stopping action with the value shown inside the drive exception table.
Shutdown	When the exception occurs, the drive immediately disables the motor by using the Disable & Coast (Cat 0) stopping action. An explicit Shutdown Reset is required to restore the drive to operation.

Network Cable Removal/Loss

Network Cable Removal/Loss is the removal or loss of the network connection from the drive to the controller or a delay in communication between the drive and controller that exceeds four packets of information.

Communication loss is one of the most severe faults that can occur because the drive is no longer receiving data from the controller and the drive must Shutdown. In the Kinetix 5500, Kinetix 5700, and Kinetix 350 drives, the communication loss causes the drive to use the Disable & Coast stopping action with the exception that Coasting Time Limit is not used (as in other Category 0 - Disable & Coast stopping). The holding brake is applied immediately upon acknowledging the exception/fault. For example, Node FLT - Late CTRL Update, (for Kinetix 5500 drives) the holding brake can be applied even if the axis is moving.

The Kinetix 6500 drive removal/loss of connection - NodeFLT LOST CTRL CONN, uses a Stop Category 1 stopping action (Current Decel & Disable). However, other NodeFLT faults can use Stop Category 0 stopping actions. Refer to the Kinetix 6200 and Kinetix 6500 Modular Multi-axis Servo Drives User Manual, publication 2094-UM002, for more information on fault handling.

IMPORTANT Avoid the Network loss condition for a vertical (or horizontal) load. Investigate the cabling and network switch (or switches) to resolve the problem. Cables and the network switch are typical sources for network related issues.

IMPORTANT Kinetix 5700 drives (catalog numbers 2198-*xxxx*-ERS4 and 2198-*xxxx*-ERS3/B, firmware 9.001 or later) include programmatic control of Network or Safety Connection Loss, and can use Stop Category 0 or Stop Category 1.

Safety Connection Removal/Loss

Removal or loss of the safety network connection has the same effect as removing the network cable. This can also be viewed as a separate cable connection in the case of a Safety Only controller configuration or when a safety controller is managing the safety connection, but not the motion connection. In this case there can be two cables and connections.

Communication loss is one of the most severe faults that can occur because the drive is no longer receiving data from the controller, and the drive must Shutdown. This communication loss causes the axis to use the Disable & Coast stopping action with the condition that the Coasting Time Limit is not used (as in other Category 0 - Disable & Coast stopping). The holding brake is applied immediately upon acknowledging the exception/fault.

IMPORTANT Avoid the Safety Connection Loss condition for a vertical (or horizontal) load. Investigate the cabling and network switch (or switches) to resolve the problem. Cables and the network switch are typical sources for network related issues.

Safe Torque Off

You can make Safe Torque Off (STO) connections via the dual-channel safety-rated hardwired inputs that come with Kinetix integrated motion on EtherNet/IP drives or controller-based integrated safety over the EtherNet/IP network (Kinetix 5500 and Kinetix 5700 drives). Both forms of STO connections provide the same safety function intended to disable the drive. When using the STO to disable the drive, we prefer to use Stop Category 1 stop type, or Current Decel & Disable which is a controlled stop. For more information on the STO connections, see Safety Related Holding Brake Application on page 32.

Kinetix Drives Exception Behavior Tables

Kinetix integrated motion on EtherNet/IP drive user manuals include drive behavior troubleshooting tables that list the various exception conditions and how they are handled within the drive. An example table from the Kinetix 5500 user manual is shown on page 29. See Additional Resources on page 58 for the user manual of your Kinetix drive to identify the exception settings in your drive that are useful for your vertical application.

IMPORTANT The selected Stopping Action (Disable MSF Stopping Action) does not always reflect the actual brake operation when an exception is active. The behavior that the drive uses is the best available stopping action to provide the most control of the motor and to protect itself. When Stop Drive is used, and an exception is active, the stopping method comes from the drive firmware that is shown in the drive behavior troubleshooting tables in the drive user manual.

IMPORTANT If the drive behavior table indicates that the Fault Action can be configured as Minor Fault, Ignore, or Alarm, those faults can be set to Fault Status Only, Stop Planner, Alarm, or Ignore in Axis Properties>Actions. These settings are less severe and can be used to handle the fault condition in logic so the drive's action of Disable & Coast is not used. As an example, ExcessPositionError by default generates a Disable & Coast condition if the Actions tab setting is StopDrive or Shutdown. This can be modified to: Stop Planner, Alarm, or Fault Status Only. The fault can be acknowledged in logic and handled accordingly to provide a controlled stop.

Stopping Categories for Vertical Applications

Stop Category Type (1)	Stopping Action Type (Kinetix definition)	Description of Operation
Stop Category 0	Disable & Coast	Drive immediately disables the inverter power structure.
Stop Category 1	Current Decel & Disable	Motor is decelerated (trigger condition determines the rate of deceleration) to zero speed and power structure is disabled.
Stop Category 2	Current Decel & Hold	Motor is decelerated (trigger condition determines the rate of deceleration) to zero speed and power structure remains enabled.

(1) The stopping actions that are applicable to a vertical axis align with IEC-60204-1 stop categories.

In this drive-behavior example table, a few Kinetix 5500 drive exceptions and their stopping action settings are displayed. See Additional Resources on page 58 for the user manual with drive-behavior troubleshooting tables specific to your Motion application.

Drive Behavior, FLT S*xx* Fault Codes

Exception Fault Code	Exception Text	Permanent Magnet Motor	Induction Motor	Fault Action				Best Available Stopping Action (applies to major faults)
				Ignore	Alarm	Minor Fault	Major Fault	
FLT S10 – INV OVERCURRENT	Inverter Overcurrent Fault	X	X	–	–	–	X	Disable/Coast
FLT S11 – INV OVERTEMP FL	Inverter Overtemperature Factory Limit Fault	X	X	–	–	–	X	Disable/Coast
FLT S13 – INV OVERLOAD FL	Inverter Thermal Overload Factory Limit Fault	X	X	–	–	–	X	Disable/Coast
FLT S14 – INV OVERLOAD UL	Inverter Thermal Overload User Limit Fault	X	X	X	X	X	X	Decel/Hold
FLT S23 – AC PHASE LOSS	AC Single Phase Loss Fault	X	X	X	X	X	X	Decel/Disable
FLT S25 – PRECHARGE FAILURE	Pre-charge Failure Fault	X	X	–	–	–	X	Disable/Coast
FLT S30 – BUS OVERLOAD UL	Bus Regulator Thermal Overload User Limit Fault	X	X	X	X	X	X	Decel/Hold

Common Exception Conditions

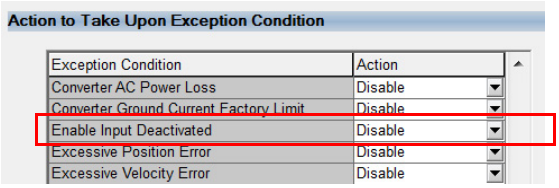
Removing the hardware enable and AC power loss are two common exception conditions.

Hardware Enable Removal

Hardware enable removal is considered an axis exception. The control 24V DC input is used as a means to enable/disable the axis outside of programmatic control. The hardware enable alone is not considered a safety rated input, so its use requires evaluation by a risk assessment on the machine.

TIP The Kinetix 5500 drive does not have a hardware enable input.

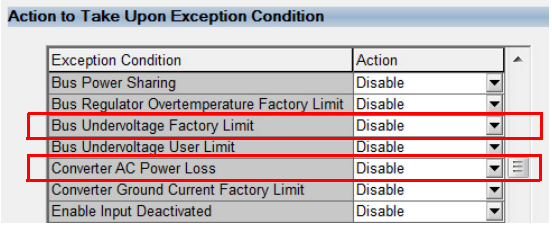
Enable Input Axis Exception



AC Power Loss/Bus Undervoltage (can have different axes handle the exception differently)

A common application of the holding brake is to consider what happens when AC Mains (AC power) is removed. The recommendation in the case of AC power removal is to trend or record the timing of the AC power loss. Timing of the power loss and what result is invoked because of that event occurring is what is critical.

AC and DC-bus Loss Axis Exception



For example, in some systems, a Bus Undervoltage fault can precede the AC Power Loss depending on the application. An alternative to trending is to use the Faults & Alarms category under Axis Properties. The Faults & Alarms category shows the last fault (this is the active fault), its time stamp, and the Action taken. See Axis Properties>Faults & Alarms Log on page 26 for an example.

Coordinate Systems

The Logix Designer application supports the use of coordinate systems. These consist of multiple axes in fixed geometry types that work together. Many of these coordinated systems contain axes that have vertical load constraints much like a non-coordinated vertical axis would. Evaluate your system to determine which axes with holding brakes need to have exception conditions changed from the default StopDrive. The Tasks and Exception Actions table on page 31 examines the action to perform and the impact on a vertical axis. Because coordinated axes need to be stopped in a controlled manner, FaultStatusOnly is a setting that requires evaluation for the application depending on which faults are occurring. FaultStatusOnly is a less severe action and is preferred to use where possible. Application code can be written to handle the fault (exception) condition once the fault is acknowledged in Logic. This prevents damage to the load and possibly the mechanism itself in the event of a fault that uses a Category 0 Stop (Disable & Coast) stopping action.

Action Tasks and Exception Actions

This table provides guidance on selecting the correct exception action for the singular event under Axis Properties>Exception Actions.

Tasks and Exception Actions

Task	Exception Action	Description	Impact on a Vertical Load
Shutdown the axis and have it coast to a stop.	Shutdown	Shutdown is the most severe action. Use it for faults that can endanger the machine or the operator if you do not remove power quickly and completely. When the exception occurs the following happens: • Axis servo action is disabled • Tracking Command output is zeroed • Appropriate Power Structure output is deactivated	• This is a Disable & Coast (Category 0 Stop) • The Holding Brake is engaged immediately upon entering the Shutdown state • The holding brake engages even if the axis was moving • Possible damage to the holding brake over repeated use • Avoid this stopping action on a vertical axis, where possible
Stop the axis where the Stopping Action Attribute is used to configure how the drive will stop.	Stop Drive	This action is triggered by MSF or by exception (fault). When an MSF is executed the following occurs: • The drive carries out the Action set by the MSF Stopping Action • The Actions are Disable & Coast (Category 0), Current Decel & Disable (Category 1) or Current Decel & Hold (Category 2) When a fault happens the following occurs: • The drive behavior follows the exception table in the user manual • Consult the drive user manual troubleshooting behavior table to determine if the exception uses a more severe stopping action	• MSF execution issues the stopping action set for MSF Stopping Action • Disable & Coast can cause the holding brake to be engaged while the axis is moving • With Disable & Coast, possible damage to the holding brake over repeated use • Avoid Disable & Coast where possible on a vertical axis • Current Decel & Disable or Current Decel & Hold is recommended where possible • Current Decel & Hold places the axis in the Stopped State, an MSF followed by an MSO instruction must be executed to resume motion
Leave the drive enabled and stop the axis at its maximum deceleration rate.	Stop Planner	Use this exception action for less severe faults. It is the gentlest way to stop. Once the axis stops, the fault must be cleared before the axis can move again. The exception is Hardware Overtravel and Software Overtravel faults, here the axis can jog or move off the limit When a fault happens the following occurs: • Axis slows to a stop at the Maximum Deceleration Rate from the Planner tab of Axis Properties without disabling servo power • Servo power is maintained	• Similar action as Current Decel & Hold except the Maximum Decel Rate (located in the Planner category) is used to decelerate the motor and not the Stopping Torque/Stopping Time • To recover using this setting, the fault must be cleared, an MSO must be executed • To disable the drive after a fault condition set for Stop Planner, an MASD (Shutdown) is issued to disable the drive, an MASR (Shutdown reset) is used to reset the drive, and an MSO to enable the drive
Program the controller to handle the axis exception with a user defined action.	Fault Status Only or Alarm	Fault Status Only: Use this action to stop the axis with a certain behavior, possibly because they are synchronized to others and require a controlled stop in conjunction with other axes. Only certain exceptions can use this Stop Type. Consult the drive user manual table for more exception behaviors. Alarm: You can use UL (User Limit) exceptions with the alarm condition to prevent an exception from occurring.	Fault Status Only or Alarm: • You can use logic to bring the axis (or synchronized axes) to a controlled stop before holding brake is engaged • Consider that this type of stop is user defined with the final output likely being an MSF instruction where that Stop Action would be carried out • Category 1 or 2 (Current Decel & Disable or Hold) type stop are preferred for a vertical axis
Ignore the exception	Ignore	The drive completely ignores the exception condition. However, for some exceptions that are fundamental to the operation of the planner, Ignore is not an available option.	Not recommended for a vertical axis. Ignoring an exception can result in damage to the holding brake.

Manual Brake Control Settings

IMPORTANT Make sure that you have safeguards in place when releasing or engaging the brake manually. For example, operating the holding brake manually is useful when performing maintenance on the axis or machine. Engaging/releasing the brake manually is done by using SSV instructions, within the Logix Designer application, rather than manipulating the 24V control power input.

See the Rockwell Automation Knowledgebase document 68763 for details and settings on how to manually control the holding brake.

Safety Related Holding Brake Application

The topics in this section are summarized as part of Vertical Axis Quick Reference/Checklist on page 48. When you have a good understanding of these concepts and best practices, use the checklist to make sure you've applied all them all in your vertical axis application.

IMPORTANT This publication does not cover functional safety and how to implement different Category levels on the axes within your application. It is assumed that for this publication a risk assessment has been performed for the safety of personnel.

The information in this publication is narrowly focused on the protection of the machine from damage and on how the STO function is used with the drive power removal that engages/releases brake power, which is relevant to a vertical axis.

Safety Related Brake Engagement

The Kinetix EtherNet/IP network drives can have Safe Torque Off (STO) inputs via an integrated safety connection or drive hardwired safety connections. Best practices for these applications can be found in the following publications at http://www.rockwellautomation.com/global/literature-library/overview.page.

Integrated Safety Over EtherNet/IP Network Drives

Resource	Drive Family
Stop Cat. 0 or 1 via a Kinetix Drive with Integrated Safe Torque Off on EtherNet/IP Networks Safety Function Application Technique, publication SAFETY-AT135	Kinetix 5700 Kinetix 5500
Actuator Subsystems – Stop Cat. 1 via Kinetix 5000 Servo Drives with Hardwired Safe Torque Off Safety Function Application Technique, publication SAFETY-AT038	
Kinetix 6200 and Kinetix 6500 Safe Torque Off Safety Reference Manual, publication 2094-RM002	Kinetix 6500 (-S0 control module)
Kinetix 350 Single -axis EtherNet/IP Servo Drives User Manual, publication 2097-UM002	Kinetix 350

Per the STO requirement in the drive, the drive must immediately remove power to the motor when either of the STO signals is removed. The holding brake is also immediately engaged when the STO request is acknowledged in the drive. This Stop Category 0 or Disable & Coast behavior can be problematic for a vertical load. Below are different ways to implement the STO function with consideration to a vertical axis.

IMPORTANT Coasting Time Limit is used with STO (see Coasting Time Limit on page 15). Do not use this value (make sure it is zero) when using a vertical axis.

Normal Operation By Using Safe Torque Off (STO) Hardwired Inputs

Kinetix integrated motion on Ethernet/IP drives have dual hardwired inputs that use 24V DC. These STO inputs are safety rated inputs and both inputs need to be simultaneously active (24V DC present) for the motor to be energized. The STO function, in part, enables the drive (when STO circuit is energized) and disables the drive (when STO circuit is de-energized). When using the drive STO hardwired inputs, the normal operation for drive power removal (disabled) is considered a Stop Category 1.

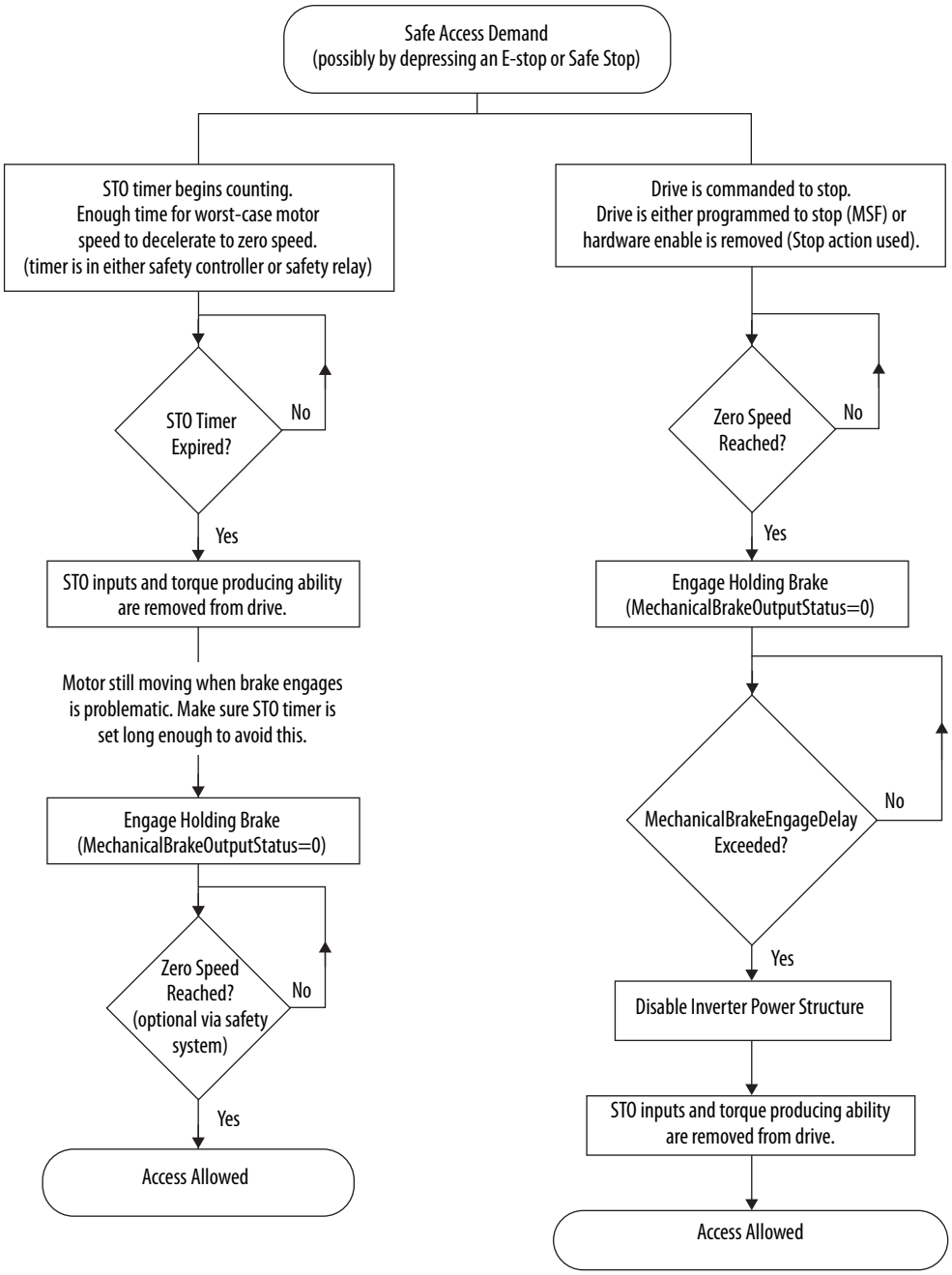
Sequence of Actions

The principle rule for applying Safe Torque Off at the drive is not until after the axis has stopped, the brake has been engaged, and the axis has been disabled.

Include these events, in this order, to produce properly written code in fully-guarded and locked safety solutions:

1. Safe access request (such as depressing an Emergency Stop or Safe Stop).
2. Begin timer until Safe Torque Off is applied.
3. Detection by the drive using hardwired enable or by the controller using an MSF instruction.
4. Deceleration to zero speed.
5. Brake engaged.
6. Drive disabled.
7. Torque removed using Safe Torque Off inputs on the drive.
8. Access allowed.

Safety Access Timing Flowchart



Guarded and Locked with Access Request

Before the doors are unlocked and access is granted to the cell, the operator must request that torque be removed from the drives. That can be done at various locations of the machine. The sequence must stop the axis, apply the brake, disable the axis, and only then remove torque. Removing torque any sooner can lead to damage of the holding brake. The simplest way to implement this type of control is through the use of a timer.

In a GuardLogix safety controller system, use a TON instruction in the Safety Task between the entry request (Emergency Stop or Safe Stop button) and the actual removal of torque from the drives. During that time, the standard control can decelerate the axis, apply the brake, and disable the axis.

With relays, use a configurable time-delay relay, for example, Bulletin MSR138DP relay or the Guardmaster® relay to give the axis time to stop. Monitor the request status in the controller (to command a controlled stop and disable) or use a hardwired enable input at the drive to perform that automatically. See page 37 for a safety relay example. Similar configurations are shown for the Kinetix 5500 drives (page 38) and the Kinetix 5700 drives (page 39) using the Bulletin 440R safety relay with EMD relay.

You can use a GuardLogix controller and manage the delay (using a Timer instruction) and/or the input using an MAS/MSF (Stop and disable) instruction. This is done to avoid an extra specialty relay outside of the controller.

Guarded but Unlocked with Sensing Only

If the doors are monitored, but not locked while the axis is moving, this can lead to a very difficult reaction time and safe distance calculation. Simply removing torque as soon as the guard door is opened can lead to torque being removed before the motor holding brake is engaged and the drive disabled. This is not recommended.

Building in a delay, as described in Guarded and Locked with Access Request, is required in the safe distance calculation. As an example, using a five-second delay relay with this intention leads to a minimum distance over 10 meters between the axis and the door.

Unguarded Safety Implementation

With safety solutions that are not fully guarded, the additional reaction time to stop the axis must be factored into the safety reaction time and the safe distance calculations. The implementation of that type of solution is not the focus of this document.

Brake Engage/Release Delays

Set the axis attributes for MechanicalBrakeEngageDelay and MechanicalBrakeReleaseDelay to the appropriate values for the motor being used. See Automatic Brake Control Configuration on page 13 for more on the parameters used for Logix Designer configuration. See Holding Brake Specifications on page 8 for the engage and release values.

Stop Actions

Use Axis Properties>Parameter List to set the stop actions that the drive uses in different circumstances. Set the following parameters for optimal performance on a vertical axis:

- ProgrammedStopMode = Fast Disable
- MSF Stopping Action = Current Decel & Disable
- Stopping Torque = Configure this for the highest stopping torque that the mechanics can sustain
- Stopping Time Limit = Set this to a value less than the request-to-access delay time

  If the hardwired enable input on the drive is wired, that also needs to be set on Axis Properties>Actions category with the following setting:

  Enable Input Deactivated = StopDrive (uses Stopping Action of Current Decel & Disable)

Abnormal Operation

There are some cases in which the Normal Operation sequence cannot be initiated. All of these conditions result in the Safe Torque Off inputs of the drive going to the presumed safe state of OFF before the drive has come to a stop and engaged the brake as defined by the Normal Operation sequence.

Potential Causes

Potential causes for abnormal operation include:

- Catastrophic power loss including brake control power

  Except in systems with dedicated cut-over to backup generators. This cannot usually be ruled out by a risk assessment.

  IMPORTANT A catastrophic power loss (for example, the entire control cabinet) causes the brake to engage as soon as there is insufficient power to keep the brake engaged. The drive uses any residual DC-bus voltage to try and stop the axis; however, the success of that is dependent on the kinetic energy of the system when the power loss occurs.

- Power loss of any part of the safety circuit, but not the brake control power
  - Apply proper wiring practices, properly selected circuit protection, and properly selected power supplies
- Physical failure of the brake itself (or safety brake, if used)
- Major fault on the safety controller (if used)
  - Avoid misapplication of code. Implement protections against common controller faults (like divide by zero)
  - Run-to-Program transition of the safety controller (if used), in this case, ProgrammedStopAction described earlier takes effect
  - Clearly define procedures to prevent this from happening as part of normal operation

The risk assessment can rule out the likelihood of any of these potential abnormal conditions from occurring.

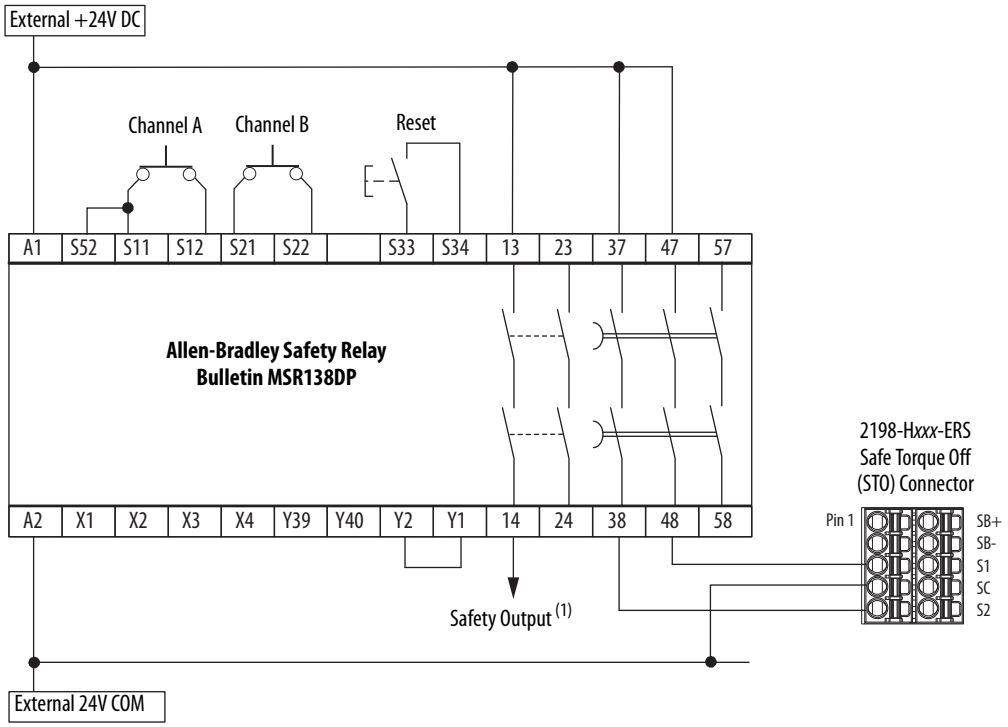
Interpose Relay and UPS

Use an Uninterruptable Power Supply (UPS) with a delay relay for the drive safety circuit. If using a hardwired safety solution, add the UPS for the safety circuitry power. If using a GuardLogix controller safety solution, add an interpose delay-relay between the distributed safety outputs and the drive.

The following guidelines apply for this Bulletin MSR138DP relay example:

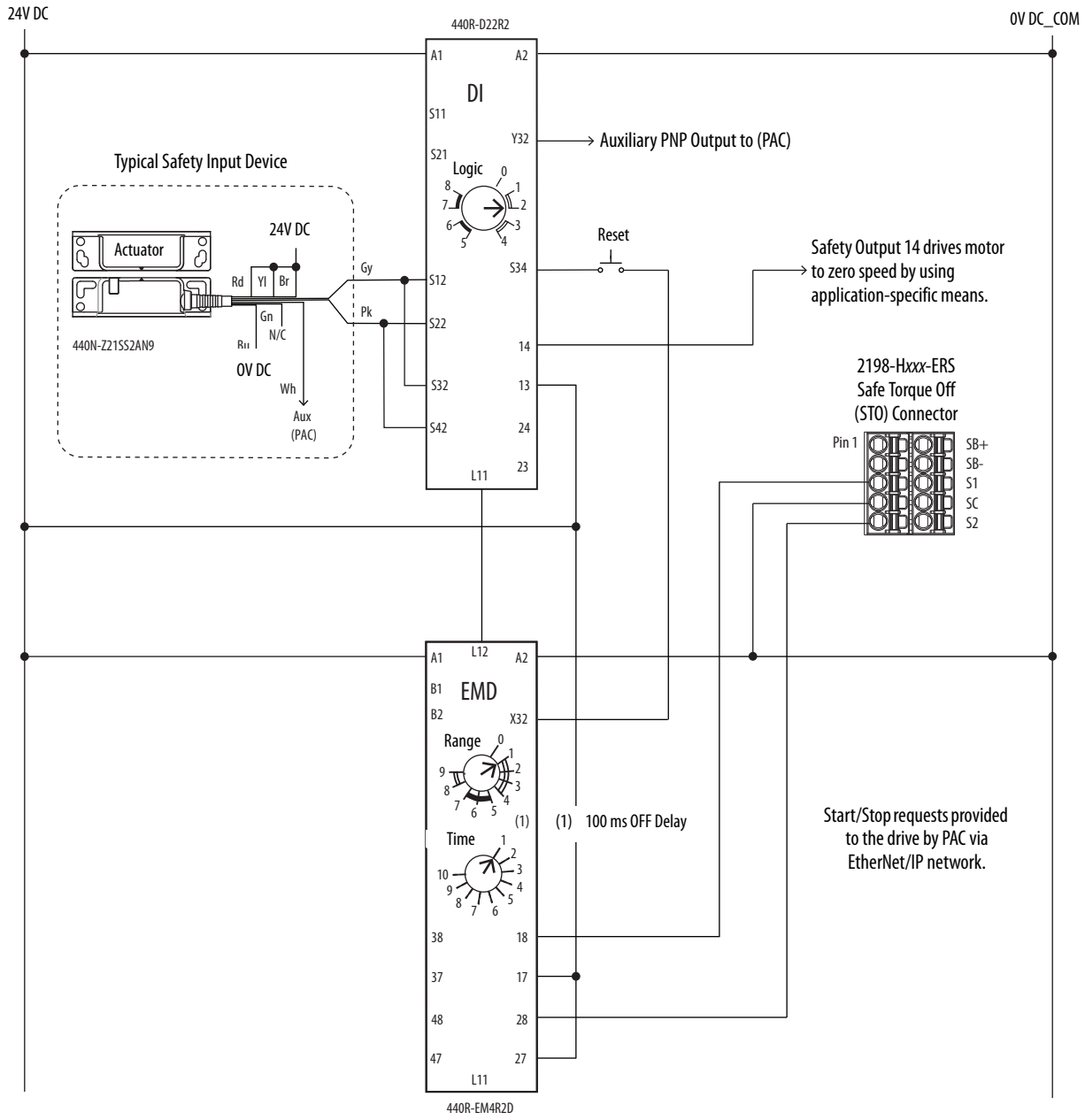
- External 24V DC power supply backed-up by a UPS.
- The output at Safety Output 14 (see diagrams on page 38 and page 39) can be omitted if the controller performs the stopping action during normal operation. This output can also be wired to the Drive Enable input. All of the abnormal operation cases can cause the drive to attempt to stop during the delay time regardless of whether this input is wired.
- For a relay-only solution (without a GuardLogix controller), the input wiring changes to match the input device. The output wiring still applies.

Safety Relay - Stop Category 1

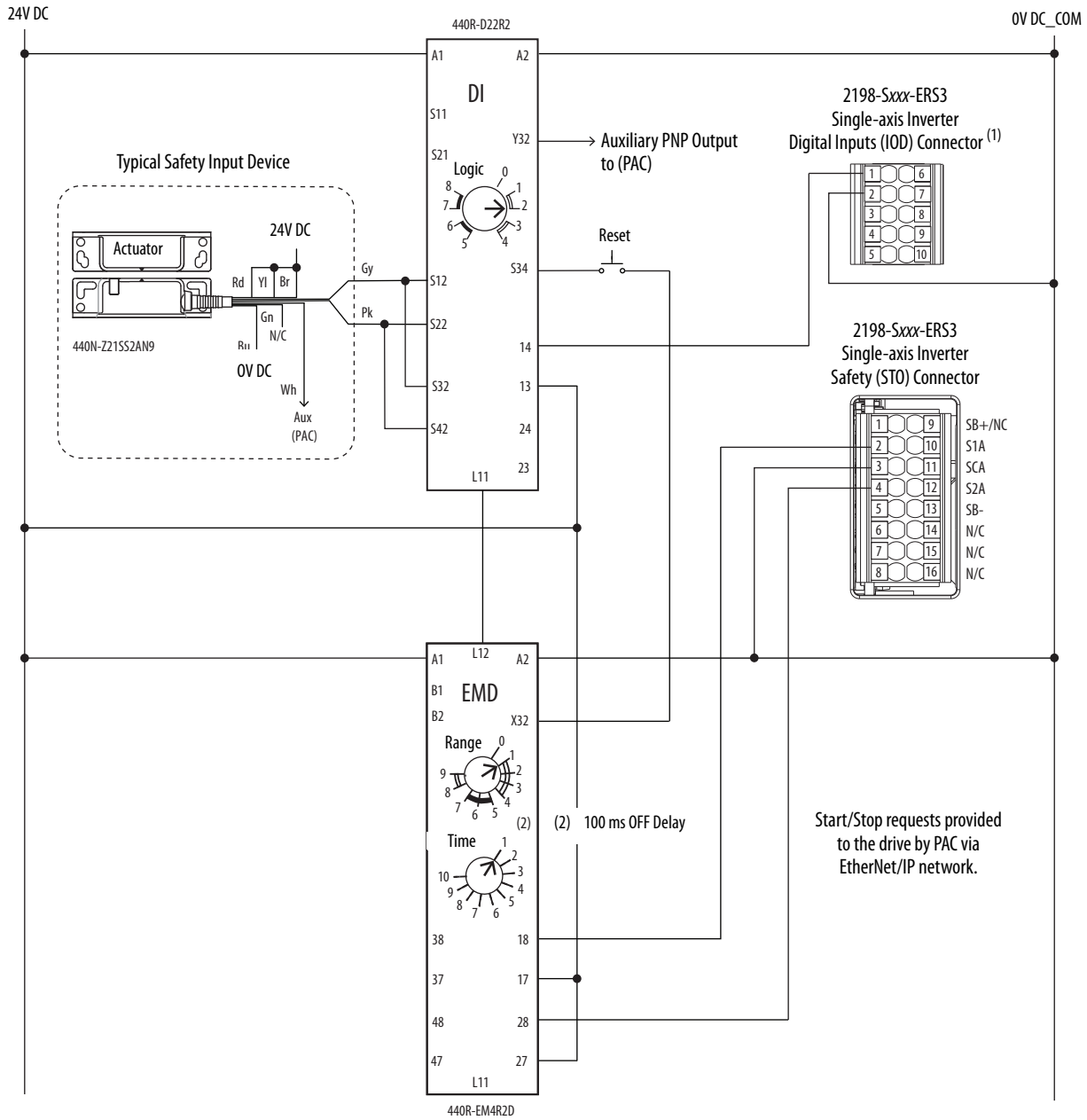


(1) Safety output 14 drives the motor to zero speed by using application-specific means.

Kinetix 5500 Drive and 440R Relay Using STO and Stop Category 1



Kinetix 5700 Drive and 440R Relay Using STO and Stop Category 1



(1) Digital input IOD-1 is configured as Drive Enable Input (IOD-2 is common).

Calculate Fault Condition Falling Distance

This example considers a hardwired safety solution (using STO) and not a network safety solution.

The potential free-fall distance from rest is calculated by the equation:

$$\text{Distance} = 0.5 * 9.81 \frac{m}{s^2} * \left(\text{Brake Action Time}\right)^2$$

Where the Brake Action Time is the total time required for the drive to set the brake, including the internal recognition of a Safe Torque Off demand and the mechanical actuation time of the brake.

For example, if the drive is at rest and enabled, and an STO request is received, the Kinetix 5500 drive has an internal reaction time of 2 ms. The Bulletin VPL-B063 motor has a brake engage delay time of up to 25 ms. This is Brake Action Time from the equation above. This leads to a total Brake Action Time of 27 ms, which equates to approximately 3.57 mm (0.14 in.) of distance and is considered the worst case of receiving the STO request and actuating the brake.

If the calculated distance for the specific application in question is greater than allowable, different techniques need to be applied. See Design Considerations on page 4 for more information.

It can also be useful to model the application using SISTEMA software. This depends on what is required in terms of safety functionality. The SISTEMA tool automates calculation of the attained Performance Level from the safety-related parts of a machine's control system to (EN) ISO 13849-1. Data for Rockwell Automation® machinery safety products is now available in the form of a library file to be used with the SISTEMA calculation tool. The combination of the two gives machinery and system designer's comprehensive time-saving support in evaluating safety to (EN) ISO 13849-1. SISTEMA is available for download from http://www.rockwellautomation.com/ by searching the keyword SISTEMA.

Network STO

The Kinetix 5500 and Kinetix 5700 drives integrated STO feature is used to stop and prevent hazardous motion. As opposed to hardwired STO inputs, Kinetix 5500 and Kinetix 5700 drives can be used with a single, module-defined, integrated STO safety tag that is controlled within the safety task of the GuardLogix controller. The Kinetix 5500 and Kinetix 5700 drive is connected via CIP Safety™ protocol over an EtherNet/IP network to the GuardLogix safety controller.

The Kinetix 5500 and Kinetix 5700 integrated STO function uses CIP Safety protocol. The CIP Safety protocol inserts the data into the CIP Safety packet twice. One piece of data is normal and the other is inverted. CIP Safety packets are also timestamped by the producer so that the consumer can determine the age of the packet when it arrives. If a good packet does not arrive before the Connection Reaction Time Limit (CRTL) expires, then the STO feature within the Kinetix 5500 drive goes to the safe state: OFF.

The CIP Safety protocol supports a direct connection between the Kinetix drive and the GuardLogix controller, making the EtherNet/IP hardware between these two end-devices a black channel. Therefore, the EtherNet/IP hardware does not have to be included in the PL calculation. The Probability of Failure per Hour (PFH) of the CIP Safety protocol has already been included in the controller PFH value. The STO feature forces the drive output power transistors to a disabled state when the STO command from the GuardLogix controller is de-energized, resulting in a condition where the drive is coasting. This feature does not provide electrical power isolation.

For safe distance calculations and reaction time calculations, the response time of the STO feature is less than 10 ms from the time the STO command is de-energized in the Kinetix 5500 drive.

When all safety input interlocks are satisfied, no faults are detected, and a proper reset occurs, the STO tags within the GuardLogix controller are set to high (1).

In summary, when a demand is placed on the safety function, the STO tag is de-energized and the motor coasts to a stop for a Category 0 Stop. Avoid the Category 0 Stop (Disable & Coast) where possible when using a holding brake. If a Category 1 Stop is being used, then the demand on the safety function drives the speed to zero (using a Logix Designer application MAS and MSF command), and after a pre-determined delay, the STO tag is de-energized. When the safety interlocks are returned to the active state (closed), and a proper reset function occurs, the Kinetix 5500 STO inputs are enabled.

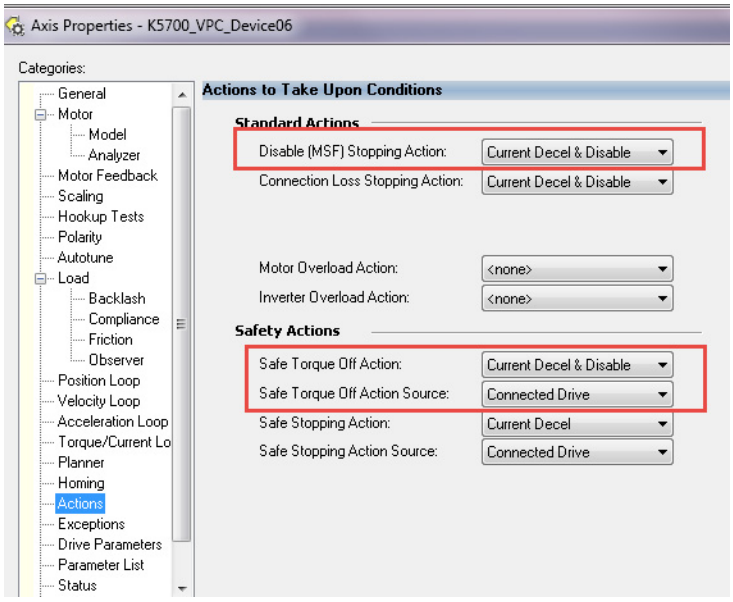
Refer to Stop Cat. 0 or 1 via a Kinetix Drive with Integrated Safe Torque Off on EtherNet/IP Networks Safety Function Application Technique, publication SAFETY-AT135, for more information on how to integrate this solution.

Kinetix 5700 Safe Monitor and STO Safety Functions

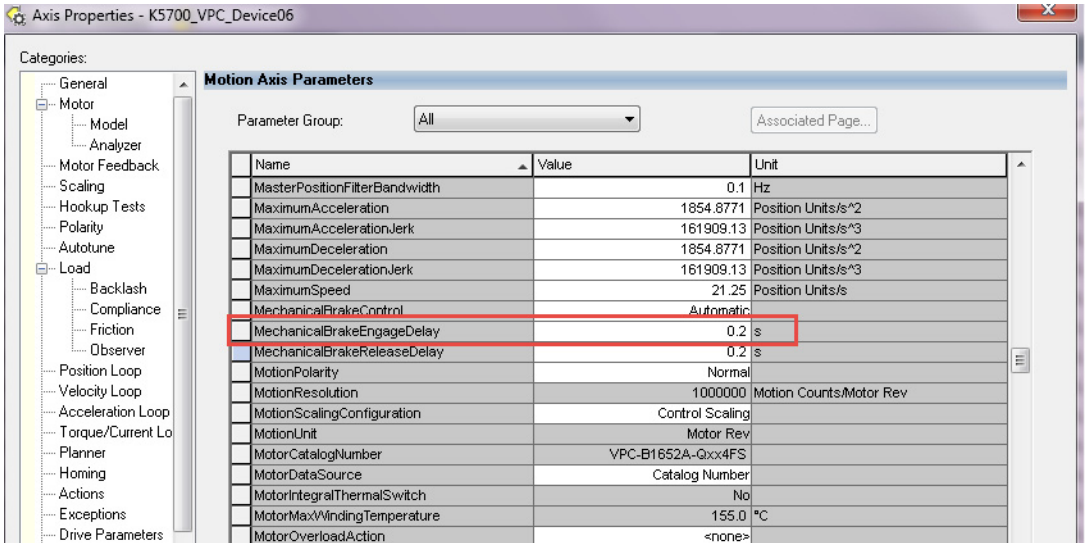
Kinetix 5700 drives (catalog numbers 2198-*xxxx*-ERS4 and 2198-*xxxx*-ERS3/B), when using GuardLogix controllers, are capable of using safe-monitoring features. The STO function with safe monitoring solution has some added functionality over the hardwired STO and integrated STO modes. Safe monitoring STO allows a Stop Category 1 to be used and includes an STO Delay. The STO Delay starts timing once the STO request is made. The delay provides time for the motor to decelerate to zero speed and engage a holding brake, before disabling the drive and disabling motor torque at the completion of the STO Delay. The drive actions depend on the drive and axis configuration. Refer to the Kinetix 5700 Safe Monitor Functions Safety Reference Manual, publication 2198-RM001, for more information on how to configure the drives and detailed use of these functions. The example below shows the holding brake operation with STO Delay timing. This example shows that the safe torque-off (STO Delay) is greater than zero.

IMPORTANT In the event of a safety fault, the safe torque-off delay (STO Delay) is not used.

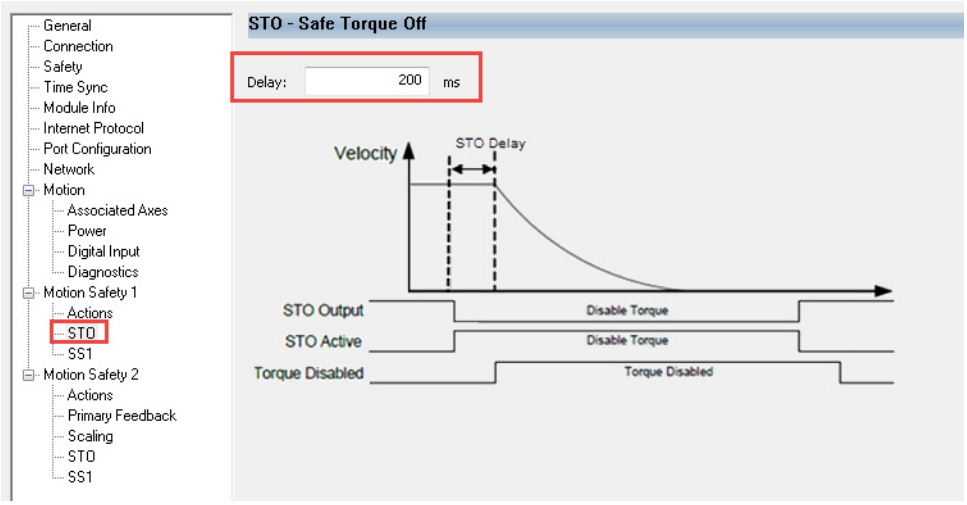
Axis Properties>Actions Category>Standard and Safety Settings



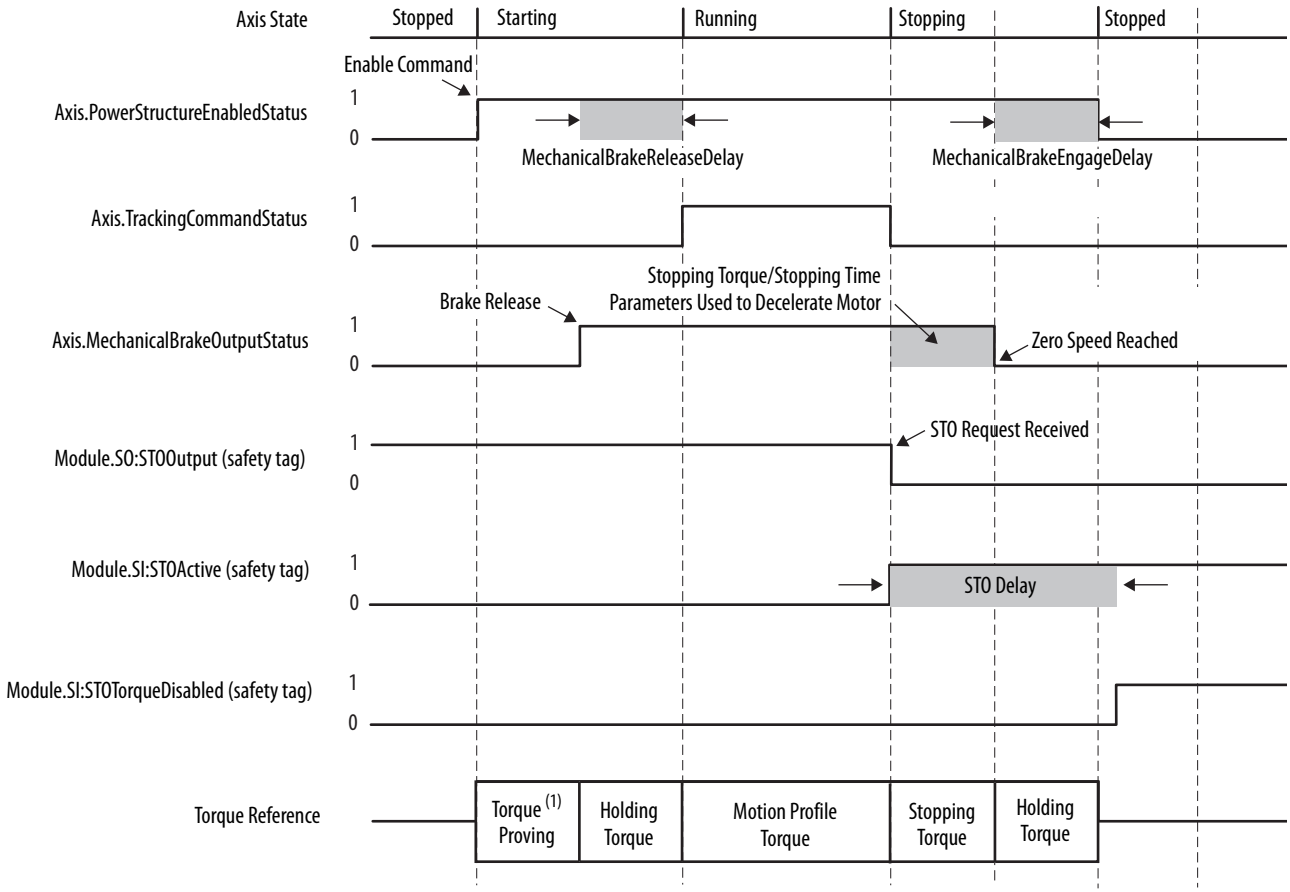
Axis Properties>Parameter List Category>Brake Engage Delay Setting



Module Properties>Motion Safety>STO Delay Configuration



Timing Diagram for the Example Configuration



(1) Includes optional brake test.

IMPORTANT Make sure the STO Delay time is long enough for the motor to reach zero speed.

Tune a Vertical Load

The topics in this section are summarized as part of Vertical Axis Quick Reference/Checklist on page 48. When you have a good understanding of these concepts and best practices, use the checklist to make sure you've applied all of them in your vertical axis application.

Gravity force is constantly applied to vertical loads. This typically presents problems with the load dropping some amount while enabling or disabling the axis. Special consideration is required when tuning an axis to minimize the dropping of the vertical axis. The tuning of a vertical axis impacts the amount of drop that is observed by the load. Generally, the higher the gains are set, the amount of drop that occurs is less. Consider, however, that load forces are not always the same throughout the vertical travel (for example, a vertical crank). Set the gains based on the worst-case application requirements. The different enable/disable conditions (described on page 22, for example) are applicable to the vertical axis while tuning. Evaluate the setting for MSF Stopping Action and make sure it is set for Current Decel & Disable or Hold. The autotune that is used below, is applicable to a vertical axis and will enable/disable the axis while engaging/releasing the holding brake automatically. Refer to Motion System Tuning Application Technique, publication MOTION-AT005, for detailed information on tuning the axis beyond what is described here.

Other Holding Brake and Tuning Considerations

As previously mentioned, the holding brake is not a stopping brake. If the application attempts to stop the load with the holding brake, the brake will become damaged over time. You can use a mechanical stopping and/or regenerative means on your axis outside of the holding brake, if you need stopping power. The capability of a motor and drive to stop a load can be modeled in the Motion Analyzer sizing and selection tool.

If a Resistive Brake Module (RBM) is available for the drive, it can reduce the axis drop because it is activated when the drive power structure is disabled helping to reduce movement on an axis. This is helpful in a Disable & Coast condition.

Brake Drops On AC Power Loss

The brake uses a spline mechanism to engage and disengage. Use of the physical holding brake requires time to engage this spline. Make sure that the MechanicalBrakeReleaseDelay (upon drive enable) and MechanicalBrakeEngageDelay (upon drive disable) are set, at a minimum, according to Holding Brake Specifications on page 8. Also, in this situation, the Stop Action setting and the timing of the fault needs to be investigated (with use of a trend or with Faults & Alarms monitoring), because depending on the axis size and bus configuration, a Bus fault can occur before the Phase Loss fault occurs, or it is possible that a Position/Velocity Error can occur before the Bus or Phase loss fault occurs.

Regardless of whether advanced tuning features like Load Observer and/or Adaptive Tuning Tracking Notch are used, we recommend applying one of the following methods to minimize the dropping effect on the vertical load.

IMPORTANT If your vertical load consists of more than one servo motor mechanically linked (torque sharing, for example), an Autotune bump test can damage the load, and possibly the other motors. In this case, see Multiple Motors Driving a Vertical Load on page 46 for the tuning procedure.

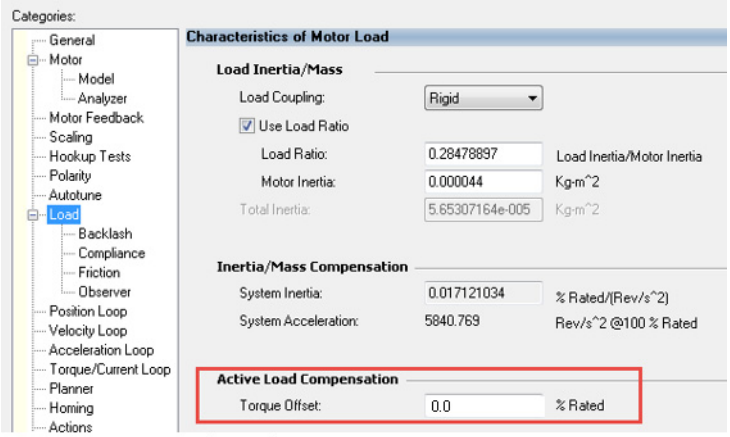
Hookup Tests and Vertical loads

When commissioning a vertical axis, it can be useful to execute a Hookup test to determine the motor encoder polarity and motor output polarity. While the Hookup tests can be performed with the load attached to the motor, it is recommended that the motor is uncoupled from the load when the Hookup tests are performed.

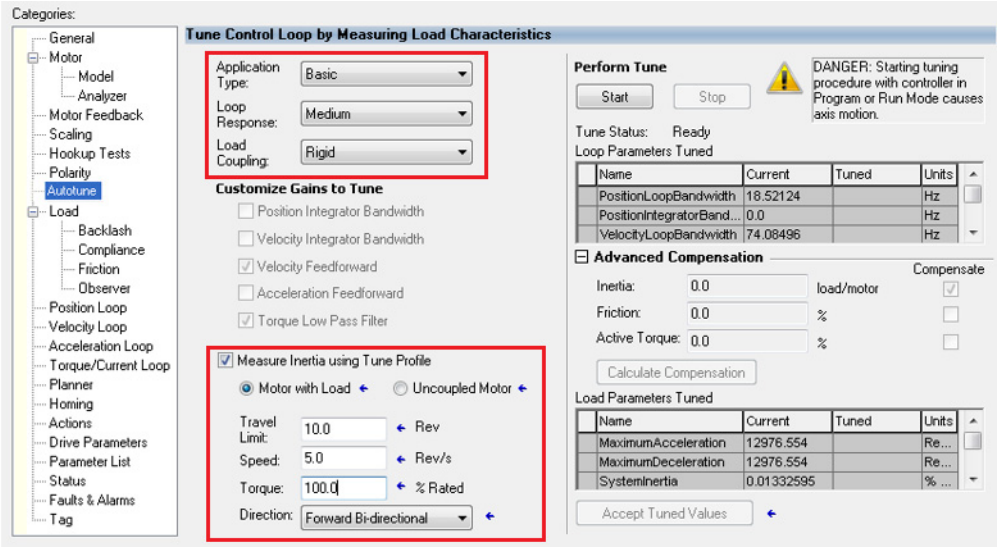
Torque Offset Method (Autotune bump test used)

Follow these steps if the bump test can be performed. If not, skip to Torque Offset Method (no Autotune bump test) on page 46.

1. From Axis Properties>Load category, set the Torque Offset value to zero.

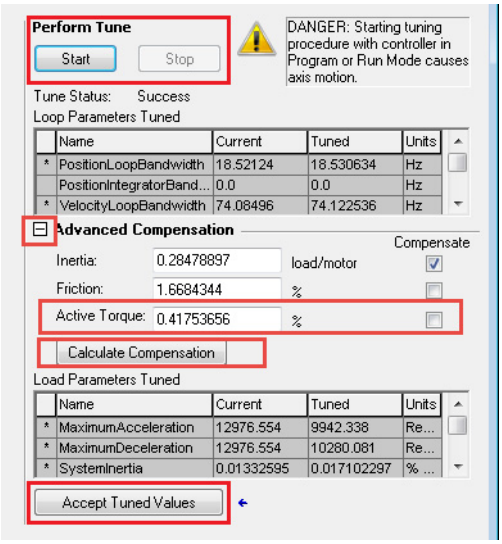


2. Select Autotune and verify that the Application Type, Loop Response, and Load Coupling settings are appropriate for your application.



3. Check Measure Inertia using Tune Profile.
4. Click Motor with Load to perform a bump test.
5. Verify that the Travel Limit, Speed, and Torque values do not exceed application limits.
6. Verify that the Autotune direction is (Forward or Reverse) Bi-directional.

7. Click Perform Tune>Start



8. When the bump test is complete, click + to expand Advanced Compensation.
9. Next to the Active Torque value, check Compensate.

TIP The Active Torque value is set after the bump test and, if accepted, also becomes the Torque Offset value.

10. Click Calculate Compensation.
11. Click Accept Tuned Values.
12. Enable the drive with an MSO instruction.
13. Verify that the performance of the drive by using the Trend tool.

    See Motion System Tuning Application Technique, publication MOTION-AT005, for information on how to trend data. Use the Trend tool to monitor axis performance by monitoring at least Current Feedback, Command Velocity, and Actual Velocity.

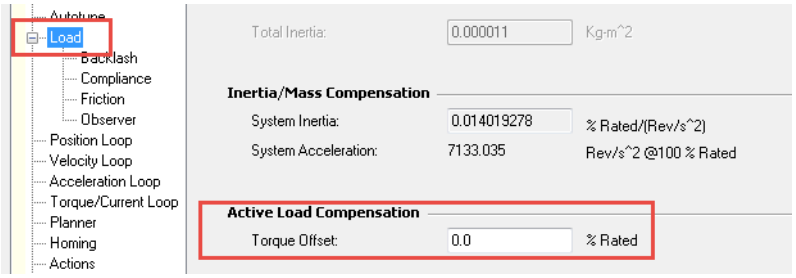
TIP Current Feedback is only available to be monitored in a Trend after the Drive Parameters in Axis Properties are set to read Current Feedback. Otherwise, the Trend always reads zero for Current Feedback.

14. Disable the drive with an MSF instruction.

Torque Offset Method (no Autotune bump test)

Follow these steps if the bump test can't be performed (axis is mechanically unable to perform a bump test). By using this method, you manually enter the Torque Offset value.

1. From Axis Properties>Load category, set the Torque Offset value to zero.



2. Use the Trend tool to monitor axis performance by monitoring at least Current Feedback, Command Velocity, and Actual Velocity.

   TIP Current Feedback is only available to be monitored in a Trend after the Drive Parameters in Axis Properties are set to read Current Feedback. Otherwise, the Trend always reads zero for Current Feedback.

3. Enable the drive with an MSO instruction.
4. Record the Current Feedback value.
5. Disable the drive with an MSF instruction.
6. Set the Torque Offset value to the Current Feedback value measured on the Trend while the axis was enabled.
7. Tune the position and velocity control gains of the drive as described in Motion System Tuning Application Technique (Chapter 4), publication MOTION-AT005.
8. Disable the drive with an MSF instruction.

Multiple Motors Driving a Vertical Load

Because the autotune bump test cannot be performed on multiple mechanically linked motors, use this method as an alternative to the Torque Offset method. This method still uses the Torque Offset functionality. In this case, the motors that are not being tuned need to be geared with MAG (Motion Axis Gearing) instructions to the motor that is being tuned. For example, if the vertical load uses four motors, and if motor #1 is being tuned, three MAG instructions (for the non-tuned motors) are used to gear the other three motors to motor #1. In this case, motor #1 is the Master while the other three motors are Slaves in the MAG instructions.

Follow these steps to tune multiple motors mechanically connected in a vertical load.

1. From Axis Properties>Load category, set the Torque Offset value to zero.
2. Determine the motor to tune (Master).
3. Enable all the motors using MSO instructions.
4. Execute MAG instructions from the Logix Designer application for the mechanically linked motors (Slave) to the Master (from step 2).

5. Use the Trend tool to monitor axis performance by monitoring at least Current Feedback, Command Velocity, and Actual Velocity.

   TIP Current Feedback is only available to be monitored in a Trend after the Drive Parameters in Axis Properties are set to read Current Feedback. Otherwise, the Trend always reads zero for Current Feedback.

6. Recored the Current Feedback value.
7. Disable all the motors by using MSF instructions.
8. Set the Torque Offset on the Master to the Current Feedback value measured on the Trend while the axis was enabled.
9. Enable all the motors by using MSO instructions.
10. Tune the drive as described in Motion System Tuning Application Technique (Chapter 4), publication MOTION-AT005.
11. When tuning is complete on the Master, disable the gearing on all the Slave motors (MAS instruction>Stop Gearing type).
12. Repeat these steps on the other Slave axes. If the mechanism connected to each motor on the vertical load is the same, the control loop gains, settings for the filters (Low-pass filter and notch filter), and Torque Offset can be copied from the master axis to the slave axes.

Integral Gain Method

This method consists of incrementally applying a small amount of position integral gain (K_{pi}) to the position loop. For an EtherNet/IP drive, a typical range of values for the position integral gain is given:

$0 \leq K_{pi} \leq K_{pp} / 4$

Where K_{pp} is the proportional gain of the position loop.

The integral gain method can be less effective than the torque offset method because the integral often lets a small period of time to accumulate from the initial conditions until it can overcome the effect of gravity on the load. In this small period of time, the load can drop.

The integral gain method can be more effective than the torque offset method regarding ease-of-use in overcoming the effect of gravity on changing inertia.

Advanced Features

The drive's Torque Notch Filters can also be used on vertical loads. You can also use Adaptive Tuning Tracking Notch configuration to automatically suppress mechanical high frequency resonances. However, do not use the Adaptive Tuning Gain Stabilization configuration to control vertical loads.

Vertical Axis Quick Reference/Checklist

Hardware and Design Checklist

page 4

- Is the brake stopping the load?
- Is the brake backlash acceptable?
- Does the holding brake have enough holding torque to hold the load?
- Does the drive brake circuit have enough current to energize the brake coil?
- Does the brake require an external relay?
- Is external brake suppression required?
- Are the motor cables installed per installation instructions?
- Are the network communication cables suitable for the environment?

Safety Related Checklist

page 32

- Has a risk assessment been performed on the machine?
- Do we know the required rating we need?
- Is the hardware Safe Torque Off function used?
- Are we using controlled stop techniques to stop the load before STO is used?

Common Vertical Axis Parameters

page 13

Have these common parameters been addressed?

- Stopping Torque (set based on the application)
- Stopping Time Limit (set based on the application)
- Mechanical Brake Engage Delay (set based on motor brake specifications)
- Mechanical Brake Release Delay (set based on motor brake specifications)
- Coasting Time Limit (set to zero for a vertical load)
- Zero Speed (if available, set based on 1% of motor speed)
- Zero Speed Time (if available, set based on Zero Speed, motor, and application)

Application Settings for Automatic Brake Control

page 22

Non-faulted Normal Control

Check these settings in the Logix Designer application:

- MSF Stopping Action
  - Which stopping Type is used for the axis (Cat. 0, Cat. 1, Cat. 2)?
  - Which stopping Action is used for the axis (Cat. 0, Cat. 1, Cat. 2)?
  - Stopping Torque/Stopping Time are used for an MSF
- Controller mode change setting made?

Faulted Control (non-safety)

Logix Designer application, Axis Properties>Actions category, review these settings:

- Exception settings
- Drive behavior based on the Stop Action of Stop Drive

Based on what is required for the application, review these settings:

- Setting for each exception (default for all is Stop Drive)
- Kinetix drive user manual to determine if the selected fault Action is acceptable for the application
- Faults & Alarms category to review Fault Timing

Faulted Control (Safety), Normal Operation

- Risk assessment performed?
  - What level of Safety rating is required?
  - SISTEMA?
- Hardwired STO used?
  - Stop Category 1 Actions configured correctly?

Tuning Required for a Vertical Load

page 43

- Can Autotune be performed?
  - Some loads can't be autotuned because of mechanical constraints
- Torque Offset method used?
- Integral gain method used?
- Advanced features used?
- Refer to Motion System Tuning Application Technique, publication MOTION-AT005.

Vertical Load Control Feature

This section describes new features that affect vertical load applications, holding brake operation, and are available with the Studio 5000 Logix Designer application (version 31 and later) and Kinetix 5700 drives (catalog numbers 2198-*xxxx*-ERS4 and 2198-*xxxx*-ERS3/B) firmware 9.001 or later.

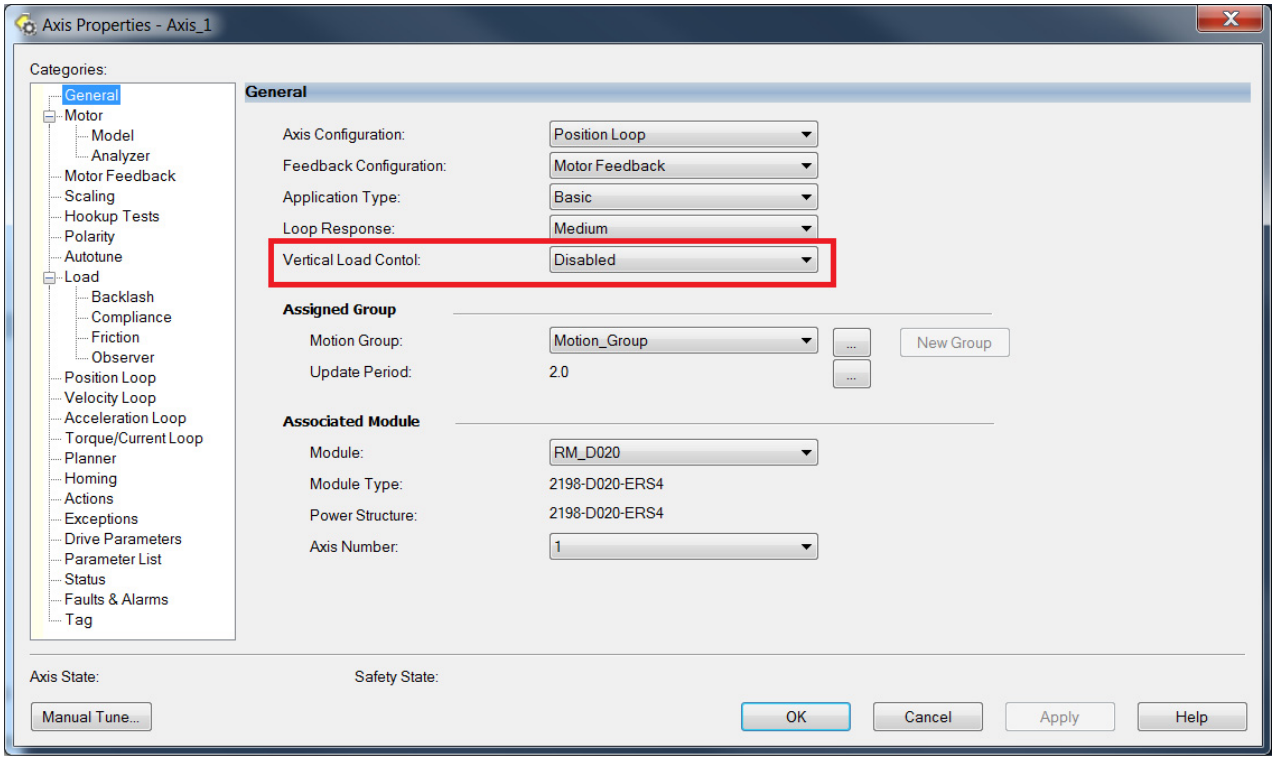
IMPORTANT Review the content of this document before proceeding. The enhancements made in Logix Designer, version 31, and a basic understanding of the hardware, software, and application settings still apply to **any** vertical load -whether the Vertical Load Control feature is used or not. Consider that changes to your Axis Properties can still be necessary when using Logix Designer, version 31 or later.

Refer to Vertical Axis Quick Reference/Checklist on page 48 when evaluating additional changes that are required when using Logix Designer (version 31 or later) and the Vertical Load Control feature.

Configure Vertical Load Control

You can configure the Vertical Load Control pull-down menu from Axis Properties>General category.

Vertical Load Control Feature



- When Vertical Load Control is disabled, the Vertical Load Control parameter settings are returned to default values. Make changes to the default values as needed (see the Vertical Load Control Parameter Settings table on page 50).
- When Vertical Load Control is enabled, Vertical Load Control parameter settings are set automatically to simplify the setup of a vertical load (see the Vertical Load Control Parameter Settings table on page 50).

Vertical Load Control Parameter Settings

Parameter	Vertical Load Control Disabled (default setting)	Vertical Load Control Enabled
MechanicalBrakeEngageDelay	0 seconds	0.3 seconds
MechanicalBrakeReleaseDelay	0 seconds	0.3 seconds
ZeroSpeed		
Frequency Mode w/InductionMotors	1.0	200 • (InductionMotorRatedSlipSpeed ÷ MotorRatedSpeed)
All other modes	1.0% Motor Rated	1.0% Motor Rated
ProvingConfiguration	Disabled	Enabled
TorqueProveCurrent	0% Motor Rated	100% Motor Rated
BrakeTestTorque	0% Motor Rated	50% Motor Rated
BrakeSlipTolerance (1)		
Rotary Motor	0	0.06 revs (default units)
Linear Motor	0	0.006 m (default units)
Standard Actions		
Disable (MSF) Stopping Action	Current Decel & Disable	Current Decel & Disable
ConnectionLossStoppingAction	Current Decel & Disable	Current Decel & Disable
Safety Actions		
SafeTorqueOffAction	Current Decel & Disable	Current Decel & Disable
SafeTorqueOffActionSource	Connected Drive	Connected Drive
Exception Actions		
Motor Overtemperature FL Fault	Disable & Coast	Current Decel & Disable
Inverter Overtemperature FL Fault	Disable & Coast	Current Decel & Disable
Excessive Position Error Fault	Disable & Coast	Current Decel & Disable
Excessive Velocity Error Fault	Disable & Coast	Current Decel & Disable

(1) Refer to Brake Test on page 54 to calculate Brake Slip Tolerance.

IMPORTANT If the axis settings are not the default settings shown in the table, they will be changed to the Enabled settings once the Vertical Load Feature is enabled.

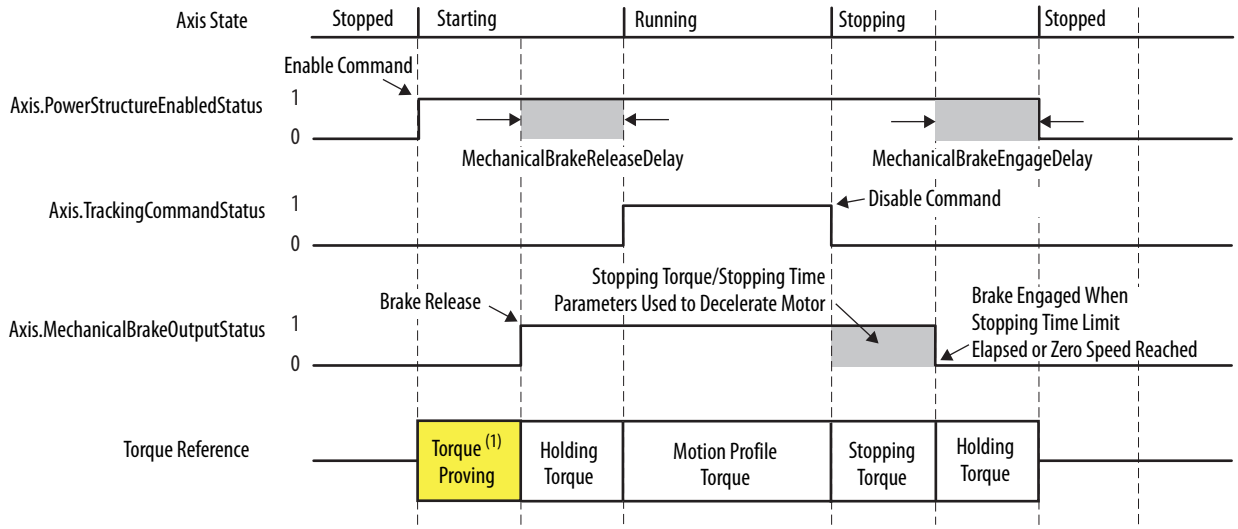
Torque Prove/Brake Tests

The ProvingConfiguration attribute (including an optional brake test) is available on Kinetix 5500 and Kinetix 5700 servo drives, and although implemented differently, is also available on PowerFlex® 755 AC drives. Refer to the PowerFlex 750-Series AC Drives Programming Manual, publication 750-PM001, for more information on PowerFlex 755 AC drives.

IMPORTANT For Kinetix 5500 and Kinetix 5700 drives, the torque prove test is **not** intended to validate if the drive/motor is capable of providing the required current to hold the load before releasing the brake. It is designed to make sure the motor has current flowing to all the phases properly and that reasonable current control exists.

The torque prove and brake tests are used on all Stop Category types in the Starting state. The timing of these tests are shown in yellow below (Stop Category 1 example).

Timing Diagram for Torque Prove/Brake Test (Stop Category 1)



(1) Includes optional brake test.

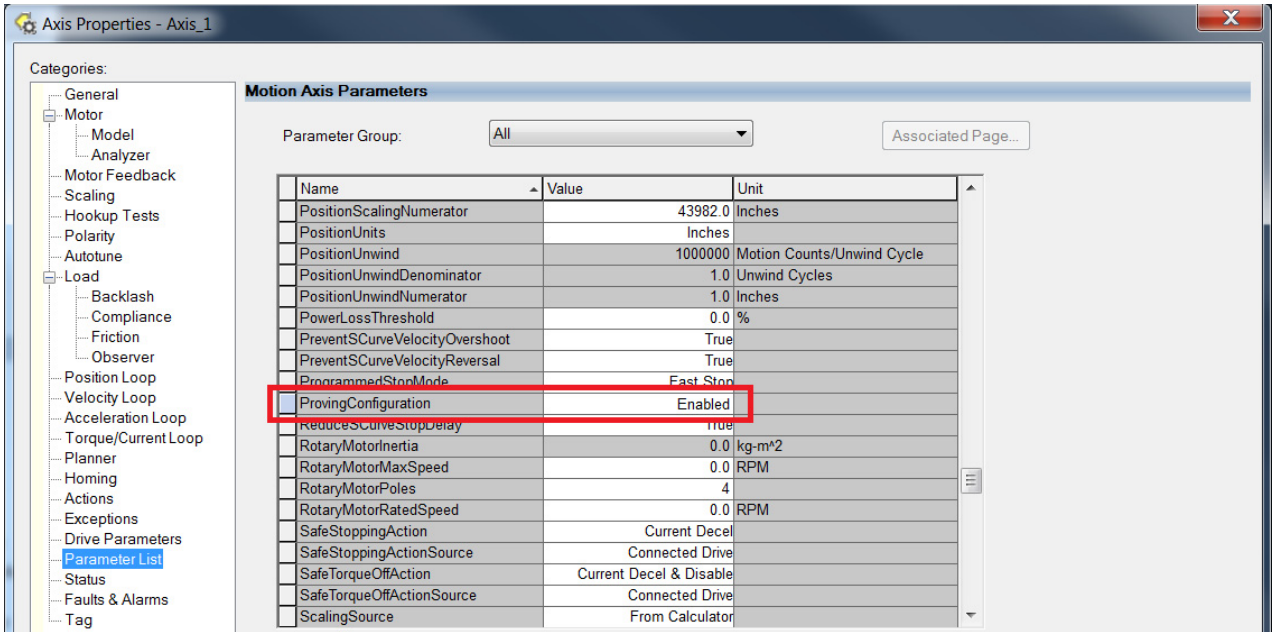
The ProvingConfiguration feature includes sub-features. The following table defines these attribute dependencies.

Attributes Used With Proving Features

Proving Sub-feature	Controlling Attributes	Attribute Prerequisite
Torque prove test	TorqueProveCurrent	ProvingConfiguration
Brake test	• Brake Test Torque • Brake Slip Tolerance	

The torque proving test is designed to determine if motor power wiring is electrically connected to a motor and that reasonable current control exists. This function works together with Mechanical Brake Control. When the ProvingConfiguration function is enabled, the drive performs a torque prove test of the motor current while in the Starting state (which is initiated once an Enable command is performed) to prove that current is flowing properly through each of the motor phases before releasing the brake. If the torque prove test fails, the motor brake stays engaged and a FLT-S09 Motor Phase Loss exception (fault) is generated.

Proving Configuration Setting



IMPORTANT Torque prove is active when the drive is commanded to enable. If the torque prove test fails, the holding brake must stay engaged. When the holding brake is under the control of the drive connected to the motor with the holding brake, this is automatic. Avoid manual external holding brake control whenever possible.

Torque Proving Startup Sequence

Startup Phase	Description
Phase 1	When the drive receives an enable request, the Starting state begins execution and torque proving starts.
Phase 2	The torque-proving feature ramps current to the motor-phase output connector and verifies that the current feedback circuitry detects current on each of the phases.
Phase 3	Once motor-current feedback has been verified in each motor phase, the drive attempts to enable the current control loop at a user-specified current level (TorqueProveCurrent setting) and verifies that the current loop error tolerance is within range.

Torque proving is available for all motor configurations including closed-loop servo control and induction motors. For permanent magnet (PM) motors, the drive attempts to apply current to the motor phases such that all current through the motor is flux current. However, due to the electrical angle of the motor at the time of the MSO instruction, it is not always possible to verify that the motor phase wiring with only flux current. Therefore, with a PM motor it is possible that the motor shaft can move slightly during torque proving if no motor brake exists to hold the load.

While torque proving functionality is available to drive control modes that are not capable of generating reliable holding torque based on a feedback device, such as Frequency Control and Sensorless Vector Control modes, do not use torque proving in these modes for applications where holding torque is critical to safe operation, such as in a typical lift or crane application.

Phase Loss Detection Attributes

This section describes the settings used for the torque proving tests and shows an example of how to set the values.

ProvingConfiguration

This attribute enables the operation of the drive's torque proving and brake proving functions that work together with Mechanical Brake Control.

Usage	Access	Data Type	Default	Minimum Value	Maximum Value	Semantics of Values
Optional - D	SSV	USINT	0	–	–	0 = Disabled 1 = Enabled 2…255: Reserved

TorqueProveCurrent

This value is used as part of the drive's torque proving and brake proving test and work together with Mechanical Brake Control. The TorqueProveCurrent attribute is motor current that is used for the torque prove test to verify current is properly flowing through each of the motor phases. The higher the TorqueProveCurrent value, the more current the drive delivers to the motor to verify that the motor phase wiring is connected and capable of that current level. Conversely, high current levels cause more thermal stress and (potentially) can cause more torque to be driven against the motor brake during the test. If the TorqueProveCurrent level selected is too small, the drive cannot distinguish the proving current from noise and the drive posts an INHIBIT M04 torque-proving configuration fault. The minimum amount of torque proving current depends on the catalog number of the drive.

Usage	Access	Data Type	Default	Minimum Value	Maximum Value	Semantics of Values
Optional - D	SSV	REAL	0	0	100	%Motor Rated

Phase-loss Detection Current Example

In this example, a 2198-H025-ERS*x* servo drive is paired with a VPL-B1003T-C motor with 6.77 A rms rated current. Use the torque-proving equation (below) and table (on page 53) to calculate the initial minimum torque-proving current as a percentage of motor rated current. Depending on the unique characteristics of your application, the required torque-proving current value can be larger than the initial recommended value.

Phase-loss Detection Equation

$$\left(\frac{\textit{Rating From Table}}{\textit{Motor Rated Current}}\right) \times 100\% = \frac{2.011\ \text{A}}{6.77\ \text{A}} \times 100\% = 29.7\%$$

Recommended Phase-loss Detection Current

Kinetix 5500 Drive Cat. No.	Phase-loss Detection Current, min A rms
2198-H003-ERS*x*	0.2514
2198-H008-ERS*x*	0.6285
2198-H015-ERS*x*	1.257

Kinetix 5500 Drive Cat. No.	Phase-loss Detection Current, min A rms
2198-H025-ERS*x*	2.011
2198-H040-ERS*x*	3.268
2198-H070-ERS*x*	5.782

TIP See the Kinetix 5700 Servo Drives User Manual, publication 2198-UM002, for those recommended Phase-loss Detection Current values.

TIP The drive parameter MotorRatedContinuousCurrent from Axis Properties>Parameter List can also be used for the Motor Rated Current value.

Brake Test

The torque proving feature includes a proactive brake test to make sure the mechanical brake is functioning properly. The brake test is enabled when BrakeTestTorque is greater than zero. When BrakeTestTorque is greater than zero, BrakeSlipTolerance also needs to be set greater than zero. Set BrakeSlipTolerance with the BrakeTestTorque value in mind. Unless another method is used to address a Brake Slip condition in the Starting state, the fault action for the Brake Slip exception is Current Decel & Hold. This fault action applies holding torque (provided by the torque limit settings) in an effort to stop the Brake Slip and transitions the axis to the faulted state. In general, brake proving functionality is only applicable to drive control modes that are capable of generating holding torque based on a feedback device. Brake proving is therefore not applicable to Frequency Control or Sensorless Vector Control modes. The brake test is optional when setting BrakeTestTorque=0. However, on vertical loads, when holding brakes are used, the brake test should be performed.

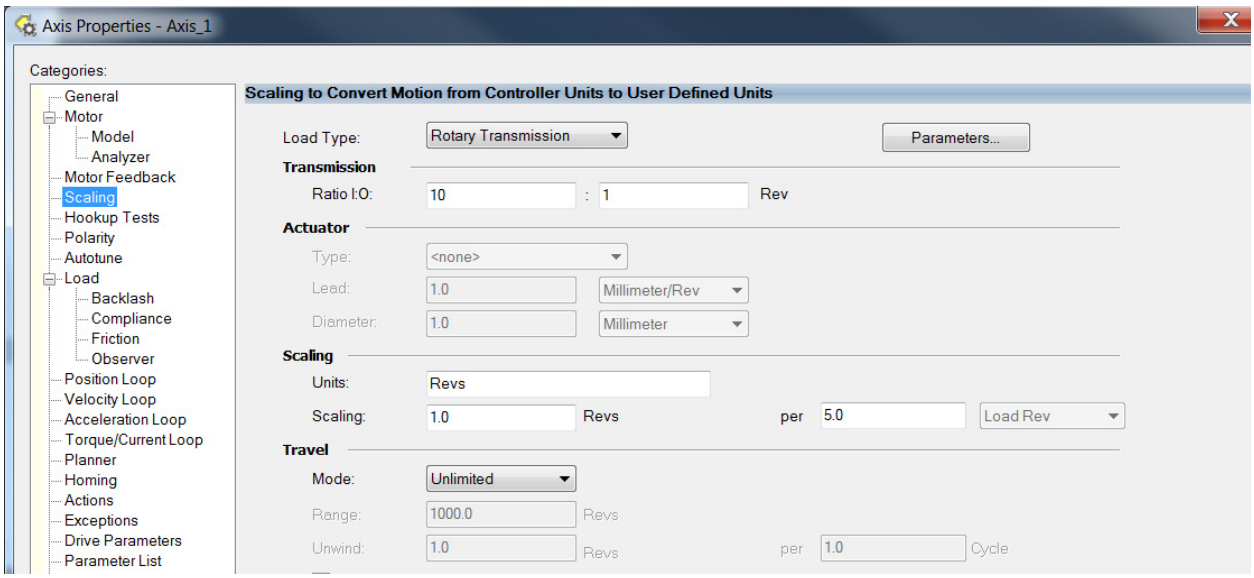
Guidelines for Brake Test Settings

In general, if BrakeSlipTolerance is a small value relative to the travel of the motor (normally this is the case), then BrakeTestTorque should also be a small value. Consider that part of the brake test ramps torque up to the BrakeTestTorque value while measuring the difference between the axis' actual position. If the change in actual position is greater than the BrakeSlipTolerance, the Brake Slip exception is asserted. If the BrakeTestTorque is a larger value (50% is the default when using the Vertical Load Control feature) and the BrakeSlipTolerance is set just outside the brake backlash specification, for example 6 arc min or 0.0015 motor revolutions, the Brake Slip exception occurs immediately when torque is generated to execute the test. So, in this case, the tolerance should be larger to accommodate the torque level while executing the test (0.06 revolutions for rotary motors and 0.006 m for linear motors is the default tolerance when using the Vertical Load Control feature).

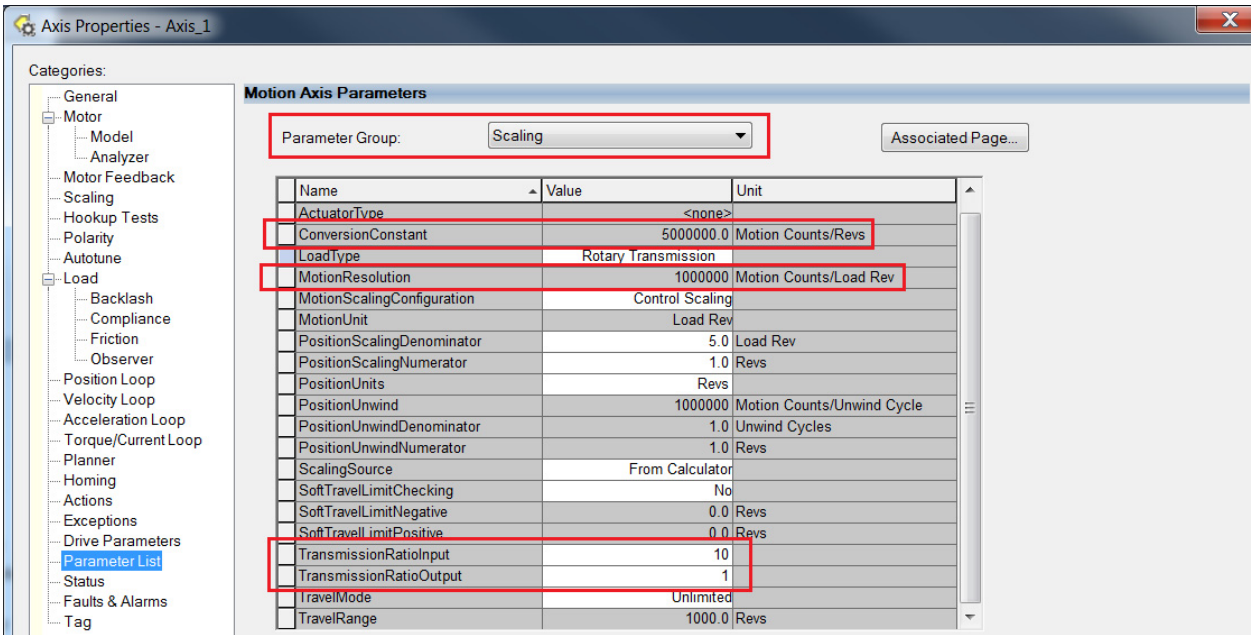
Set the BrakeSlipTolerance Parameter

Follow these steps to set the BrakeSlipTolerance parameter.

1. From the Axis Properties<Scaling category enter the scaling units and values.
   In this example, the units are revolutions and the values are 1.0 revolution per 5.0 load revolutions.



2. Select the Parameter List category.
   The highlighted values in this example are used in the Brake Slip Tolerance calculation.

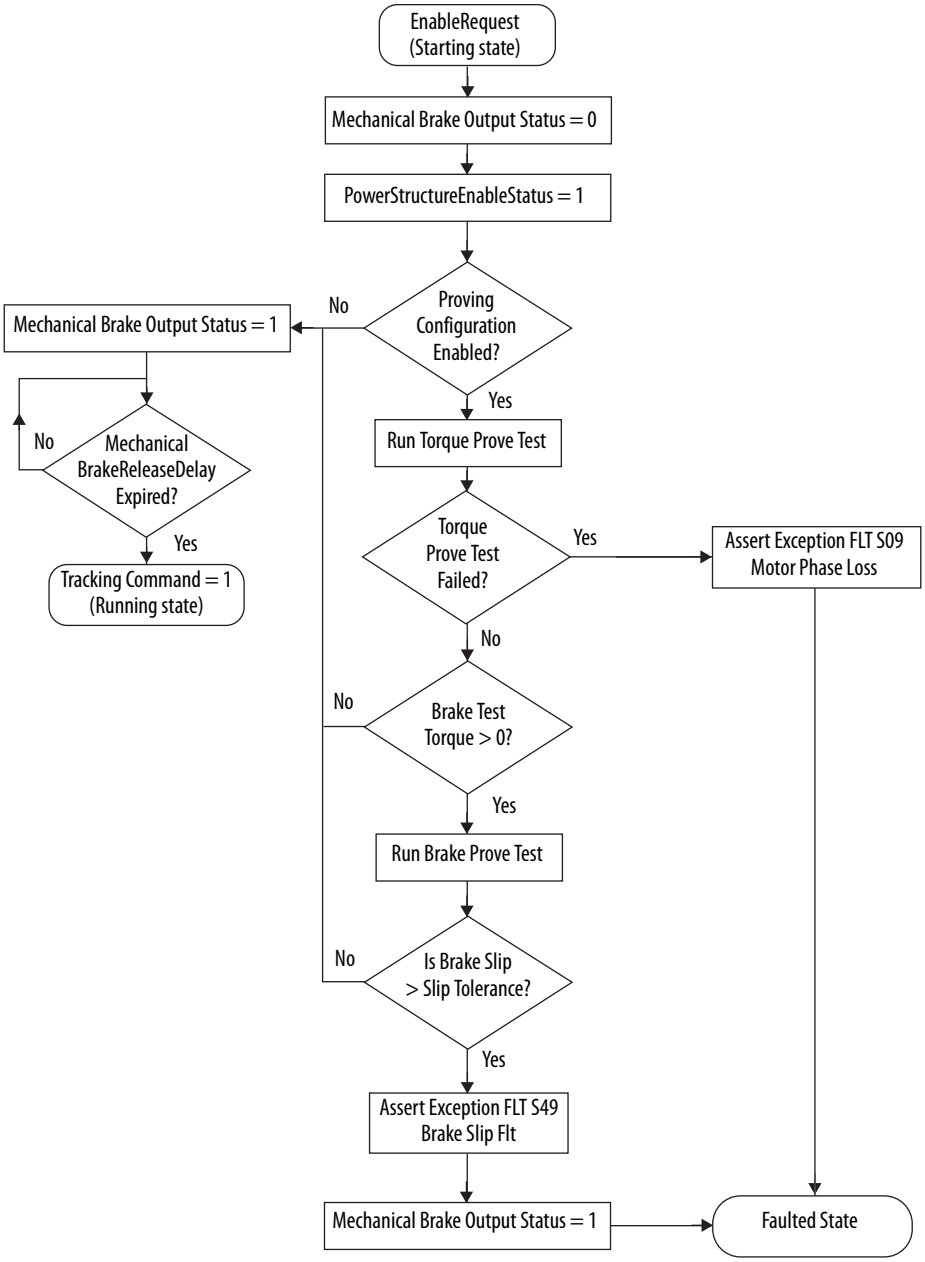


3. Apply the scaling parameter values to the BrakeSlipTolerance formula.

$$\text{BrakeSlipTolerance (rotary motor)} = 0.06 \cdot \left(\frac{\text{TransmissionRatioOutput}}{\text{TransmissionRatioInput}}\right) \cdot \left(\frac{\text{MotionResolution}}{\text{ConversionConstant}}\right)$$

$$\text{BrakeSlipTolerance (linear motor)} = 0.006 \cdot \left(\frac{\text{TransmissionRatioOutput}}{\text{TransmissionRatioInput}}\right) \cdot \left(\frac{\text{MotionResolution}}{\text{ConversionConstant}}\right)$$

Torque Prove and Brake Test Flowchart (starting state)



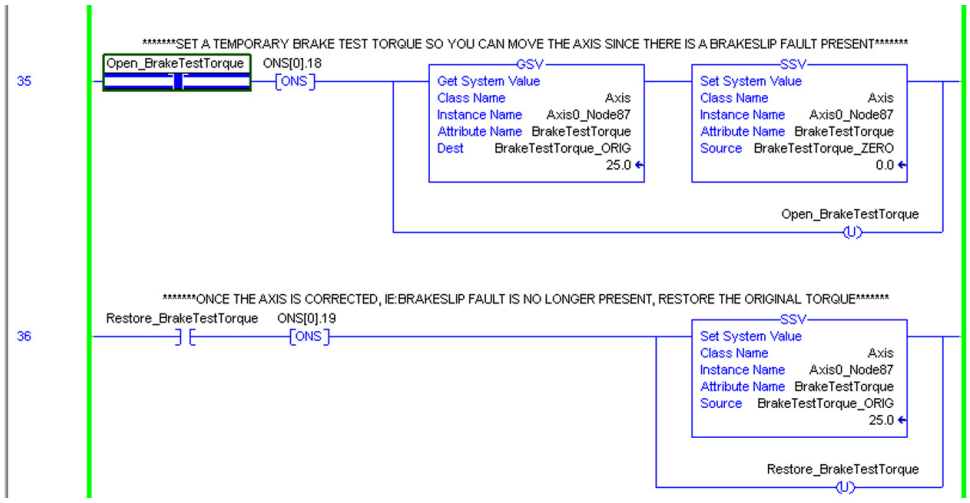
Brake Test Recovery

Brake test failure (BrakeSlip exception is active) can be caused by one of the following conditions:

- The BrakeSlipTolerance parameter value is too small (refer to Set the BrakeSlipTolerance Parameter on page 55)
- The BrakeTestTorque parameter value is too different from the BrakeSlipTolerance value (refer to Guidelines for Brake Test Settings on page 54).
- There may be a legitimate problem with the holding brakes and they no longer function properly.

The Brake Slip exception (from the Exceptions category) is programmable with the default being Current Decel & Hold. Once in this state, there are many options for recovery. Because the drive is still enabled when this exception is active, a similar approach to the other Current Decel & Hold exceptions can be used. However, there is one difference, because the recovery likely includes issuing an MSO for the drive to return to a RUNNING state, the brake test must be re-executed. If the brake slip is repeatable, it will fail again. The BrakeTestTorque can be changed to zero to eliminate the brake test from the Proving Configuration. Once the torque is changed, an MAFR can clear the fault and an MSF takes the drive to the STOPPED state. An MSO enables the drive and permits movement to a home location to address the holding brake fault. Once the fault is resolved, the original Brake Test Torque can be restored.

Logic to Change the Brake Test Torque (and then restore it)



Additional Resources

These documents contain additional information concerning related products from Rockwell Automation.

Resource	Description
Kinetix Rotary Motion Specifications Technical Data, publication KNX-TD001	Provides product specifications for Kinetix VP (Bulletin VPL, VPC, VPF, and VPS), MP-Series (Bulletin MPL, MPM, MPF, and MPS), RDD-Series™, and HPK-Series™ rotary motors.
Kinetix 5700 Servo Drives User Manual, publication 2198-UM002	Provides information on installing, configuring, startup, troubleshooting, and applications for your Kinetix servo drive system.
Kinetix 5500 Servo Drives User Manual, publication 2198-UM001	
Kinetix 6200 and Kinetix 6500 Modular Multi-axis Servo Drives User Manual, publication 2094-UM002	
Kinetix 350 Single-axis EtherNet/IP Servo Drives User Manual, publication 2097-UM002	
Kinetix 5700 Safe Monitor Functions Safety Reference Manual, publication 2198-RM001	Provides a description of integrated stopping functions and safe monitoring functions with a GuardLogix controller and Kinetix 5700 servo drives.
Stop Cat. 0 or 1 via a Kinetix Drive with Integrated Safe Torque Off on EtherNet/IP Networks Safety Function Application Technique, publication SAFETY-AT135	Provides information on how to program the logic (GuardLogix controller) and configure the actuator (Kinetix drive with integrated Safe Torque Off) subsystems of a safety function.
Actuator Subsystems – Stop Cat. 1 via Kinetix 5000 Servo Drives with Hardwired Safe Torque Off Safety Function Application Technique, publication SAFETY-AT038	Provides information on how to combine a Guardmaster dual-input safety relay, a Guardmaster multifunction-delay expansion module, and the actuator (Kinetix 5500 or Kinetix 5700 servo drive with Safe Torque Off) subsystems of a safety function.
Kinetix 6200 and Kinetix 6500 Safe Torque Off Safety Reference Manual, publication 2094-RM002	Provides information on how the Kinetix 6200 and Kinetix 6500 drives can be used in Safety Integrity Level (SIL) CL3, Performance Level [PLe], or Category (CAT) 4 applications.
System Design for Control of Electrical Noise Reference Manual, publication GMC-RM001	Provides information, examples, and techniques designed to minimize system failures caused by electrical noise.
Kinetix Motion Control Selection Guide, publication KNX-SG001	Provides an overview of Kinetix servo drives, motors, actuators, and motion accessories designed to help make initial decisions for the motion control products best suited for your system requirements.
Motion System Tuning Application Technique, publication MOTION-AT005	Provides information on tuning a Kinetix drive system.
Integrated Motion on the EtherNet/IP Network Reference Manual, publication MOTION-RM003	Provides information on the AXIS_CIP_DRIVE attributes and the Studio 5000 Logix Designer application Control Modes and Methods.
Rockwell Automation Product Selection website http://www.rockwellautomation.com/global/support/selection.page	Provides online product selection and system configuration tools, including AutoCAD (DXF) drawings.
Motion Analyzer System Sizing and Selection Tool website https://motionanalyzer.rockwellautomation.com/	Comprehensive motion application sizing tool used for analysis, optimization, selection, and validation of your Kinetix Motion Control system.
Product Certifications website, rok.auto/certifications	Provides declarations of conformity, certificates, and other certification details.
Industrial Automation Wiring and Grounding Guidelines, publication 1770-4.1	Provides general guidelines for installing a Rockwell Automation industrial system.

You can view or download publications at http://www.rockwellautomation.com/global/literature-library/overview.page.

Notes:

Rockwell Automation Support

Use the following resources to access support information.

Technical Support Center	Knowledgebase Articles, How-to Videos, FAQs, Chat, User Forums, and Product Notification Updates.	www.rockwellautomation.com/knowledgebase
Local Technical Support Phone Numbers	Locate the phone number for your country.	www.rockwellautomation.com/global/support/get-support-now.page
Direct Dial Codes	Find the Direct Dial Code for your product. Use the code to route your call directly to a technical support engineer.	www.rockwellautomation.com/global/support/direct-dial.page
Literature Library	Installation Instructions, Manuals, Brochures, and Technical Data.	www.rockwellautomation.com/literature
Product Compatibility and Download Center (PCDC)	Get help determining how products interact, check features and capabilities, and find associated firmware.	www.rockwellautomation.com/global/support/pcdc.page

Documentation Feedback

Your comments will help us serve your documentation needs better. If you have any suggestions on how to improve this document, complete the How Are We Doing? form at http://literature.rockwellautomation.com/idc/groups/literature/documents/du/ra-du002_-en-e.pdf.

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