IMPULSE·VG+
Series 4
Adjustable Frequency/Vector Crane Controls

Yale® YK/Shaw-Box® SK Crane Kit Drive Synchronization Software Technical Manual

MAGNETEK

COLUMBUS McKINNON
CORPORATION

FAMILY OF BRANDS

CM BUDGIT Hoists CHESTER HOIST COFFING HOISTS UNIFIED Yale® SHAW-BOX MAGNETEK

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PREFACE AND SAFETY

Product Safety Information

Magnetek, Inc. (Magnetek) offers a broad range of radio remote control products, control products and adjustable frequency drives, and industrial braking systems for material handling applications. This manual has been prepared by Magnetek to provide information and recommendations for the installation, use, operation and service of Magnetek's material handling products and systems (Magnetek Products). Anyone who uses, operates, maintains, services, installs or owns Magnetek Products should know, understand and follow the instructions and safety recommendations in this manual for Magnetek Products.

The recommendations in this manual do not take precedence over any of the following requirements relating to cranes, hoists, lifting devices or other equipment which uses or includes Magnetek Products:

- Instructions, manuals, and safety warnings of the manufacturers of the equipment where the Magnetek Products are used,

- Plant safety rules and procedures of the employers and the owners of the facilities where the Magnetek Products are being used,

- Regulations issued by the Occupational Health and Safety Administration (OSHA),

- Applicable local, state, or federal codes, ordinances, standards and requirements, or

- Safety standards and practices for the industries in which Magnetek Products are used.

This manual does not include or address the specific instructions and safety warnings of these manufacturers or any of the other requirements listed above. It is the responsibility of the owners, users and operators of the Magnetek Products to know, understand and follow all of these requirements. It is the responsibility of the employer to make its employees aware of all of the above listed requirements and to make certain that all operators are properly trained. **No one should use Magnetek Products prior to becoming familiar with and being trained in these requirements and the instructions and safety recommendations for this manual.**

Product Warranty Information

Magnetek, hereafter referred to as Company, assumes no responsibility for improper programming of a drive by untrained personnel. A drive should only be programmed by a trained technician who has read and understands the contents of this manual. Improper programming of a drive can lead to unexpected, undesirable, or unsafe operation or performance of the drive. This may result in damage to equipment or personal injury. Company shall not be liable for economic loss, property damage, or other consequential damages or physical injury sustained by the purchaser or by any third party as a result of such programming. Company neither assumes nor authorizes any other person to assume for Company any other liability in connection with the sale or use of this product.

For information on product warranties by product type, please visit www.columbusmckinnon.com.

DANGER, WARNING, CAUTION and NOTE Statements

Read and understand this manual before installing, operating, or servicing this product.

The following conventions indicate safety messages in this manual. Failure to heed these messages could cause fatal injury or damage products and related equipment and systems.

DANGERS, WARNINGS and CAUTIONS

<u>Throughout this document DANGER, WARNING and CAUTION statements have been deliberately placed to highlight items critical to the protection of personnel and equipment.</u>

⚠ **DANGER**

DANGER indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations.

⚠ WARNING

WARNING indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

⚠ CAUTION

CAUTION indicates a potentially hazardous situation which, if not avoided, could result in minor or moderate injury. It may also be used to alert against unsafe practices.

NOTICE

NOTICE indicates an equipment damage message.

NOTE: *A NOTE statement is used to notify people of installation, operation, programming or maintenance information that is important, but not hazard-related.*

Table of Contents

1 Product Overview

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⚠️**WARNING**

Improper programming of a drive can lead to unexpected, undesirable, or unsafe operation or performance of the drive.

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1.1 Introduction to Drive Synchronization

Synchronization Software allows one or more IMPULSE® VG+ Series 4 driven motors to be synchronized to a Master Encoder signal. The Master Encoder provides a pulse reference to the Follower Variable-Frequency Drives (VFDs), which results in each Follower VFD commanding its motor to rotate at the speed determined by the pulse reference. The Follower VFD monitors the pulse feedback from both the Master Encoder and its own encoder while also sending timing status information back to the Master. The Follower will then compensate for any position errors by adjusting its motor's speed, resulting in near perfect alignment between the Master and the Follower motor shafts.

1.2 Automatic Re-Synchronization

Automatic Re-Synchronization is a means that the Follower drive uses to track its position relative to the Master drive. When both drives are running there is no accumulation of position error, so alignment will always be maintained. The Follower VFD possesses the ability to automatically re-synchronize the motors. This feature is accomplished by storing the position error generated when either the Master or the Follower hoists are run independently. (The position error may also be stored in memory while the VFD is powered down, but cannot keep track of shaft movements while powered down when option card PS-A10L or PS-A10H is not used). When the hoists are again run together, the Follower VFD is first commanded to run in order to cancel the accumulated position error with the Master VFD via the automatic re-synchronization process. Once the position error has been resolved, the Follower VFD will turn its Follower Ready Multi-Function Digital Output (MFDO) on and the Master VFD will begin to run at the commanded speed and direction. The Follower VFD will again track the pulse reference generated by the Master.

> *NOTE: While running in synchronization mode (C15-14 = 0), the speed at which the Follower VFD is allowed to cancel the accumulated position error is limited to 4 Hz. This allows the Follower motor to potentially rotate up to four (4) Hz faster than the Master in order to compensate for position error. While re-synchronizing, the speed at which the Follower is allowed to cancel the accumulated position error is limited to the Proportional and Integral Limits to allow for a faster Re-Synchronization. It is a good practice to manually align the hoists by eye to get them close to their respective positions and then let automatic Re-Synchronization finish eliminating the position error.*

1.3 Setting Position Error

If Automatic Re-Synchronization is enabled (C15-14 = 1 or 2), any position error is stored in the Follower VFD. The position error will be cleared by running the hoists in synchronization mode and allowing the Follower to cancel the error, but the error may be cleared by two other methods:

- Auto Re-Synchronization enabled (C15-14 = 1): The position error will be cleared by an Upper Limit 2 input (MFDI 7 or B – Upper Limit Stop) when the run command is removed. This acts as a "home" position for the hoists at which they (Followers) will begin operation with no accumulated error.

- Auto Re-Synchronization enabled by MFDI (C15-14 = 2): With this option, an MFDI (H01-xx = 78) to the Follower(s) is programmed to clear the accumulated error. This allows the hoists to be set to any position (aligned with or offset from each other) and have the accumulated error cleared. The hoists will then run at this set position while in hoist synchronization mode. If position error is not stored in memory during power-down (C15-17 = 0), position error will always be zero upon power-up.

1.4 Electronic Gearing

The Follower VFD also possesses an electronic gearing feature. This allows the Follower to operate at a ratio of the Master to accommodate differences in hoist speeds. Two separate ratios may be used if the Follower is required to follow different Masters. The software can also accommodate encoders with Pulses Per Revolution (PPR) that differ from the Follower VFD.

> **NOTE:** If multiple Masters are used, they must have an identical PPR.

1.5 How TO Apply this Software

- Speed Matching – Two (2) or more independent systems, such as independent hoists, bridges, or trolleys that are not mechanically linked or bound together.

- System needs to be able to correct error without being mechanically bound (for example, through the wheels of an end truck).

- Bridge applications where two synchronized motors are driving opposite end trucks.

> **NOTE:** This does not compensate for SKEW.

1.6 How NOT to Apply this Software

- Load Sharing – Two (2) or more coupled systems (coupled by mechanical synchronization).

- Motor shafts directly coupled.

- Motor shafts coupled through gearing and wheels on the same runway.

- Bridge applications where two synchronized motors are driving the same end truck.

1.7 Terms

DIO: Digital Input/Output Terminal

Master: A VFD that controls one or more Follower VFDs

MFAI: Multi-Function Analog Input

MFAO: Multi-Function Analog Output

MFDI: Multi-Function Digital Input

MFDO: Multi-Function Digital Output

PPR: Pulses Per Revolution

Follower: A VDF that follows commands from a Master VFD

VFD: Variable Frequency Drive

2 Parameters

2.1 Programming Parameters

Parameter	Display	Description	Range	Initial Value
C15-01	Sync Mode	Synchronization Mode Selection	0–2	0
	0 Master Only	Master Mode Only		
	1 Follower Enable MFI	Follower Mode enabled by MFDI		
	2 Follower Only	Follower Mode Only		
C15-02	Master Encoder	The number of output pulses per revolution from the Master Encoder. Copy the setting of F01-01 from the Master VFD to C15-02 of the Follower.	0–60000 PPR	1024
C15-03	Master # of Poles	The number of poles in the Master Motor. Copy the setting of E02-04 from the Master VFD to C15-03.	2–48	4
C15-04	Sync Ratio Num 1	Used in conjunction with C15-06 to set up the default sync ratio of the Follower. $$\text{Default Sync Ratio} = \frac{\text{Sync Ratio Num1 (C15-04)}}{\text{Sync Ratio Den (C15-06)}}$$ **NOTE:** *Sync Ratio Numerator 1 is active all the time. If the ratio is programmed to something other than 1:1, the Follower speed will be scaled to this value.* Example: With C15-04 = 4, and C15-06 = 1, the ratio will be 4/1, or 4. With this ratio, for every revolution of the Master, the Follower will make four (4) revolutions.	1–10000	1
C15-05	Sync Ratio Num 2	Used in conjunction with C15-06 to set up the alternate ratio of the Follower. $$\text{Alt Sync Ratio} = \frac{\text{Sync Ratio Num2 (C15-05)}}{\text{Sync Ratio Den (C15-06)}}$$ The Alternate Sync Ratio Numerator (C15-05) can be selected by setting MFDI (H01-xx = 79). All hoist motors must be stopped (zero speed) in order to switch gear ratios. A "Can't SW - Motor Running" alarm will be displayed on the keypad if trying to switch ratios "on the fly." Example: With C15-05 = 250, and C15-06 = 1000, the ratio will be 1/4, or 0.25. With this ratio, for every revolution of the Master, the Follower will make 0.25 revolutions.	1–10000	1
C15-06	Sync Ratio Den	This is the denominator for Sync Ratio Num 1 and Sync Ratio Num 2.	1–10000	1

Parameter	Display	Description	Range	Initial Value
C15-07	Position P Gain	Position Proportional Gain	0–100	10
		This increases the speed compensation based on the magnitude of the position error. Increasing the proportional gain makes the Follower more responsive to position errors.		
C15-08	Position I Time	Position Integral Time	0.00–100.00 sec	0.10
		The 'Integral Time' adjusts the Follower's speed reference to compensate for any position error between the Master and Follower over a given time period. Decreasing the integral time makes the Follower more responsive to position errors.		
C15-09	Proportional Lim	Limits the frequency output of the position regulator for High-Speed Re-Synchronizing. See C15-18 for detailed explanation of High-Speed Re-Synchronization.	0.000–30.000 Hz	22.500
C15-10	Integral Limit	Limits the integral output of the position regulator for High-Speed Re-Synchronizing. See C15-18 for a detailed explanation of High-Speed Re-Synchronization.	0.000–30.000 Hz	22.500
C15-11	Position D Time	Position Derivative Time	0.00–100.00 sec	0.00
		Provides control of the derivative function of the PID control loop. The derivative provides a means to stabilize the position error over a given time period. A setting of zero will disable the derivative.		
C15-12	Sync Err Det Lvl	Synchronization Error Detection Level	0–1000 rev	1
		Sets the maximum allowable position error in motor revolutions between the Master and the Follower before posting an "Out of Sync" alarm or fault. Once this level is exceeded, the Follower will respond according to the C15-13 setting. Use caution not to set this parameter to an unsafe level.		
C15-13	Sync Err Action	Synchronization Error Action	0–2	2
		Selects the action when the position error between Master and Follower exceeds the sync error detection level (C15-12).		
	0 *None*	No fault or alarm		
	1 *Alarm Only*	Alarm Only		
	2 *Fault*	Fault		
		NOTE: *A setting of 0 or 1 should only be used for troubleshooting purposes.*		

Parameter	Display	Description	Range	Initial Value
C15-14	Auto Resync	Auto-Resynchronization Selection	0–2	0
		The Follower can be configured to accumulate or ignore position errors when it is under power but not running in synchronization mode. When set to 1 or 2, the Follower will monitor the position of both the Master and the Follower motors. If a position error develops via movement of the Master or Follower, the Follower will correct the position error at the initiation of a run command.		
	0 Disabled	The Follower holds the position error to zero when either drive is operating independently.		
	1 Enabled 0 by UL2	Allows the user to clear accumulated position error by running the hoists to the Upper Limit 2.		
	2 Enabled 0 by MFI	Allows the user to clear the accumulated position error at any point by using MFDI (H01-xx = 78).		
C15-15	Switching Speed	The Master motor must be rotating at or less than this speed in order to switch from a Master to a Follower, or vice versa. If the user attempts to switch from a Follower to a Master while above this speed, a fault will display "Can't SW – Motor Running" and the motor will coast to a stop and require a new run command. If the user attempts to switch from a Master to a Follower, the same fault will be displayed and the motor will coast to a stop, but a new run command will not be required. The Follower's motor speed must be below this level before it will follow a speed reference other than the Master.	0.0–10.0 Hz	0.5
C15-16	Adv/Ret TrimRate	The Follower can be Advanced or Retarded at this rate without accumulating position error. The Adv/Ret Trim Rate is entered in pulse counts/10 ms.	0–1000 Pulse/ 10 ms	20
C15-17	Store Pos Err	Stores Synchronization Position Error Selection	0, 1	1
	0 Disabled	No position error is stored.		
	1 Enabled	Position error between the Master and Follower is stored on power-down.		
C15-18	H-Spd Resync Rev	High-Speed Re-Synchronization Level	0–60000 rev	5
		When the Follower's Synchronization Error Revs (U07-04) is greater than the High-Speed Synchronization Rev level (C15-18), the Follower will re-synchronize its position with the Master at a high speed. Limits are set by C15-09 and C15-10.		

Parameter	Display	Description	Range	Initial Value
C15-19	RunFollower Off Dly	The Run Follower MFDO (H02-xx = 16) will stay on for this set duration of time after the Master reaches Load Float at the end of a run. This will allow the Follower drive to sync to the Master's position while in Load Float. If this delay is too short, the Follower may become slightly out of sync after every run. Setting C15-14 = 1 or 2 will cause the Follower to sync to the Master's position on every run.	0.0–10.0 sec	0.5

2.2 Digital Input (DI-A3 and S4IO) Option Setup

Parameter	Display	Description	Range	Initial Value
C09-01	Digital In Sel	Provides additional programmable MFDI.	0–2	0
	0 Disabled	No additional MFDI are being used.		
	1 Enabled S4IO	S4IO or S4I card is enabled.		
	2 Enabled DI-A3	DI-A3 card is enabled.		

Parameter	Display	Terminal Designation			Range	Initial Value
		DI-A3	S4I	S4IO		
C09-02*	DIO Terminal 1	0	I1	I1	00–FF	F
C09-03*	DIO Terminal 2	1	I2	I2	00–FF	F
C09-04*	DIO Terminal 3	2	I3	I3	00–FF	F
C09-06*	DIO Terminal 4	3	I4	I4	00–FF	F
C09-06*	DIO Terminal 5	4	-	-	00–FF	F
C09-07*	DIO Terminal 6	5	-	-	00–FF	F
C09-08*	DIO Terminal 7	6	-	-	00–FF	F
C09-09*	DIO Terminal 8	7	-	-	00–FF	F
C09-10*	DIO Terminal 9	8	-	-	00–FF	F
C09-11*	DIO Terminal 10	9	-	-	00–FF	F
C09-12*	DIO Terminal 11	A	-	-	00–FF	F
C09-13*	DIO Terminal 12	B	-	-	00–FF	F
C09-14*	DIO Terminal 13	C	-	-	00–FF	F
C09-15*	DIO Terminal 14	D	-	-	00–FF	F
C09-16*	DIO Terminal 15	E	-	-	00–FF	F
C09-17*	DIO Terminal 16	F	-	-	00–FF	F

* See Table 5-67 in the Series 4 Advanced Instruction Manual for MFDI selections.

2.3 Digital Output (DO-A3) Option Setup

Parameter	Display	Terminal Designation		Range	Initial Value
		DO-A3	S4IO		
F05-01*	DO Ch1 Select	M1-M2	O1-O2	0–148	F
F05-02*	DO Ch2 Select	M3-M4	O3-O2	0–148	F
F05-03*	DO Ch3 Select	P1-PC	O4-O5	0–148	F
F05-04*	DO Ch4 Select	P2-PC	O6-O5	0–148	F
F05-05*	DO Ch5 Select	P3-PC	-	0–148	F
F05-06*	DO Ch6 Select	P4-PC	-	0–148	F
F05-07*	DO Ch7 Select	P5-PC	-	0–148	F
F05-08*	DO Ch8 Select	P6-PC	-	0–148	F
F05-09*	DO Function Sel 0 8ch Individual 1 Binary Output 2 8ch Selected	Selects how the DO-A3 option card will work with the drive.		0–2	2

* See Table 5-71 in the Series 4 Advanced Instruction Manual for MFDO selections.
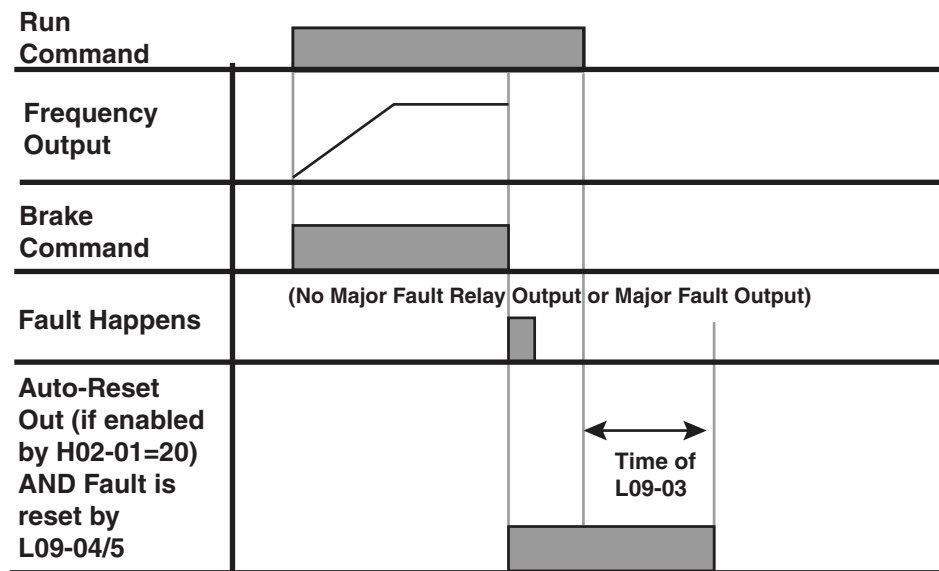
2.4 Automatic Fault Reset

When a fault occurs during operation, the IMPULSE® VG+ Series 4 can be programmed for an auto-reset operation to automatically reset the fault.

Parameter	Display	Description	Range	Initial Value
L09-01	Reset Select 0 Disabled 2 Enabled	Activates the fault auto-reset function.	0, 1	1
L09-02	Reset Attempts	Sets the number of reset attempts. Reset attempt counter returns to zero if no faults occur within 10 minutes.	0–10	3
L09-03	Reset Time	Sets the reset starting time.	0.5–180.0 sec	0.5
L09-04*	Reset Flt Sel 1	Reset Fault Select 1.	0–FFFF	1001
L09-05*	Reset Flt Sel 2	Reset Fault Select 2.	0–FFFF	E000
L09-06	Flt Contact Sel 0 Flt Outp Disabld 1 Flt Outp Enabled	Fault contact operation during reset attempts	0, 1	0

* To program L09-04 and L09-05, refer to the example on the following page and follow steps 1 through 4:

1. Assign 1 to each fault code to enable the auto-reset.
2. Assign 0 to each fault code to disable the auto-reset.
3. Convert all digits (1 to 4) from binary to hexadecimal.
4. Program L09-04 and L09-05 by entering the hexadecimal number obtained from step 3.

Run Command	
Frequency Output	
Brake Command	
Fault Happens	(No Major Fault Relay Output or Major Fault Output)
Auto-Reset Out (if enabled by H02-01=20) AND Fault is reset by L09-04/5	Time of L09-03

Figure 2-1: Automatic Fault Reset

Example:

Enable auto-reset for Cant SW, UV1, and CE faults.

Table 2-1: Auto-Reset Programming

	Digit 4				Digit 3				Digit 2				Digit 1			
Hex	1				0				0				1			
Binary	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
L09-04	EFO	-	-	CANTSW	LF	PF	UT1	UT2	OH1	SC	OV	GF	OC	UV3	UV2	UV1
Hex	0				0				8				0			
Binary	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
L09-05	BE1	BE2	BE3	BE4	OL1	OL2	OT1	OT2	CE	CALL	EFF8	EFF7	EFF6	EFF5	EFF4	EFF3

Table 2-2: Auto-Reset Programming Summary

L09-04	Binary	Hex	L09-05	Binary	Hex
Digit 4	0001	1	Digit 4	0000	0
Digit 3	0000	0	Digit 3	0000	0
Digit 2	0000	0	Digit 2	1000	8
Digit 1	0001	1	Digit 1	0000	0

Table 2-3: Binary to Hexadecimal Conversion

Binary Number	Hexadecimal Number
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	A
1011	B
1100	C
1101	D
1110	E
1111	F

2.5 Monitor Parameters

Parameter	Display	Description	Units	Range
U01-01	Frequency Ref	While in synchronization mode, the Follower frequency reference after the gear ratio and proportion/integral compensation displays at U01-01.	0.01 Hz	0–E01-04
U01-25	Opt In Low	Displays the reference value input from the DI option card (DI-A3, S4I, or S4IO) lower 8 bits.	binary	00000000–11111111
U01-26	Opt In High	Displays the reference value input from the DI option card (DI-A3, S4I, or S4IO) upper 8 bits.	binary	00000000–11111111
U07-01	Master Reference	Displays the frequency reference from the Master motor prior to gear ratio adjustments. The Follower motor speed will not exceed its maximum output frequency based on E01-04.	0.01 Hz	-400.00–400.00
U07-02	Gear Ratio Ref	Displays the frequency reference from the Master drive after gear ratio adjustments. The Follower motor speed will not exceed its maximum output frequency based on E01-04.	0.01 Hz	-400.00–400.00
U07-03	Sync Error Cnts	Displays the error (in encoder pulses) between the Master and Follower to allow for monitoring of position error while it is less than one revolution. Monitoring this while running can help correct overshoot/undershoot problems when tuning the P/I regulator.	1 Pulse	-4096–4096
U07-04	Sync Error Revs	Displays the error (in motor revolutions) between the Master and Follower to allow for monitoring of position error while it is greater than one revolution. Monitoring this during automatic re-synchronization will indicate how close (or far) the Follower is from being re-synchronized to the Master.	1 Rev	-65535–65535
U07-05	Proportion Corr	Displays the frequency adjustment to the Follower's speed reference based on the proportional gain setting.	0.001 Hz	-30.000–30.000
U07-06	Integral Correct	Displays the frequency adjustment to the Follower's speed reference based on the integral time setting.	0.001 Hz	-30.000–30.000

2.6 Multi-function Digital Inputs (MFDI) Selectable for H01-0x and C09-0x

Setting Value	Display	Function
76	Follower Ready In	Open: Follower is not ready. Master should hold the current position until Follower Ready signal is received.
		Closed: Follower inverter is ready and waiting to follow the Master.
77	Sync Mode Enable	Open: Drive becomes a Master.
		Closed: Drive becomes a Follower (C15-01 = 1) enabled by MFI.
78	Clear Sync Error	Open: Position error accumulates.
		Closed: The accumulated position error resets.
79	Sync Ratio Num 2	Open: Sync Ratio Numerator 1 is used (C15-04).
		Closed: Sync Ratio Numerator 2 is used (C15-05).
7A	Sync Advance	Open: Normal synchronization.
		Closed: Follower will increase motor position without accumulating position error.
7B	Sync Retard	Open: Normal Synchronization.
		Closed: Follower will decrease motor position without accumulating position error.
7C	Sync Ultra-Lift	If using Ultra-Lift during synchronization mode, take some precautions. Configure Ultra-Lift so that it will not be automatically enabled unless there is a near-empty hook. It is crucial that the Follower has enough motor torque above base speed to not only maintain and lift the load, but also to correct for position error. For this reason, in independent mode, set the Ultra-Lift Enabling Torque so Ultra-Lift is not enabled when a load is present. The Master and Follower(s) must also be interlocked. Each Follower must be configured with an output (MFDO 3C - Sync Ultra-Lift) that will permit the Master to utilize Ultra-Lift Speeds. The Master must then accept this signal via MFDI 7C Sync Ultra-Lift. If using multiple Followers, the output signals must be wired in series.
		Open: Ultra-Lift is disabled.
		Closed: Follower indicates to Master that it has sufficient torque to use Ultra-Lift.
7D	Sync Slack Cable	If using Slack Cable detection during synchronization mode, use interlock wiring. This input will cause the Master to act according to the setting of C11-02. An 'SLC2 - Slack Cable Det' Alarm will display on the keypad.
		Open: Operation is normal.
		Closed: Follower indicates to Master that it has detected a Slack Cable condition.
7E	Sync Load Check	If using Load Check II detection during synchronization mode, use interlock wiring. This input will cause the Master to act according to the setting of C05-02. An 'LC2 - Load Check Det' Alarm will display on the keypad.
		Open: Operation is normal.
		Closed: Follower indicates to Master that it has detected a Load Check condition.

2.7 Multi-function Digital Outputs (MFDO) Selectable for H02-0x and F05-0x

Setting Value	Display	Function
15	Follower Ready Out	Open: Follower is not ready. Master should hold the current position until Follower Ready signal is received.
		Closed: Follower inverter is ready and waiting to follow the Master.
16	Run Follower	Open: No run command to Follower(s).
		Closed: Command Follower(s) to Run.
17	Out of Sync	Open: Operation is normal.
		Closed: An "Out of Sync" Alarm or Fault condition is present.
27	Load Check Det	If using Load Check II during synchronization mode, take some precautions. Configure Load Check II so that if a Load Check condition is encountered by the Follower that the Master will stop accelerating and hold speed. This output must be wired in series to the Master. The Master must then accept this signal via MFDI 38 Acc/Dec Ramp Hold.
		NOTE: Load Check II used in conjunction with synchronization may not work in all applications. Careful review of the application should precede the use of Load Check II. All hoists should be of equal speed.
		Open: Normal operation.
		Closed: Load Check condition detected. The Follower indicates to the Master that it has a Load Check condition and that it is performing a check.
3C	Sync Ultra-Lift	If using Ultra-Lift during synchronization mode, take some precautions. Configure Ultra-Lift so that it will not be automatically enabled unless there is a near-empty hook. It is crucial that the Follower has enough motor torque above base speed to not only maintain and lift the load, but also to correct for position error. For this reason, in independent mode, set the Ultra-Lift Enabling Torque so Ultra-Lift is not enabled when there is a load present. The Master and Follower(s) must also be interlocked. Each Follower must be configured with an output (MFDO 3C - Sync Ultra-Lift) that will permit the Master to utilize Ultra-Lift Speeds. The Master must then accept this signal via MFDI 7C Sync Ultra-Lift. If using multiple Followers, the output signals must be wired in series. This will ensure that ALL Followers are capable of Ultra-Lift.
		NOTE: Ultra-Lift used in conjunction with synchronization may not work in all applications. Careful review of the application should precede the use of Ultra-Lift. All hoists should be of equal speed.
		Open: Ultra-Lift is disabled - Follower is indicating to Master that it has insufficient torque available to use Ultra-Lift.
		Closed: Follower is indicating to Master that it has sufficient torque to use Ultra-Lift.

3 Alarms, Faults and OPE Conditions

3.1 Alarms

Alarm Display	Description	Master/Follower	Cause	Corrective Action
SYNC	Out of Sync	Follower	The position error between the Master and Follower exceeded the allowable amount programmed in C15-12.	1. Check for proper encoder feedback from Master and Follower(s). Test all hoists individually for proper functionality. 2. Check for physical obstruction of the Follower motion, i.e., Brake, Load Hang-up. 3. Ensure that the load is not too heavy. 4. Decrease acceleration/deceleration time(s) on Master (B05-01 and B05-02). 5. The maximum speed of the Master drive (E01-04) should be set to at least 4 Hz less than the Follower(s) to allow for correction of position error.
SNR	Follower Not Ready	Master	1. The Master is waiting for the Follower Ready signal (this may be normal for a short time at start). 2. While running, the 'Follower Ready' input is lost or has detected a problem.	1. Is there a problem with the Follower motion? Alarm/Fault, etc.? **NOTE:** *Verify proper interlock wiring scheme and wiring itself. Follower should shut down Master if it has certain alarm/faults present.* 2. Check the wiring between the Master and Follower(s). 3. Verify that the Follower Ready terminal is functioning properly. Verify change in state by monitoring U01-10 or U01-25 and U01-26.

Alarm Display	Description	Master/Follower	Cause	Corrective Action
Load Share	Load Share/Sync	Master or Follower	Using Load Sharing and Synchronization simultaneously.	Load Sharing and hoist synchronization are not compatible and cannot be used simultaneously. 1. Ensure that Load Sharing mode is disabled during Synchronization (terminal with H01-0x = 66 is OFF during Synchronization).
SLC2	Sync Slack Cable	Master	One of the Follower VFDs has detected a slack cable condition and is signaling the Master to take action set by C11-02.	1. There is a Slack Cable condition on one of the Follower hoists (SLC). 2. This may be normal operation. Take up the slack. 3. Check wiring. 4. Verify Slack Cable parameter settings.
LC2	Sync Load Check	Master	One of the Follower VFDs has detected a Load Check condition and is signaling the Master to take action set by C05-02.	1. There is a Load Check condition on one of the Follower hoists (LC). 2. The hoist is overloaded. Set the load down. 3. Check wiring. 4. Verify Load Check parameter settings.

3.2 Faults

Fault Display	Description	Master/Follower	Cause	Corrective Action
Can't SW	Motor Running	Master or Follower	1. Switching between synchronization mode and normal operation while in motion. 2. Switching between gear ratio 1 and gear ratio 2 while in motion.	1. Do not switch modes while in motion. 2. Increase C15-15 for instability at zero speed.
SYNC	Out of Sync	Follower	The position error between the Master and Follower exceeded the allowable amount programmed in C15-12.	1. Check for proper encoder feedback from Master and Follower(s). Test all hoists individually for proper functionality. 2. Check for physical obstruction of the Follower motion, i.e., Brake, Load Hang-up. 3. Ensure that the load is not too heavy. 4. Increase acceleration/deceleration time(s) on Master. 5. The maximum speed of the Master drive (E01-04) should be set to at least 4 Hz less than the follower(s) to allow for correction of position error.
LC2	Sync Load Check	Master	One of the Follower VFDs has detected a Load Check condition and is signaling the Master to take action set by C05-02.	1. There is a Load Check condition on one of the Follower hoists (LC). 2. The hoist is overloaded. Set the load down. 3. Check wiring. 4. Verify Load Check parameter settings.

3.3 OPE Errors

Alarm Display	Description	Master/Follower	Cause	Corrective Action
OPE12	Sync & Slack Cable	Master or Follower	Master: Drive is programmed for Slack Cable and requires an MFDI to be programmed for Sync Slack Cable In (H01-0x or C09-0x = 7D). Follower: Drive is programmed for Slack Cable and requires an MFDO programmed for Slack Cable Detect (H02-0x or F05-0x = 28).	Special programming/wiring is required to use Slack Cable and hoist synchronization. 1. Ensure that the proper wiring scheme is in place to utilize Slack Cable. 2. Set H02-0x = 28 or H1-0x = 7D and ensure proper interlock wiring is used.
OPE13	Sync & Ultra-Lift	Master or Follower	Master: Drive is programmed for Ultra-Lift and requires an MFDI to be programmed for Sync Ultra-Lift (H01-0x or C09-0x = 7C). Follower: Drive is programmed for Ultra-Lift and requires an MFDO to be programmed for Sync Ultra-Lift (H02-0x or F05-0x = 3C).	Special programming/wiring is required to use Ultra-Lift and hoist synchronization. 1. Ensure that the proper wiring scheme is in place to utilize Ultra-Lift. 2. Set H01-0x = 7C or H02-0x = 3C or both according to interlock wiring requirements.
OPE14	Sync & Load Check	Master or Follower	Master: Drive is programmed for Load Check and requires an MFDI to be programmed for Sync Load Check In (H01-0x or C09-0x = 7E). Follower: Drive is programmed for Load Check and requires an MFDO to be programmed for Load Check Det (H02-02 or F05-0x = 27).	Special programming/wiring is required to use Load Check and hoist synchronization. 1. Ensure that the proper wiring scheme is in place to utilize Load Check. 2. Set H02-0x = 27 or H01-0x = 7E and ensure proper interlock wiring is used.

4 Configuration/Operation Notes

1. The Master drive requires one PG-X3 card. All Master/Follower and Follower drives require two PG-X3 cards. Each drive will output its current motor position. This will cause some propagation delay down the line. At this time it is unknown how long the propagation delay will be.

2. The PG-X3 in slot CN5-C must always be used for motor feedback. The PG-X3 in CN5-B must always be used for frequency reference from the Master drive or Follower drive upstream.

3. When multiple Masters are used, each Master Encoder must have the same PPR.

4. When the Master operates in its normal forward direction, monitor U07-03 of the Follower should display a positive value. If it does not, it may be necessary to reverse the channel A wires at terminals 1 and 2 of the Follower's PG-X3.

5. When running the Master independently, the Follower Ready Input signal needs to be forced "On/Closed" with external logic. In the event that the Master is capable of becoming a Follower (H01-0x = 77 - Sync Mode Enable), forcing this input on is not necessary since the VFD knows which mode it should be in based on this input. When it doesn't have this input (H01-0x = 77), it assumes it is always a Master and will wait for the Follower Ready Input signal before moving.

6. When controlling identical systems, keep parameters identical whenever possible. Possible exceptions include programming the multi-function inputs/outputs and the motor tuning parameters.

7. If the Follower's U07-03 display is positive, when the drive is commanded to run via input to terminal S1, the motor should rotate in the proper direction and the Follower's U01-05 monitor should display a positive value. If the motor direction is incorrect, it may be necessary to reverse any two of the motor leads on the VFD output. If the motor fails to rotate, or is unstable, it may be necessary to reverse the channel A wires at terminals 1 and 2 of the PG-X3.

8. Slow-down and stop limit inputs are ignored in the Follower(s) during synchronization mode. The limits will be observed in the Master drive, causing the Master reference to decrease and the Follower to follow.

   > **NOTE:** *UL3 - Upper Limit 3 (Weighted Limit) is always active for both Master and Follower. For the Follower, slow-down/stop limits and their respective deceleration times will be observed during automatic re-synchronization. During automatic re-synchronization, if the motor speed is greater than the slow-down limit speed, the P and I limits will be limited to 1/2 the respective slow-down limit speed.*

9. For the Follower, the only reference used is the pulse input from the Master drive. All other external references will be ignored.

10. For the Master, Max Frequency (E01-04) should be set 4 Hz less than the Follower(s) to allow for correction of position error between the drives. Note that this value will change after an auto-tune is performed and should be changed back to having a 4 Hz difference from the Follower(s). When multiple Masters are possible, it may become necessary to leave E01-04 identical for all Masters and Followers and limit the maximum speed reference possible through B02-01 or B02-04.

    > **NOTE:** *B2 group parameters do not affect synchronization speed references (during synchronization mode).*

11. When using Load Check II on the Follower, it may be necessary to set the holding and settling timers slightly shorter than the Master on each of the Follower drives. This will ensure that the Follower(s) are finished checking the load prior to the Master accelerating to the next look speed. Also note that the degree of accuracy will not be as good as the Master due to the fact that the Follower is still correcting for position error even while the Master is being held at a constant speed.

    > **NOTE:** *If the Follower detects a Load Check Err, it will not stop its own motion; instead, it will display Load Check on the keypad and turn on an MFDO set for Load Check. This signals the Master to stop while maintaining synchronization.*

12. Weight Measurement and Load Check are disabled during Automatic Re-Synchronization.

13. When using Synchronized Weight Measurement, use Automatic Weight Measurement (C10-01 = 1) rather than by MFDI, as "Out of Sync" faults may occur due to constant position correction.

14. Follower Ready output: When Automatic Re-Synchronization is used, the Follower Ready output will remain off until position error is cancelled. If the Follower is in an upper or lower limit condition (UL2/ LL2), the Follower may not be able to re-synchronize in the appropriate direction. In this case, the Follower Ready signal will be energized during re-synchronization, thus causing the Master and Follower to move simultaneously and additional position error may be accumulated without causing an "Out of Sync" fault.

    > NOTE: Proper operation should correct error as the hoists move off of the limit switches, but it may take some time to align the hooks depending on how far apart they are.

15. If the Master is capable of being powered down independently from the Follower, a PGO-2-H fault will occur on the Follower if F01-16 = Enabled and the Follower is in synchronization mode (C15-01 = 2 or H1-0x = 77 is on). When F01-16 = Enabled and synchronization mode is not enabled, PGO-2-H will function normally. If synchronization is Enabled by MFDI, but is not in synchronization mode (Follower may be in independent mode), PGO-2-H is automatically disabled so the Master may be powered down. If PGO-2-H faults are occurring, make certain that the controls are not in synchronization mode while powering down the Master VFD.

16. Sync Ultra-Lift is not backwards-compatible with the IMPULSE® Series 2 Drives; an IMPULSE® Series 3 or Series 4 Master and Follower VFD is required. When using Sync Ultra-Lift Enable, and when running the Master independently, the Enable signal must be "ON" in order to use Ultra-Lift. In some applications, it may not be possible to use Ultra-Lift. Configure Ultra-Lift to only allow running above base speed with NO load.

17. If the user has switched modes while running (switched from independent to synchronization mode by MFDI 77 - Sync Mode Enable), a "Can't Switch - Motor Running" alarm will be displayed until motion has stopped. The run command must be cycled at this point to completely switch to synchronization mode. This will allow the Follower Ready output to turn on.

18. Slack Cable is generally intended for hoists with below-the-hook attachments and may not be a good application for synchronization. If attempting it, use interlocking wiring of the Master and Follower(s). For the Follower(s), Slack Cable may be detected during automatic re-synchronization. In this case, the Master will be stopped (waiting for the Follower Ready) and cannot take action until it is run. This is a rare circumstance, but use caution when using Slack Cable and automatic re-synchronization if it is possible for the Master hook position to hang lower than the Follower(s) and a slack condition may occur.

19. In a Follower drive (C15-01 = 1), loss of the Sync Enable signal will not stop the motor; it will continue to follow the Master until motion stops. Loss of the Run Follower signal will stop the Follower, regardless of the Sync Enable status or Encoder signal.

20. Sync Load Check II is not backwards-compatible with IMPULSE® Series 2 and Series 3 drives.

5 Hardware

5.1 PG-X3
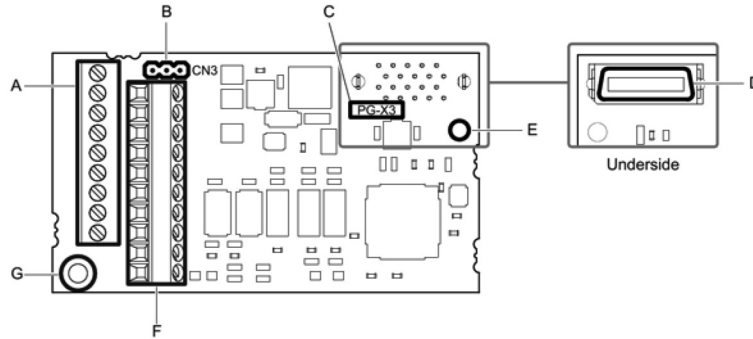
A – Terminal block TB1

B – Jumper for PG power supply voltage (CN3)
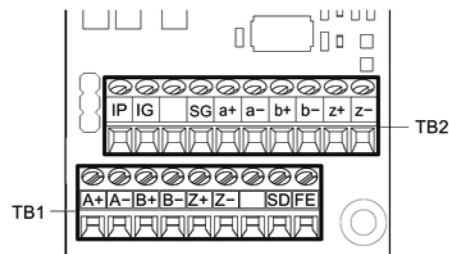
C – Model number

D – Connector (CN5)

E – Installation hole

F – Terminal block TB2

G – Ground terminal (installation hole)*

* Terminal for ground wire packaged with the option card.

Figure 5-1: PG-X3 Option Components

5.2 Terminal Blocks TB1 and TB2

Figure 5-2: Terminal Blocks

Table 5-1: Option Terminal Functions

Terminal Block	Terminal	Function	Description
TB1	A+	A pulse signal input	• Inputs for the A channel, B channel, and Z pulses from the PG • Signal level matches RS-422
	A-	A inverse pulse signal input	
	B+	B pulse signal input	
	B-	B inverse pulse signal input	
	Z+	Z pulse signal input	
	Z-	Z inverse pulse signal input	
	SD	NC pin (open)	Open connection port for use when cable shields should not be grounded
	FE	Ground	Used as the shield ground termination point
TB2	IP	PG power supply	• Output voltage: 12.0 V ± 5% or 5.5 V ± 5% • Max. output current: 200 mA*
	IG	PG power supply common	
	SG	Monitor signal common	• Output signal for monitoring A channel, B channel, and Z pulses from the PG • Signal level matches RS-422
	a+	A pulse monitor signal	
	a-	A pulse inverse monitor signal	
	b+	B pulse monitor signal	
	b-	B pulse inverse monitor signal	
	z+	Z pulse monitor signal	
	z-	Z pulse inverse monitor signal	

* A separate power supply is needed if the PG requires more than 200 mA to operate. Select a UL-listed class 2 power supply.

> **NOTE:** *The Z channel is not required for operation.*

6 Special Function Compatibility Table

While the Follower is in synchronization mode, it is required to follow the reference of the Master, hence many special functions are disabled in the Follower drive. The following table illustrates the functional limitations of the Master and Follower drive.

Special Function	MASTER Can Use During Sync Mode?	FOLLOWER Can Use During Sync Mode?	Remark
Accel/Decel: B5 Group, MFDI 1A, 1B, 1C, 40, 42	Yes	No	Follower needs to follow reference from Master (automatically disabled in sync mode).
Jump Frequencies: B8 Group	Yes	No	Follower needs to follow reference from Master (automatically disabled in sync mode).
Quick Stop: C01-01, C01-02	Yes	No	Follower needs to follow reference from Master (automatically disabled in sync mode).
Reverse Plug: C01-03–C01-05	Yes	No	Follower needs to follow reference from Master (automatically disabled in sync mode).
Micro-Speed: C2 Group, MFDI E, 10	Yes	No	Follower needs to follow reference from Master (automatically disabled in sync mode).
Travel Limits: C3 Group, MFDI 6–D, 12, 62	Yes	Yes	Slow-down and stop limits are disabled during Sync. UL3: always Active; LL1,LL2/UL1,UL2: active during automatic re-sync only.
Load Float: Automatic (C08-10) or MFDI 35	Yes	Yes	Follower needs to follow reference from Master (automatically disabled in sync mode).
Load Check II: C5 Group	Yes	Yes	Follower does not stop motion if LC detected. Alarm only action. Must interlock Master and Follower. Accuracy may not be as good in sync mode due to constant position correction.
Ultra-Lift: C6 Group	Yes	Yes	Master and Follower must be interlocked. Intended for No Load only. Be sure there is enough I/O.
Torque Limit: C7 Group, MFDI 14	Yes	Yes	-
No Load Brake Hoist: A01-03, C8 Group	Yes	Yes	-
Traverse: A01-03 = 0	Yes	Yes	-
Standard Hoist: A01-03 = 1 (hoist has a mechanical load brake)	Yes	Yes	Consult factory for special configuration for use with a mechanical load brake.
No Load Brake Hoist: A01-03 = 2	Yes	Yes	Consult factory for special configuration for use with a No Load Brake Hoist.

Special Function	MASTER Can Use During Sync Mode?	FOLLOWER Can Use During Sync Mode?	Remark
Brake Answerback: C8 Group, MFDI 58	Yes	Yes	BE4/BE5 must be interlocked from Follower to Master.
S4IO: C9 Group	Yes	Yes	-
Weight Measurement: C10 Group	Yes	Yes	Accuracy may not be not as good in sync mode due to constant position correction. Automatic measurement is recommended (C10-01 = 1). Measuring on the fly (by MFDI) may cause unwanted "Out of Sync" faults.
Slack Cable: C11 Group	Yes	Yes	Slack Cable interlock wiring must be in place. May not work consistently in sync mode. Depends on application. Intended for below-the-hook attachments.
Snap Shaft (Drive Train Discontinuity): C11 Group	Yes	No	Follower needs PG-X3 for Master reference (automatically disabled in sync mode).
Timer Functions: C12 Group	Yes	Yes	-
Maintenance Timer: C12-05, C12-06, MFDO 37	Yes	Yes	Follower will not be able to limit speed, only annunciate.
Inching/Indexing Control: C13 Group - MFDI 17–19, 60	Yes	No	Follower needs to follow reference from Master (automatically disabled in sync mode).
DC Injection: D1 Group	Yes	Yes	-
Slip Compensation: D2 Group	Yes	Yes	-
Automatic Speed Regulation (ASR): D4 Group	Yes	Yes	Uses Sync ASR + D4 Group.
Torque Control: D5 Group - MFDI 34	Yes	No	Recommended to oversize Follower to handle extremely fast acc/dec changes (automatically disabled in sync mode).
S-Curve Accel/Decel: D9 Group	Yes	No	Follower needs to follow reference from Master. Acc/Dec times are ignored in sync mode.
V/F Pattern: E1 Group	Yes	Yes	-
Serial/High Speed Communications: H5, F6 Group	Yes	Yes	Modbus TCP, PROFIBUS-DP, PROFINET, Ethernet/IP Master: Can be controlled serially Follower: Monitor only.
Pulse Input/Output: H6 Group	Yes	Yes	Follower needs to follow reference from Master (automatically disabled in sync mode).
Motor Overload Protection: L1 Group	Yes	Yes	-
PowerLoss RideThrough: L2 Group	Yes	Yes	Traverse only
Speed Agree: L4 Group	Yes	Yes	-

Special Function	MASTER Can Use During Sync Mode?	FOLLOWER Can Use During Sync Mode?	Remark
Under/Over Torque Detection: L6 Group, MFDI 70 - OT/UT 0/1	Yes	Yes	-
Hardware Protection: L8 Group	Yes	Yes	-
Automatic Fault Reset: L9 Group	Yes	Yes	-
Jog Control: B01-17, MFDI 15, 16	Yes	No	Follower needs to follow reference from Master (automatically disabled in sync mode).
Drive Enable: MFDI 55	Yes	Yes	-
Allow Run at Powerup: B03-10	Yes	Yes	-
F5 Digital Output Group	Yes	Yes	-
Phantom Fault: MFDI 5F, 63	Yes	Yes	-
BE6 Up Speed Limit: C08-17, MFDI 5B	Yes	Yes	The Follower needs to follow reference from the Master. If the Follower has BE6 detection, it must be interlocked with the Master. It will then limit the speed of the Master and its own speed is therefore limited by the Master. The input to the Follower is ignored while sync mode is enabled, but may be used if the Follower can become a Master.
Brake Test: MFDI 61	Yes	Yes	Brake test is only used while stopped, not during sync mode. It is a maintenance-only function.
Load Share: MFDI 66	Yes	No	Cannot be used during sync operation. If the Master is a Load Share drive, the Follower should be oversized to accommodate fast change in torque and quick response. Follower: If the Follower is also capable of Load Share, sync and Load Share cannot be used simultaneously. A "Load Share/Sync" alarm will occur.
Fault Annunciation: MFDO 40– FF	Yes	Yes	-
Load Cell: MFAI 16	Yes	Yes	-
Hook Height: MFAI 17	Yes	Yes	-
Local Remote Control by Mode/Service Key or by MFDI 31	Yes	Yes	The Follower needs to be commanded by the Master. Local/Remote will override sync mode. **NOTE:** *Switching on the fly by B03-09 = 1 will cause "Out of Sync" fault.*
Change Motor Rotation: B03-04	Yes	Yes	-
Change Encoder Phases: F01-05	Yes	Yes	-

Special Function	MASTER Can Use During Sync Mode?	FOLLOWER Can Use During Sync Mode?	Remark
Load Float Extension Time	Yes	Yes	Both the Master and Follower should be the same.
BE6/BE8 detection	Yes	Yes	Fault will be detected on the Master drive.
PGO Hardware failure detection for CH1 and CH2 of PG-X3	Yes	Yes	CH2 disabled when sync mode is disabled.
Load Catch	Yes	Yes	Must be interlocked like BE6. (BE8)
Test Mode - L5 Group	No	No	-

6.1 Typical Hoist Synchronization Interconnect

Yale® YK/Shaw-Box® SK Crane Kit Drive Synchronization Software Technical Manual
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