YASKAWA

Electronic Lineshaft With Alignment F7 Drive Software Technical Manual

Software Number: VSF11005X, Drive Models: CIMR-F7UXXXXXX-064, CIMR-F7UXXXXXX-065
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This document is intended to provide proper installation and use of the Yaskawa drive with custom software. This document is a supplement to the standard drive technical manual. It describes the effects on the drive parameters and functions with the software installed. Read and understand this document and the standard drive technical manuals before attempting to install, adjust, operate, inspect, or maintain the drive. ***Observe all cautions and warnings in this document and the standard drive technical manuals.*** *Custom software is written to add functionality to a standard AC drive to enhance or enable use in a specific application. The software is loaded to the flash ROM area of the control board, and replaces the standard drive software. Custom software can add new functions, modify standard functions, or even inhibit standard functions. It can be used to modify display text or parameter names. Custom software is usually loaded to the drive before delivery. The control board and drive nameplate are assigned unique part numbers and the software is registered, archived, and retrievable.*

When seeking support for a drive with custom software, it is imperative to provide the unique part number shown on the drive nameplate. The software has been flashed to the control board memory and the operation of parameters, functions, and monitors are different than the standard drive software, as described herein.

1.0 Overview

The Electronic Lineshaft (ELS) function allows a drive to precisely follow a master encoder (PG) signal in speed, direction, and phase. The follower can match its position (phase angle) to the master within several quadrature encoder counts. The function is used in applications where the machinery being driven requires two mechanically isolated, moving parts to maintain a constant position relationship. The gear ratio between the master and the follower is infinitely adjustable. In addition, a gear ratio adjustment ("draw") can be added to the speed reference via parameter, analog input, multi-function input, MOP, or network communication. The drive can also be run in a pure speed follower mode for applications that do not require matched position, only velocity following.

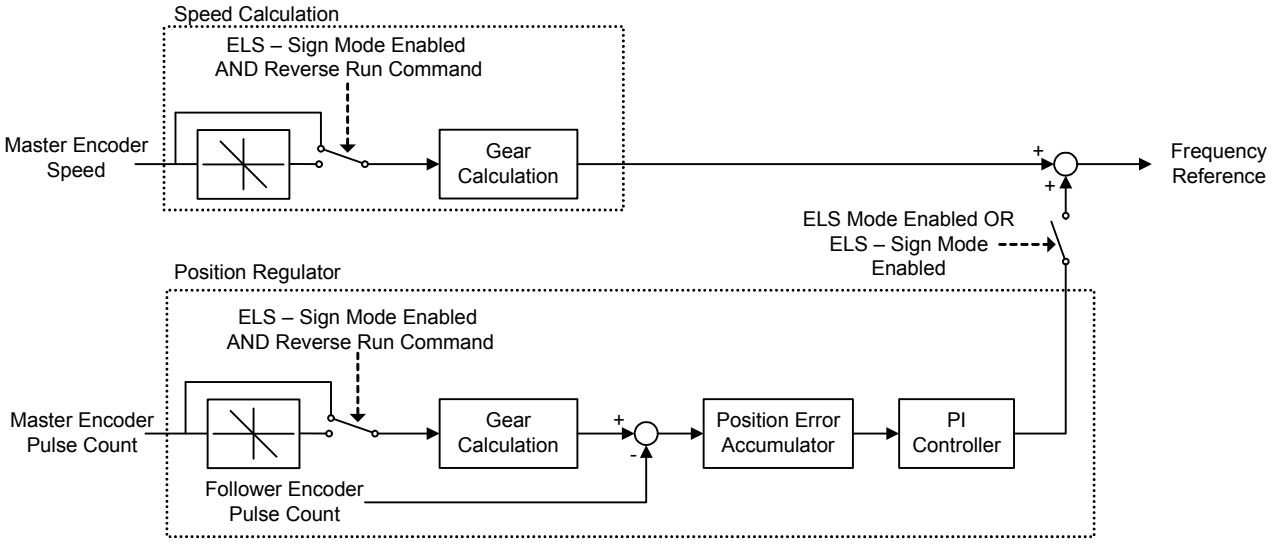
Both the master and follower encoder signals are fed into the follower drive's dual encoder (PG) option card. The master encoder speed is multiplied by the programmed gear ratio to determine the speed reference. The error between the master and follower position is determined. This is fed into a PI controller, which is in turn added to the previously calculated speed reference. When the drive is configured as a speed follower, the position regulator is disabled.

A signed-run mode is also available in ELS. When P1-01 = 5 (Electronic Line Shaft - Sign Run), ELS functions identically to standard ELS (P1-01 = 4), with the following difference:

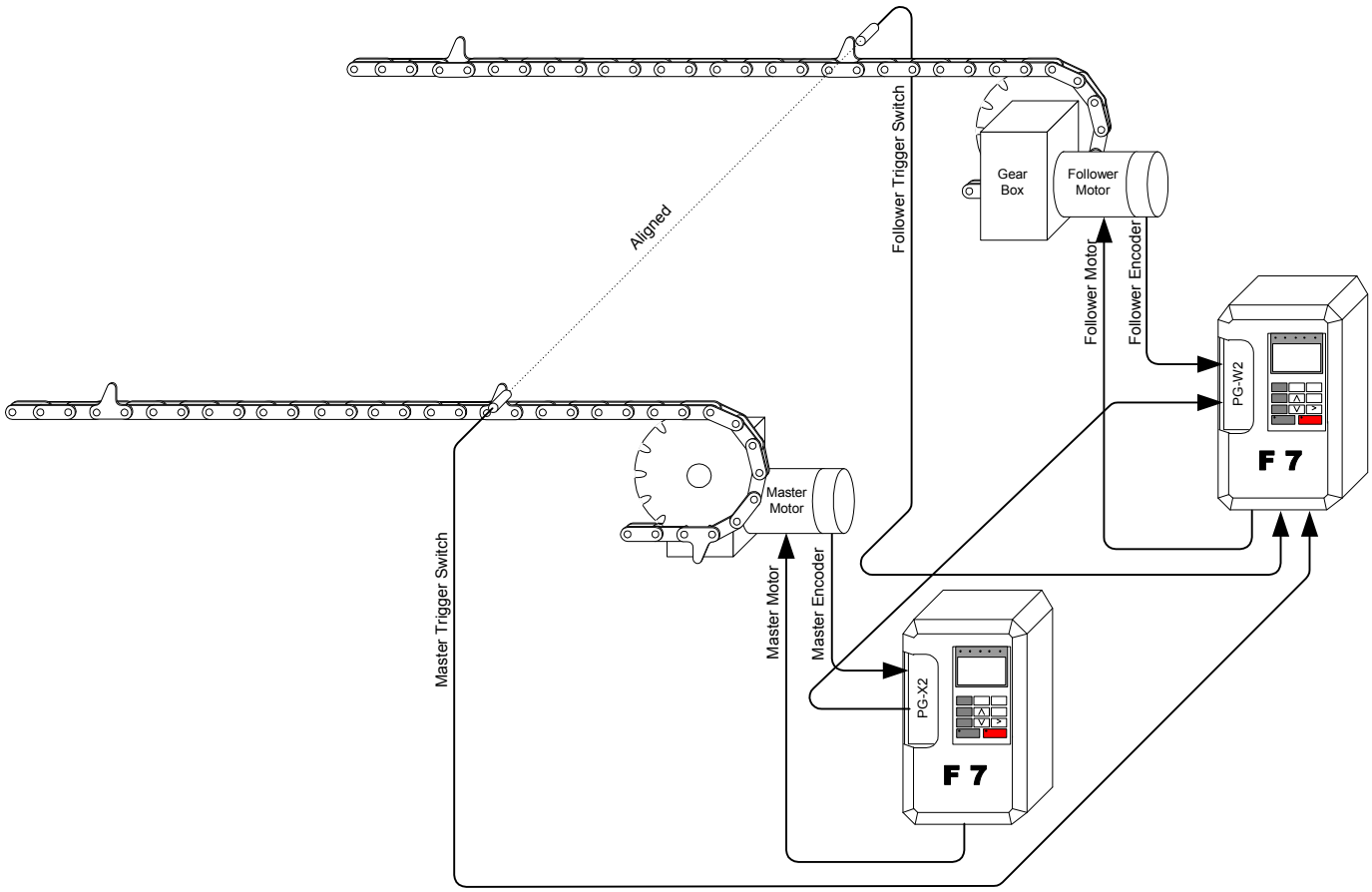
- When a reverse run command is given through the terminal S2 digital input, the follower will match the velocity and phase of the master, but in the opposite direction. If the master runs in the forward direction, the follower will run in reverse direction. If the master runs in the reverse direction, the follower will run in the forward direction.

- When a forward run command is present through terminal S1, the follower will run in the same direction is the master.

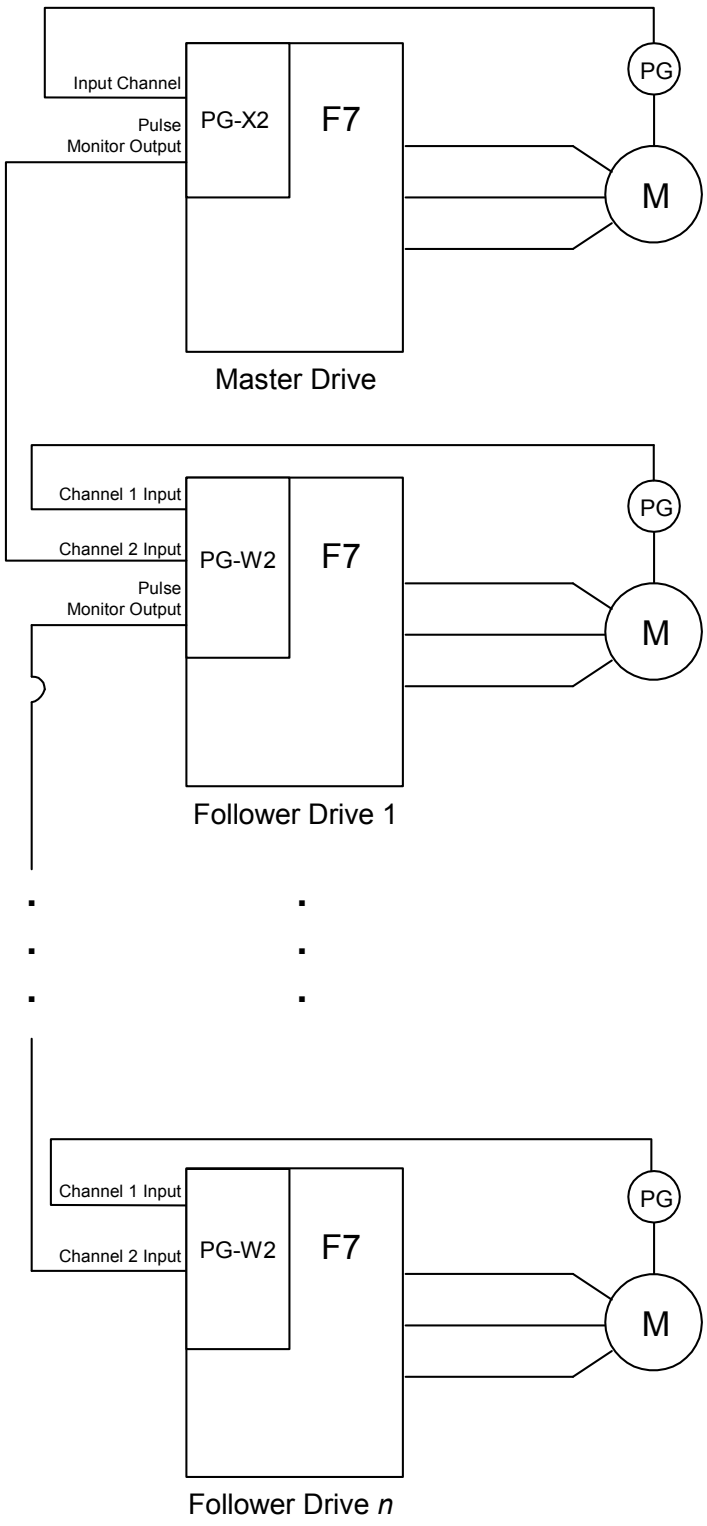
With revision VSF110052, the software adds an automatic alignment feature to the base electronic line shaft software. This is accomplished by using two proximity switches connected to the trigger inputs on the follower drive. One switch is used to indicate the position of the master, and the other switch is used to indicate the position of the follower. When the alignment feature is activated and the machine is running, the distance between the trigger switches is measured and then compensated for by either advancing or retarding the follower motor.



Simplified Block Diagram of the Electronic Lineshaft Function



Simplified Application Example of Electronic Lineshaft with Alignment Function



Typical Connection Diagram for Electronic Lineshaft

2.0 Changes from Standard Product

a. The Motor 2 Selection (H1-0X = 16) multi-function digital input function is deleted (only Motor 1 can be used).
b. The kWh monitors (U1-29 and U1-30) are deleted.
c. Parameter E2-04 (Motor Poles) is available in all control modes (Advanced access level only for V/f and Open Loop Vector).
d. The follower drive uses acceleration and deceleration times of zero during standard Electronic Line Shaft (P1-01 = 4, 5).
e. All "A2" parameters along with the entire user access level have been deleted from this software.

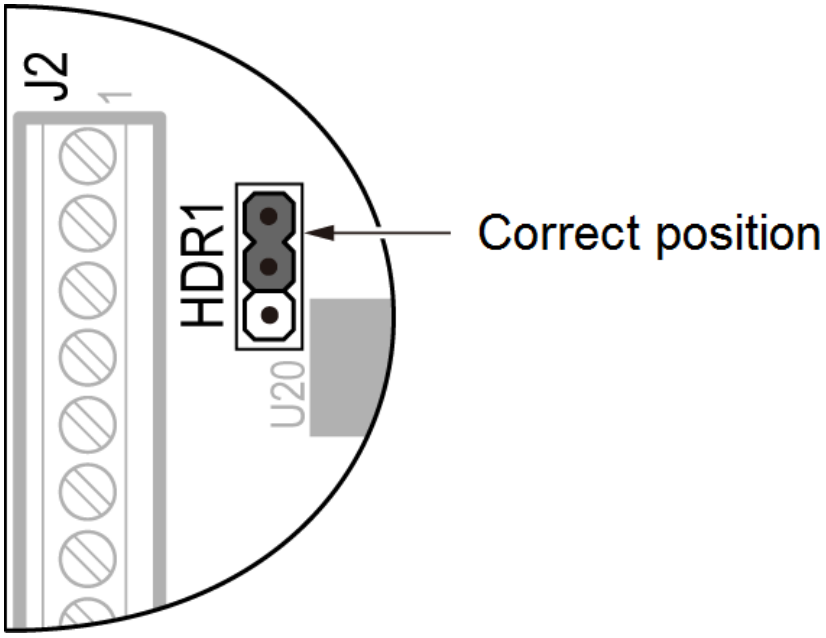
3.0 Limitations

a. For ELS modes (P1-01 = 4, 5), Flux Vector control mode is highly recommended (A1-02 = 3).
b. For ELS modes (P1-01 = 4, 5), the gear ratio must be exactly expressed, including remainder, to prevent phase drift (error). See section 5.0.
c. The proper encoder (PG) option card must be used based on the control mode and follower mode selection. The table below shows the supported option cards for each configuration.
d. If the "Clear Position Error" digital input is activated when an alignment is being performed, the drive could possibly experience a step-change in frequency reference.
e. Alignment accuracy will be lessened at higher speeds. This is due to latency in the trigger switches themselves and the drive's digital inputs and internal scan rate.

Encoder (PG) Option Card Selection

Control Mode	P1-01 = 1, 2, 3 (Speed Follower)	P1-01 = 4, 5 (ELS)
V/f	PG-B2, PG-T2, PG-X2, PG-W2, PG-Y2, PG-Z2	PG-W2, PG-Y2, PG-Z2
V/f w/ PG	PG-W2, PG-Y2, PG-Z2	
Open Loop Vector	PG-B2, PG-T2, PG-X2, PG-W2, PG-Y2, PG-Z2	
Flux Vector	PG-W2, PG-Y2, PG-Z2	

Note: If the PG-W2 option is used, jumper HDR1 must be set to the correct position according to the figure below.



4.0 Related Parameters and Functions

4.1 Parameters

Parameter Number	Modbus Address	Parameter Name ***Digital Operator Display***	Description	Range	Default	Change During Run	Control Mode *1			
							V/f	V/f w/ PG	Open Loop Vector	Flux Vector
P1-01	600H	Follower Mode Selection ***Follower Mode***	Selects the follower mode. 0: ***Disabled*** Follower mode is disabled and the follower drive runs from the normal frequency reference (B1-01). 1: ***Speed – Both Dir*** The follower drive follows the master encoder speed in both directions. 2: ***Speed – One Dir*** The follower drive follows the master encoder speed in the direction of the run command only. 3: ***Speed – Abs Val*** The follower drive follows the master encoder speed but ignores the master encoder direction (motion is always in the direction of the run command). 4: ***Elec Line Shaft*** The follower drive follows the master encoder speed and position (both directions). Terminals S1 or S2 can be used to issue the run command. There is no directional effect. 5: **ELS – Sign Run** The follower drive follows the master encoder speed and position (both directions). When a forward run command is present (terminal S1), the drive follows the master in the same direction. When a reverse run command is present (terminal S2), the drive follows in the opposite direction of the master.	0 ~ 5	0	No	Q	Q	Q	Q

*1: Access Level (A1-01): Q = “Quick Start”, A = “Advanced”, F = “Factory”.

4.1 Parameters (continued)

Parameter Number	Modbus Address	Parameter Name ***Digital Operator Display***	Description	Range	Default	Change During Run	Control Mode *1			
							V/f	V/f w/ PG	Open Loop Vector	Flux Vector
P1-02	601H	Master Encoder PPR ***Master PG PPR***	Sets the pulses per revolution (PPR) of the master encoder (PG).	20 ~ 60,000 Pulses	1024	No	Q	Q	Q	Q
P1-03	602H	Ratio Numerator (Upper 4 Digits) ***Ratio Num High***	Sets the upper 4 digits of the primary gear ratio numerator. See section 5.1.	0 ~ 9999	1000	Yes	Q	Q	Q	Q
P1-04	603H	Ratio Denominator (Upper 4 Digits) ***Ratio Den High***	Sets the upper 4 digits of the primary gear ratio denominator. See section 5.1.	0 ~ 9999	1000	Yes	Q	Q	Q	Q
P1-05	604H	Ratio Numerator (Lower 4 Digits) ***Ratio Num Low***	Sets the lower 4 digits of the primary gear ratio numerator. See section 5.1.	0 ~ 9999	0	Yes	A	A	A	A
P1-06	605H	Ratio Denominator (Lower 4 Digits) ***Ratio Den Low***	Sets the lower 4 digits of the primary gear ratio denominator. See section 5.1.	0 ~ 9999	0	Yes	A	A	A	A
P1-07	606H	Ratio 2 Numerator ***Ratio 2 Num***	Sets the numerator of the secondary gear ratio. Active when a multi-function digital input is set to 81 (Ratio 2 Select) and the input is closed.	1 ~ 65,535	1	Yes	A	A	A	A
P1-08	607H	Ratio 2 Denominator ***Ratio 2 Den***	Sets the denominator of the secondary gear ratio. Active when a multi-function digital input is set to 81 (Ratio 2 Select) and the input is closed.	1 ~ 65,535	1	Yes	A	A	A	A
P1-09	608H	Position Error Accumulation Selection ***Pos Accum Select***	Sets when the position error accumulator is enabled in the follower drive. 0: Only During Run Position error is only calculated when the follower drive is running *(not during High Slip Braking)*. 1: Always Position error is calculated whenever power is applied to the follower drive. *Note: ELS modes only.*	0 ~ 1	0	No	A	A	A	A

*1: Access Level (A1-01): Q = "Quick Start", A = "Advanced", F = "Factory".

4.1 Parameters (continued)

Parameter Number	Modbus Address	Parameter Name ***Digital Operator Display***	Description	Range	Default	Change During Run	Control Mode *1			
							V/f	V/f w/ PG	Open Loop Vector	Flux Vector
P1-10	609H	Position Units Selection ***Position Units***	Selects the units used for the follower drive Position Error Monitor (U1-96). 0: ***Encoder Counts*** Position error is displayed in quadrature follower encoder counts (cts). 1: ***Motor Revs*** Position error is displayed in follower motor revolutions (0.001rev). 2: ***Motor Degrees*** Position error is displayed in follower motor degrees (0.1°). 3: ***Motor Radians*** Position error is displayed in follower motor radians (0.001rad). *Note: ELS modes only.*	0 ~ 3	0	Yes	A	A	A	A
P2-01	60AH	Digital Ratio Adjustment ***Digital RatioAdj***	Sets the digital gear ratio adjustment of the follower drive. The gear ratio adjustment is also influenced by the analog, MOP and communication gear ratio adjustments.	-99.99 ~ +99.99 %	0.00	Yes	A	A	A	A
P2-02	60BH	MOP Adjust Time ***MOP Adjust Time***	Sets the time for the MOP ratio adjustment to change by 100.00% when the MOP Adjust Increase or MOP Adjust Decrease multi-function input is closed.	0.0 ~ 6000.0 sec	50.0	Yes	A	A	A	A
P2-03	60CH	Gear Ratio Adjustment Ramp Time ***Ratio Adj Ramp***	Sets the time for the composite gear ratio adjustment of the follower drive to change by 100.00%.	0.0 ~ 6000.0 sec	10.0	Yes	A	A	A	A

*1: Access Level (A1-01): Q = “Quick Start”, A = “Advanced”, F = “Factory”.

4.1 Parameters (continued)

Parameter Number	Modbus Address	Parameter Name ***Digital Operator Display***	Description	Range	Default	Change During Run	Control Mode *1			
							V/f	V/f w/ PG	Open Loop Vector	Flux Vector
P2-04	60DH	Advance/Retard Mode Selection ***Adv/Ret Mode Sel***	Selects the advance/retard functionality of the follower drive. 0: ***Continuous*** The follower will advance or retard continuously while the Advance Follower or Retard Follower multi-function input is closed. P2-05 sets amount of advance/retard encoder counts per second. 1: ***Step*** The follower will advance or retard by the amount set in parameter P2-05 each time the Advance Follower or Retard Follower multi-function input is closed. *Note: ELS modes only.*	0 ~ 1	0	No	A	A	A	A
P2-05	60EH	Advance/Retard Amount ***Adv/Ret Amount***	Sets the number of quadrature follower encoder counts the follower will advance/retard per second when P2-04 = 0. Sets the step amount of the advance/retard function when P2-04 = 1. *Note: ELS modes only.*	0 ~ 65,535 Counts	2048	Yes	A	A	A	A
P2-06	60FH	Follower Deviation Level ***Follower Dev Lvl***	Sets the amount of position error in quadrature follower encoder counts that will activate the follower deviation detection. Also sets the scaling for the Position Error analog output selection (H3-05, H3-09 = 94). *Note: ELS modes only.*	0 ~ 65,535 Counts	4096	No	A	A	A	A

*1: Access Level (A1-01): Q = “Quick Start”, A = “Advanced”, F = “Factory”.

4.1 Parameters (continued)

Parameter Number	Modbus Address	Parameter Name ***Digital Operator Display***	Description	Range	Default	Change During Run	Control Mode *1			
							V/f	V/f w/ PG	Open Loop Vector	Flux Vector
P2-07	610H	Follower Deviation Selection ***Follower Dev Sel***	Selects the follower drive action when the position error exceeds the P2-06 setting. 0: ***No Detection*** The drive continues to run. 1: ***Alarm*** The drive continues to run and an FDEV alarm flashes on the digital operator. 2: ***Fault*** (Coast to Stop) The FDEV fault is displayed, the drive fault contact is activated, and the motor coasts to a stop.	0 ~ 2	2	No	A	A	A	A
P2-08	611H	Encoder (PG) Monitor Channel Selection ***PG Mon Ch Select***	Selects which input encoder signal is sent to the PG monitor output when using a dual channel PG option card (PG-W2, PG-Y2, or PG-Z2). 0: ***Channel 1*** Encoder 1 is sent to the monitor output. 1: ***Channel 2*** Encoder 2 is sent to the monitor output.	0 ~ 1	1	Yes	A	A	A	A
P2-09	612H	MOP Adjustment Memorization at Power Off ***MOP Mem @Pwr Off***	Determines if the MOP gear adjustment is memorized when the drive loses power. 0: ***Disabled*** MOP adjustment is not memorized at power down. 1: ***Enabled*** MOP adjustment is memorized at power down.	0 ~ 1	0	No	A	A	A	A
P3-01	614H	Position P Gain ***Position P Gain***	Sets the proportional gain of the position regulator PI loop. *Note: ELS modes only.*	0.00 ~ 100.00	5.00	Yes	A	A	A	A
P3-02	615H	Position I Time ***Position I Time***	Sets the integral time of the position regulator PI loop. *Note: ELS modes only.*	0.00 ~ 50.00 sec	0.00	Yes	A	A	A	A

*1: Access Level (A1-01): Q = “Quick Start”, A = “Advanced”, F = “Factory”.

4.1 Parameters (continued)

Parameter Number	Modbus Address	Parameter Name ***Digital Operator Display***	Description	Range	Default	Change During Run	Control Mode *1			
							V/f	V/f w/ PG	Open Loop Vector	Flux Vector
P3-03	616H	Position Regulator Filter Time ***Pos Filter Time***	Sets the filter time of the position regulator output. This is a first order lag filter. *Note: ELS modes only.*	0.00 ~ 1.50 sec	0.00	Yes	A	A	A	A
P3-04	617H	Position PI Limit ***Pos PI Limit***	Sets the limit (+/-) of the position regulator output. Set as a percentage of the maximum output frequency E1-04. *Note: ELS modes only.*	0.00 ~ 10.00 %	8.00	Yes	A	A	A	A
P3-05	618H	Position Regulator Trim Mode ***Pos Trim Mode***	Selects how the position regulator output is used to trim the follower drive speed reference (master encoder frequency). 0: ***Constant*** The position regulator output is independent of the master encoder speed reference. 1: ***Speed Prop*** The position regulator output is proportional to the master encoder speed reference. *Note: ELS modes only.*	0 ~ 1	0	Yes	A	A	A	A
P3-06	619H	Speed Proportional Position Trim Lower Limit ***SpdProp LowerLim***	Sets the lower limit of the position regulator trim when P3-05 = 1.	0.00 ~ 100.00 %	10.00	Yes	A	A	A	A
P3-07	61AH	Ratio Change Speed Agree Width ***RatioChg SpdAgrF***	Sets the frequency width used to determine “Speed Agree” when the drive is accelerating or decelerating due to one of the following: ▪ Gear ratio change ▪ Change in state of the Follower Disable multi-function input ▪ Change in state of the run command	0.0 ~ 20.0 Hz	0.5	Yes	A	A	A	A

*1: Access Level (A1-01): Q = “Quick Start”, A = “Advanced”, F = “Factory”.

4.1 Parameters (continued)

Parameter Number	Modbus Address	Parameter Name ***Digital Operator Display***	Description	Range	Default	Change During Run	Control Mode *1			
							V/f	V/f w/ PG	Open Loop Vector	Flux Vector
P4-01	106H	Alignment Select ***Alignment Sel***	Enables and disables the alignment feature. 0: Alignment Disabled 1: Manual Align 2: Auto Align at Start 3: Continuous Align	0 ~ 3	0	N	A	A	A	A
P4-02	107H	Alignment Trim Rate ***Align Trim Rate***	Sets the amount of speed added or subtracted from the follower drive during an alignment procedure. *2	0.1 ~ 30.0 Hz	6.0	Y	A	A	A	A
P4-03	108H	Alignment Offset ***Align Offset***	Sets an offset value to correct for the physical misalignment of the trigger inputs. A positive value moves follower alignment forward. A negative value moves the follower alignment in reverse.	-99.99 ~ 99.99 rev	0.00	N	A	A	A	A
P4-04	109H	Alignment Check ***Alignment Check***	Used in conjunction with a digital output to detect if the master and the follower trigger pulses are within a preset window. When the number of follower quadrature encoder counts between the two trigger inputs is less than this value, the "Alignment Check" digital output will activate. (H2-0X = 42)	0 ~ 65535 Cts	100	Y	A	A	A	A
P4-05	10AH	Trigger Switch Type ***Trigger Sw Type***	Sets the normal (not activated) state of the Master and Follower trigger switches 0: Both NO 1: Mstr NO Folwr NC 2: Mstr NC Folwr NO 3: Both NC	0 ~ 3	0	N	A	A	A	A
P4-06	10BH	Align Fault Select ***Align Fault Sel***	Sets the reaction of the drive when the distance (follower motor revolutions) between the two trigger inputs exceeds the P4-07 setting. 0: Disabled 1: Ignore First Trigger 2: Fault	0 ~ 2	0	N	A	A	A	A

*1: Access Level (A1-01): Q = "Quick Start", A = "Advanced", F = "Factory".
*2: The software will add speed in terms of (whole number) encoder counts / 5ms. Therefore the trim rate may not be exact. Also, the minimum amount of trim is 1 encoder count / 5ms, which could result in a faster than expected rate, especially for low resolution encoders (less than 1024PPR).

4.1 Parameters (continued)

Parameter Number	Modbus Address	Parameter Name ***Digital Operator Display***	Description	Range	Default	Change During Run	Control Mode *1			
							V/f	V/f w/ PG	Open Loop Vector	Flux Vector
P4-07	10CH	Maximum Alignment Distance ***Max Align Dist***	Sets the maximum number of follower motor revolutions between the trigger inputs before an Alignment Fault will occur (P4-06).	1 ~ 5000 rev	1000	N	A	A	A	A
P4-08	10DH	Maximum Alignment Speed ***Max Align Speed***	Sets the maximum follower speed that will be allowed for an alignment to occur. This can be used to prevent alignment at high speeds where accuracy is diminished. A setting of 0.0 Hz disables this function.	0.0 ~ 400.0 Hz	0.0	Y	A	A	A	A

*1: Access Level (A1-01): Q = "Quick Start", A = "Advanced", F = "Factory".

4.2 Monitors (U1-XX)

Monitor Number	Modbus Address	Monitor Name ***Digital Operator Display***	Description	Scaling for Multi-function Analog Output Terminals FM and AM (H4-01, H4-04)	Unit	Control Mode *1			
						V/f	V/f w/ PG	Open Loop Vector	Flux Vector
U1-90	720H	Master Encoder Reference ***Master PG Fref***	Displays the frequency of the master encoder before gear ratios and MOP gains are applied.	100% = Maximum Output Frequency (E1-04)	0.1 Hz	Q	Q	Q	Q
U1-91	721H	Follower Reference After Gear Ratio ***Fref After Gear***	Displays the frequency of the master encoder after the active gear ratio (P1-03 ~ P1-08) is applied.	100% = Maximum Output Frequency (E1-04)	0.1 Hz	Q	Q	Q	Q
U1-92	722H	Gear Ratio Adjustment ***Gear Ratio Adj***	Displays the total gear ration adjustment (sum of digital, analog, MOP and communication adjustments).	100% = 100.00%	0.01%	Q	Q	Q	Q

*1: Access Level (A1-01): Q = "Quick Start", A = "Advanced", F = "Factory".

4.2 Monitors (U1-XX) (continued)

Monitor Number	Modbus Address	Monitor Name ***Digital Operator Display***	Description	Scaling for Multi-function Analog Output Terminals FM and AM (H4-01, H4-04)	Unit	Control Mode *1			
						V/f	V/f w/ PG	Open Loop Vector	Flux Vector
U1-93	723H	Follower Reference After Gear Ratio Adjustment ***Fref After Adj***	Displays the frequency from the master encoder after the digital, analog, MOP and network communication gear ratio adjustments are applied.	100% = Maximum Output Frequency (E1-04)	0.1 Hz	Q	Q	Q	Q
U1-94	724H	Master Counts/5ms ***Master Cts/5ms***	Displays the number of quadrature encoder counts per 5ms scan from the master drive. *Note: ELS modes only.* *Note: This monitor is representative only and should be used only to confirm that encoder counts are being received.*	100% = Counts/5ms at Maximum Output Frequency (E1-04)	Counts	Q	Q	Q	Q
U1-95	725H	Follower Counts/5ms ***Follower Cts/5ms***	Displays the number of quadrature encoder counts per 5ms scan from the follower drive. *Note: ELS modes only.* *Note: This monitor is representative only and should be used only to confirm that encoder counts are being received.*	100% = Counts/5ms at Maximum Output Frequency (E1-04)	Counts	Q	Q	Q	Q
U1-96	726H	Position Error ***Position Error***	Displays the position error between the master and follower encoders in quadrature follower encoder counts. *Note: ELS modes only.*	100% = Maximum Output Frequency (E1-04)	1 Count *2	Q	Q	Q	Q

*1: Access Level (A1-01): Q = "Quick Start", A = "Advanced", F = "Factory".

*2: Unit is dependent on the setting of the Position Units Selection (P1-10). When the position error is greater than the maximum value that can be displayed, the digital operator will flash "***OVER***" in place of the U1-96 data. When reading by network communication (register 726H), the unit is fixed at quadrature encoder counts.

4.2 Monitors (U1-XX) (continued)

Monitor Number	Modbus Address	Monitor Name ***Digital Operator Display***	Description	Scaling for Multi-function Analog Output Terminals FM and AM (H4-01, H4-04)	Unit	Control Mode *1			
						V/f	V/f w/ PG	Open Loop Vector	Flux Vector
U1-97	727H	Position Regulator P Output ***Position P Out***	Displays the proportional gain contribution of the position PI regulator. *Note: ELS modes only.*	100% = Maximum Output Frequency (E1-04)	0.01%	Q	Q	Q	Q
U1-98	728H	Position Regulator I Output ***Position I Out***	Displays the output of the integrator of the position PI regulator. *Note: ELS modes only.*	100% = Maximum Output Frequency (E1-04)	0.01%	Q	Q	Q	Q
U1-99	729H	Position Regulator PI Output ***Position PI Out***	Displays the output of the position PI regulator. *Note: ELS modes only.*	100% = Maximum Output Frequency (E1-04)	0.01%	Q	Q	Q	Q

*1: Access Level (A1-01): Q = “Quick Start”, A = “Advanced”, F = “Factory”.

4.3 Multi-function Digital Input Settings (H1-0X)

Setting	***Name*** Description	Control Mode *1			
		V/f	V/f w/ PG	Open Loop Vector	Flux Vector
80	***Follower Disable*** Closed: Follower mode (P1-01) is disabled and the follower drive will follow the normal frequency reference (based on B1-01 setting) and use the selected Accel/Decel times.				
81	***Ratio 2 Select*** Closed: Gear Ratio 2 (P1-07 and P1-08) is selected. When in either ELS mode (P1-01 = 4 or 5), the follower drive will clear its position error and follow the C1-03 and C1-04 Accel/Decel times to ramp to the new ratio. Upon reaching speed agree, the position loop will re-enable.				
82	***Advance Follower*** Closed: Follower position is advanced relative to the master encoder. No position error is accumulated. See P2-04 and P2-05. *Note: ELS modes only.*				
83	***Retard Follower*** Closed: Follower position is retarded relative to the master encoder. No position error is accumulated. See P2-04 and P2-05. *Note: ELS modes only.*				
84	***MOP Adjust Increase*** Closed: The MOP ratio adjustment is increased. See P2-02 and P2-09.				
85	***MOP Adjust Decrease*** Closed: The MOP ratio adjustment is decreased. See P2-02 and P2-09.				
86	***MOP Adjust Reset*** Closed: The MOP ratio adjustment is reset to zero. See P2-02 and P2-09.				
87	***Position Error Reset*** Closed: Position error is reset to zero. *Note: ELS modes only.*				
88	***Position Regulator Integral Reset*** Closed: Position regulator integral is reset to zero. *Note: ELS modes only.*				
89	***Follower Trigger*** This input is connected to a switch which detects the position of the follower machine. Configurable using parameter P4-05.				
8A	***Master Trigger*** This input is connected to a switch which detects the position of the master machine. Configurable using parameter P4-05.				
8B	***Align Fol Cmd*** Commands the align function to begin when parameter P4-01 = 1 or 2. This input is edge triggered (open to closed transition).				

*1: = Available, – = Not Available.

4.4 Multi-function Digital Output Settings (H2-0X)

Setting	***Name*** Description	Control Mode *1			
		V/f	V/f w/ PG	Open Loop Vector	Flux Vector
40	***Follower Position Deviation*** Closed: The position error has exceeded the Follower Deviation Level (P2-06). *Note: ELS modes only.*				
41	**Align Complete** – Closed after a successful alignment operation completes. Opens when the follower is stopped, faulted, or electronic line shaft position error is cleared or disabled. Also opens when an advance/retard command is given.				
42	**In Alignment** – Closed after both trigger inputs are received AND the distance between them is less than the P4-04 value. Open after: • The first trigger has been received, and the accumulated distance exceeds the sum of the |P4-03| and P4-04 distances. • When the follower is stopped, faulted, or electronic line shaft position error is cleared or disabled. • An advance/retard command is given.				

*1: = Available, – = Not Available.

4.5 Multi-function Analog Input Settings (H3-0X)

Setting	***Name*** Description	Scaling	Control Mode *1			
			V/f	V/f w/ PG	Open Loop Vector	Flux Vector
20	***Analog Ratio Adjustment*** Input value is added to the digital, MOP and network communication ratio adjustment to form the total gear ratio adjustment.	100% = 100.00%				

*1: = Available, – = Not Available.

4.6 Network Communication Functions

Modbus Address	***Name*** Description	Scaling
61CH	***Network Communication Gear Ratio Adjustment*** Allows gear ratio adjustment via network communication. The total gear ratio adjustment is the sum of the analog, digital, MOP and network communication ratio adjustments. Data is interpreted as signed, so the adjustment can be set from –327.68% ~ 327.67%. *Note: The ENTER command is not required when writing to this register.*	1 = 0.01%
61DH	***Network Communication Advance/Retard Counts*** Allows for advancement/retardment of the follower drive via network communication. Data is interpreted as signed, so the advance/retard counts can be set from –32768 ~ 32767. This is set in quadrature follower encoder counts. After this register is set, its data returns to zero automatically. *Note: ELS modes only.* *Note: The ENTER command is not required when writing to this register.*	1 = 1 quadrature encoder count

4.7 Faults

Fault Display	Description	Causes	Countermeasures
OPE12 Follower Sel Err	There is a problem with the configuration of the Follower function.	▪ P1-01 = 4, 5 (ELS modes) and the PG-W2, PG-Y2, or PG-Z2 is not installed. ▪ P1-01 = 1, 2, 3 (Speed Follower modes), the control mode is V/f w/ PG or Flux Vector and the PG-W2, PG-Y2, or PG-Z2 is not installed. ▪ P1-01 = 1, 2, 3 (Speed Follower modes), the control mode is V/f or Open Loop Vector and one of the following option cards is not installed: PG-B2, PG-T2, PG-X2, PG-W2, PG-Y2, or PG-Z2.	Install the appropriate encoder (PG) option card for the control mode and follower mode selection.

4.7 Faults (continued)

Fault Display	Description	Causes	Countermeasures
FDEV Follower Pos Dev	The position error has exceeded the Follower Deviation Level (P2-06) and the Follower Deviation Selection (P2-07) is set to 2 (Coast to Stop).	▪ Mechanical binding of the follower motor. ▪ The Follower Deviation Level (P2-06) is too low. ▪ The master encoder is rotating, the follower is stopped, and the Position Error Accumulation Selection (P1-09) is set to 1 (error is always accumulated). ▪ The master input frequency is greater than the follower maximum frequency (E1-04).	▪ Confirm the machinery is operating correctly and the follower motor is not binding. ▪ Increase P2-06. ▪ If the application requires that the master encoder rotate while the follower is stopped, set P1-09 = 0 (position error only during run). ▪ Set E1-04 to 10% faster than the maximum master input frequency.
PL Loss of Position	The follower drive has lost its position information. This has occurred because one of the following conditions exist: ▪ The position error has exceeded 268,435,456 counts. ▪ The pulse frequency after the gear ratio is so high that the follower cannot run at this speed without exceeding the encoder option card hardware limitation (300kHz).	▪ Mechanical binding of the follower motor. ▪ The master encoder is rotating, the follower drive is stopped, and the Position Error Accumulation Selection (P1-09) is set to 1 (position error is always accumulated). ▪ The desired follower speed is too high for the PPR of the installed encoder.	▪ Confirm the machinery is operating correctly and the follower motor is not binding. ▪ If the application requires that the master encoder rotate while the follower is stopped, set P1-09 = 0 (position error only during run). ▪ Replace the follower motor's encoder with a lower PPR model.
AF Alignment Fault	▪ Too much distance (follower motor revolutions) was counted between the two trigger inputs during an alignment routine. ▪ The distance measured between the two trigger pulses (during alignment) has exceeded 268,435,456 encoder counts. (Regardless of the P4-07 setting).	▪ The distance between the master and the follower exceeded the allowable amount (P4-07). ▪ Malfunctioning or mis-wired trigger switches.	▪ Check the machine integrity. ▪ Check the trigger switches for proper wiring and operation.

4.8 Alarms

Alarm Display	Description	Cause	Countermeasures
FDEV Follower Pos Dev	The position error has exceeded the Follower Deviation Level (P2-06) and the Follower Deviation Selection (P2-07) is set to 1 (Alarm Only).	▪ Mechanical binding of the follower motor. ▪ The Follower Deviation Level (P2-06) is too low. ▪ The master encoder is rotating, the follower drive is stopped, and the Position Error Accumulation Selection (P1-09) is set to 1 (error is always accumulated). ▪ The master input frequency is greater than the follower maximum frequency (E1-04).	▪ Confirm the machinery is operating correctly and the follower motor is not binding. ▪ Increase P2-06. ▪ If the application requires that the master encode rotate while the follower is stopped, set P1-09 = 0 (position error only during run). ▪ Set E1-04 to 10% faster than the maximum master input frequency.

5.0 Function Description

5.1 Basic Electronic Lineshaft

When the Follower Mode Selection P1-01 = 1 ~ 3 (speed follower mode), the follower drive will follow the speed of the master encoder signal. Using the gear ratio parameters P1-03 ~ P1-06, the follower drive can be made to run at a ratio of the master speed. The alternate gear ratio (P1-07 & P1-08) can be selected using the Ratio 2 Select multi-function digital input (H1-0X = 81). The basic gear ratio formula is:

Follower Frequency Reference = Master Encoder Frequency Reference x (Numerator / Denominator)

For the primary gear ratio, the formula is:

$$\text{Master Encoder Frequency Reference (U1-90)} \times \frac{\overbrace{\text{XXXXXXXX}}^{\text{P1-03, P1-05}}}{\underbrace{\text{XXXXXXXX}}_{\text{P1-04, P1-06}}} = \text{Follower Frequency Reference (U1-91)}$$

The pairs of numerator and denominator parameters are used together to form an 8-digit number divided by an 8-digit number. For ratio's that can be expressed using 4-digit numbers or less, simply use P1-03/P1-04. Gear ratio 2 can only be expressed as a 4-digit number divided by a 4-digit number.

The gear ratio needed for the application must be able to be exactly expressed by the above formula. This includes the complete remainder. If the ratio cannot be exactly expressed, the follower will drift in phase over time.

The gear ratio can be further adjusted using the Digital Ratio Adjustment P2-01), the Analog Ratio Adjustment (H3-05/09 = 20), the MOP Adjust multi-function inputs (H1-0X = 84 ~ 86), and the Network Communication Ratio Adjustment (Modbus register 61CH). These adjustments are summed and then added to 100% to produce the total gear ratio adjustment, which is multiplied by the master encoder frequency (after gear ratio calculation). See Figure 8 at the end of the document.

When Follower Mode Selection P1-01 = 4 or 5 (ELS modes), the drive will track follower position relative to the master encoder. A PI regulator is applied to the position error. The output of the position PI regulator is used to trim the speed reference calculated from the master encoder signal, gear ratio parameters, and gear ratio adjustment. In this manner, the position of the follower motor will be synchronized with the position of the master encoder. The Advance Follower (H1-0X = 82) and Retard Follower (H1-0X = 83) multi-function inputs can be used to change the position of the follower relative to the master. See Figure 7 at the end of the document.

When the gear ratio of the drive is changed instantaneously in ELS mode (either due to the gear ratio parameters being changed during run or because of a change of state of the Ratio 2 Select multi-function input), the drive will ramp to the new ratio using Accel/Decel Time 2 (C1-03/C1-04). The position error will be held to zero during the ratio change until the drive re-enters Speed Agree (based on the Ratio Change Speed Agree Width P3-07).

Notes:

- In speed follower mode (P1-01 = 1, 2, 3), the follower motor direction is determined based on the run command direction, the master encoder direction, and the exact P1-01 setting.
- In standard ELS mode (P1-01 = 4), the follower motor direction is always the same as the master encoder direction. Forward (terminal S1) and reverse (terminal S2) run commands are treated identically.
- Parameter F1-05 (PG Rotation) only affects the encoder 1 input (follower encoder) when the dual PG feedback option (PG-W2, PG-Y2, or PG-Z2) is used. It does not affect the encoder 2 input or pulse monitor output.
- In either ELS mode, the Position P Gain setting (P3-01) is scaled in relation to the drive's Max Frequency (E1-04), so if the E1-04 setting is changed the proportional contribution of the position regulator will be influenced.
- ***The follower drive's Maximum Output Frequency (E1-04) must be set higher than the maximum input frequency from the master source for proper position control. As a general rule, set E1-04 in the follower to be 10% (or at least equal to P3-04 Position PI Limit) greater than the maximum input frequency of the master source. Failure to do so can result in large continuous amounts of Position Error (U1-96).***
- ***The exact gear ratio (including remainder) must be known and able to be expressed using the gear ratio parameters. Any error in the gear ratio settings will result in follower motor drift.***

5.2 Electronic Lineshaft with Sign

When Follower Mode Selection P1-01 = 5 (ELS – Sign Run mode), the drive behaves identically to when P1-01 = 4 (Standard ELS mode), except when a reverse run command (terminal S2) is given. A reverse run command will cause the follower drive to match speed and position in the opposite direction of the master.

In the Standard ELS mode, when an Advance Follower input (H1-0X = 82) is active, the follower drive moves in the absolute positive direction with respect to the master and in the absolute negative direction when the Retard Follower input is active. These functions behave the same way in ELS – Sign Run mode when a forward run command (terminal S1) is given. When a reverse run command (terminal S2) is given during ELS – Sign Run mode, the Advance Follower input will move the follower drive in the absolute negative direction while the Retard Follower input will move the follower drive in the absolute positive direction.

For the ELS – Sign Run mode (P1-01 = 5), the functionality of the Communication Advance/Retard Counts Register is adjusted in the same way. With a forward run command, a positive value in the register will move the follower drive in the absolute positive direction and a negative value will move the follower drive in the absolute negative direction, while with a reverse run command these directions are switched. The direction the follower is moved by the Advance/Retard command is always with respect to the run command direction. The functionality of Advance/Retard for both P1-01 = 4 (Standard ELS) and P1-01 = 5 (ELS - Sign Run) is shown on the following page.

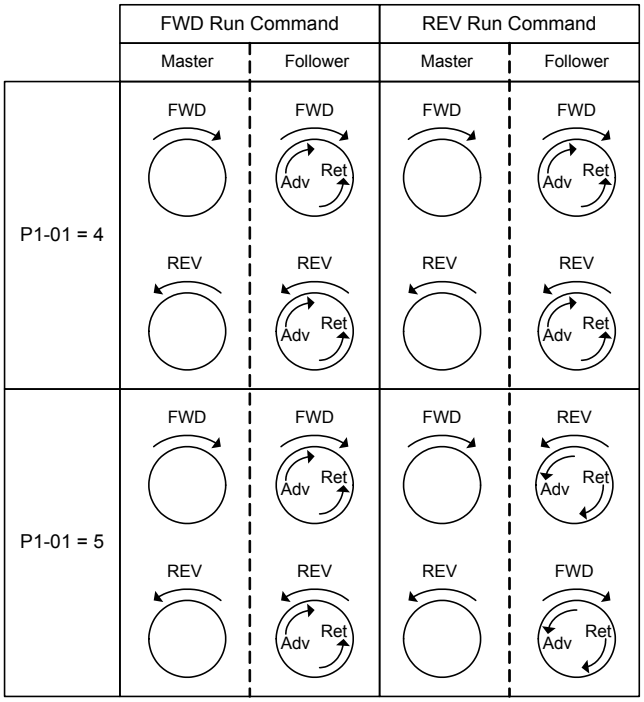
When the drive is put into local mode (digital input or keypad button) or when the drive is given a forward or reverse jog command, the frequency reference is switched back to standard frequency reference and the selected Accel / Decel times are used.

The table below shows the direction of the Follower depending on the direction of the Master, P1-01 setting, B1-04 (reverse operation prohibit selection) setting, and the forward run / reverse run digital input signal.

Follower Rotation Direction for Various Settings and Master Direction

B1-04 (Reverse Operation)	Digital Input Signal	P1-01 = 1		P1-01 = 2		P1-01 = 3		P1-01 = 4		P1-01 = 5	
		Master: FWD	Master: REV	Master: FWD	Master: REV	Master: FWD	Master: REV	Master: FWD	Master: REV	Master: FWD	Master: REV
B1-04 = 0 Enabled	FWD	FWD	REV	FWD	NONE	FWD	FWD	FWD	REV	FWD	REV
	REV	REV	FWD	NONE	REV	REV	REV	FWD	REV	REV	FWD
B1-04 = 1 Disabled	FWD	FWD	NONE	FWD	NONE	FWD	FWD	FWD	NONE	FWD	NONE
	REV	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE

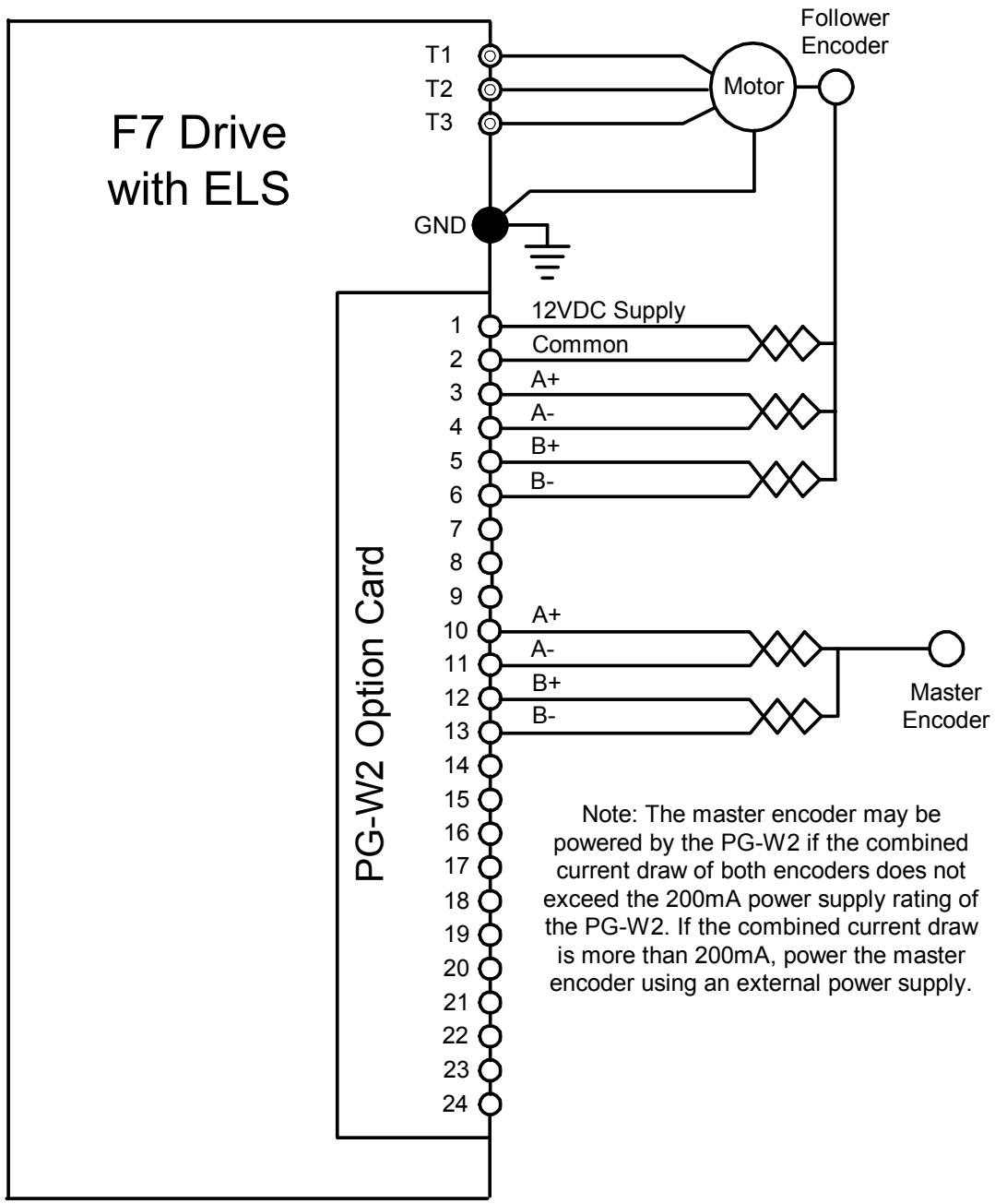
The diagrams below outline the Follower direction and Advance/Retard behavior for P1-04 settings and forward / reverse run command selections.



Follower Direction and Advance/Retard Behavior

5.3 Wiring the Encoders for Electronic Lineshaft

The master signal (encoder) and the follower encoder must be wired to a dual input encoder card (ex. PG-W2). All signals need to be a line driver type circuit. Wire the master signal (encoder) input into terminals 10 ~ 13 of the PG-W2. Wire the follower encoder input into terminals 3 ~ 6 of the PG-W2. For other dual input encoder cards, consult their installation guide for exact terminals. The marker (Z) pulse is not required for this Electronic Lineshaft software. The figure below details the wiring of the PG-W2 option card.



Wiring Example of PG-W2 Option Card

5.4 Alignment Function

5.4.1 Alignment Enable

In order for the alignment function to be enabled, both the master and the follower trigger multi-function digital input functions need to be programmed into the H1-0X parameters, and parameter P4-01 needs to be set to a non-zero value.

The alignment function will NOT operate under the following conditions:

- Drive is faulted
- Drive is not running
- Follower is ramping between forward & reverse run commands
- Electronic Lineshaft is disabled via a multi-function input (H1-0X = 80)
- Electronic Lineshaft is disabled via parameter (P1-01 < 4)
- Drive is in "Local" mode
- A "Jog" is being commanded of the follower drive
- Drive is ramping to speed due to a gear ratio change or Lineshaft being re-enabled
- Position error is being cleared via a multi-function input (H1-0X = 87)

5.4.2 Alignment Select

The alignment select parameter (P4-01) enables / disables the alignment feature. When P4-01 = 0, the drive will not do an alignment and the two digital outputs associated with alignment (H2-0X = 41 & H2-0X = 42) will remain de-energized.

- P4-01 = 0 – **Disabled**. The drive will NOT perform an alignment.
- P4-01 = 1 – **Manual Alignment**. The drive must see the rising edge of the align command (H1-0X = 8B) in order to start the alignment process. The drive will not attempt another alignment until there is another rising edge on the align command.
- P4-01 = 2 – **Auto Align at Start**. The drive will attempt to complete the alignment process once as soon as the run command is applied. The drive will then respond to the align command as stated above (P4-01 = 1).
- P4-01 = 3 – **Continuous Alignment**. The drive will attempt to complete the alignment process as soon as the run command is applied. Each time two valid trigger inputs are received, the drive will automatically re-start the alignment process. Trigger pulses will be ignored if the drive has not completed the previous alignment attempt.

5.4.3 Alignment Process

The alignment function can be used to align the follower to the master using fixed trigger positions. This process does not control the master drive. All correction is made by the follower drive. The amount of the correction is controlled by the quadrature counts that are accumulated from the time when the first (leading) trigger starts the process and continues until the second (trailing) trigger stops it. The speed of the correction is controlled by parameter P4-02. The correction will be made as soon as the trailing trigger input becomes active. The rate at which the drive accelerates or decelerates during the alignment procedure is fixed. For a 1024 PPR encoder, the ramp rate will be about 20 Hz/ 1 sec. The alignment process is intended to be performed at low speed, but will function as long as the triggers provide at least a 15 millisecond signal so that the follower drive can see the trigger inputs.

Maximum alignment speed: If an alignment is in process and the follower needs to run faster to "catch up" to the master, it will only be allowed to compensate at a rate of up to 95% of the follower's maximum frequency setting. If the follower is already running at or above the 95% speed level, the alignment function will not complete.

Minimum alignment speed: If an alignment is in process, and the follower needs to slow down in order for the master to "catch up", the follower drive *could* run in reverse. If reverse on the follower is disabled (b1-04 = 1), the follower drive will only be allowed to run at a minimum of zero speed (no reverse).

5.4.4 Alignment Fault Select

When the Alignment Fault Selection parameter is set to "disabled" (P4-06 = 0), there is no settable limit to the number of follower motor revolutions that can elapse between master and follower trigger inputs.

Note: To prevent internal overflow, the maximum number of encoder counts allowed between the two trigger inputs is 268,435,456. (65,536 motor revolutions with a 1024 PPR encoder)

When the Alignment Fault Select parameter is set to "Ignore 1st Pulse" (P4-06 = 1), it will disregard the first trigger input (regardless of master or follower) once the P4-07 distance (either direction) has elapsed. As shown in the timing diagrams below in Section 6, if the align command is asserted between the time that the master and follower trigger inputs are read, and then the P4-07 distance elapses, the drive will then disregard the first input and wait for two valid trigger inputs. When using this mode, it is useful to program the P4-07 distance to 50% to 90% the total trigger-to-trigger distance.

When the Alignment Fault Select parameter is set to "Fault" (P4-06 = 2), the drive will fault out on an "AF – Alignment Fault" and coast to stop after the P4-07 distance (follower motor revolutions) has elapsed after the first trigger input (regardless of master or follower). When this mode is used, it is useful to set the P4-07 parameter greater than the normal trigger-to-trigger distance. This fault is only active while the alignment function is being commanded.

5.4.5 Align Complete / In Alignment Multi-function Digital Outputs

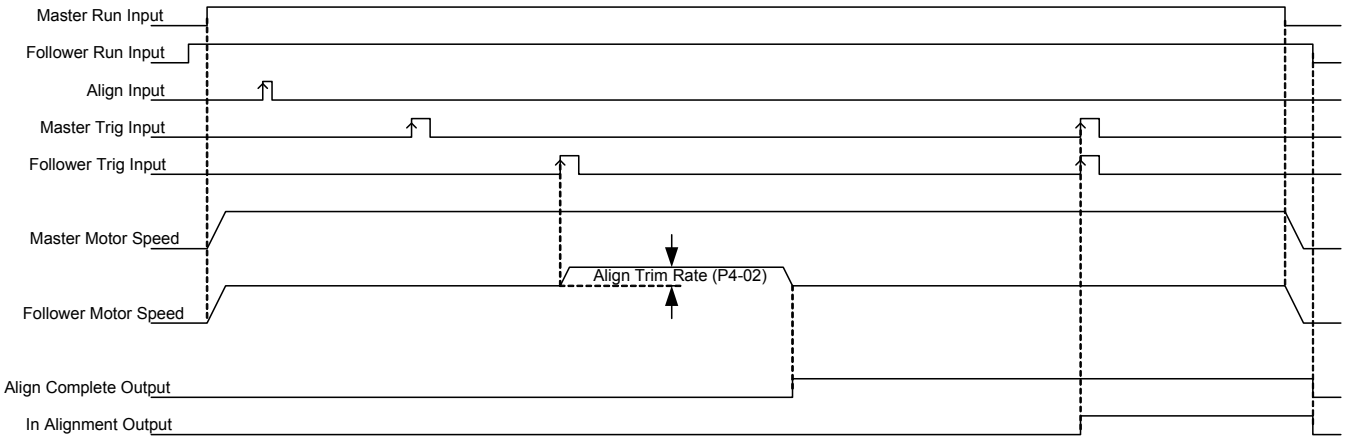
The Align Complete" digital output (H2-0X = 41) will close whenever a successful align procedure has been completed. The Align Complete digital output will de-energize whenever the rising edge of an Align Follower Command is detected. If the drive is set to reset position error at stop (P1-09 = 0), the Align Complete digital output will also de-energize when the run command is removed or if electronic line shaft is disabled (H1-0X = 80). If the drive is set to accumulate position error at all times (P1-09 = 1), the Align Complete will de-energize only if electronic line shaft is disabled, or another align command is received.

The "In Alignment" digital output (H2-0X = 42) is provided to indicate whether the trigger inputs are activated within a settable quadrature encoder count range. An Alignment Check output will energize when the triggers are within the P4-07 setting and will de-energize when the P4-07 setting is exceeded. This output will only change state after the trailing trigger has activated.

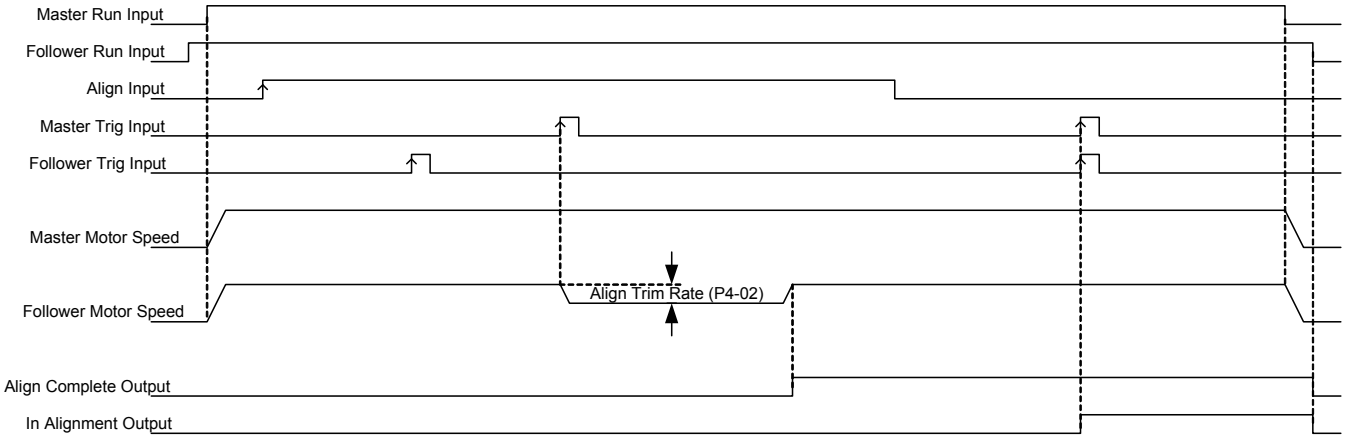
5.4.6 Alignment Function Diagrams

The following several pages detail the alignment function using detailed diagrams.

Forward Run - Alignment - Master Before Follower

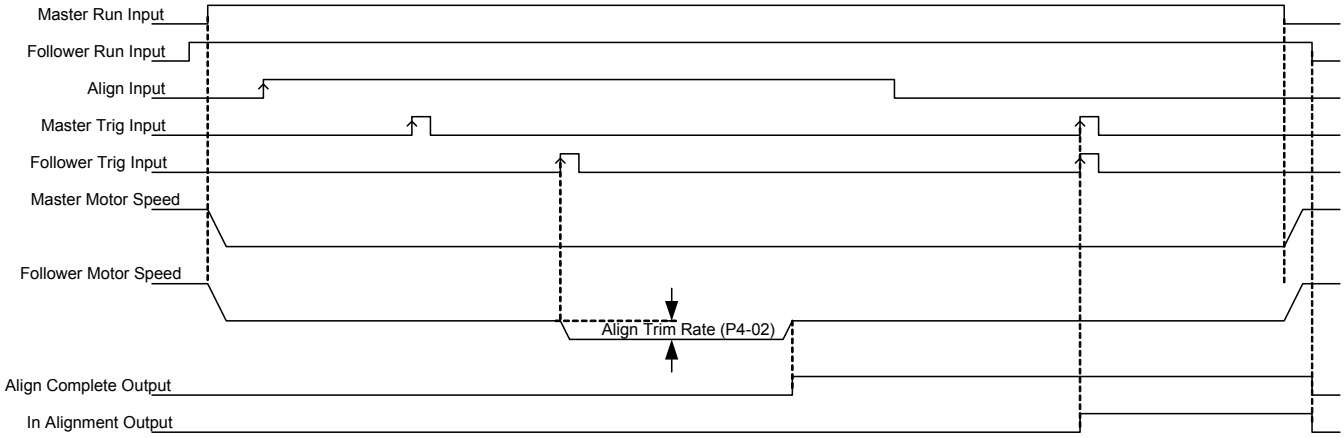


Forward Run - Alignment - Follower Before Master

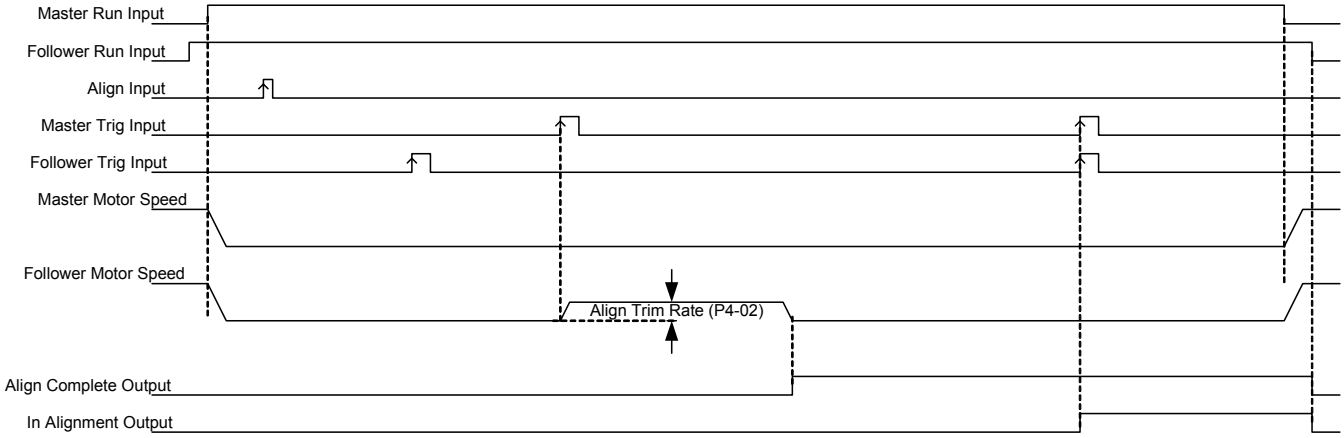


Note: The "Align Input" is edge triggered. It doesn't matter whether the input is maintained or momentary.

Reverse Run - Alignment - Master Before Follower

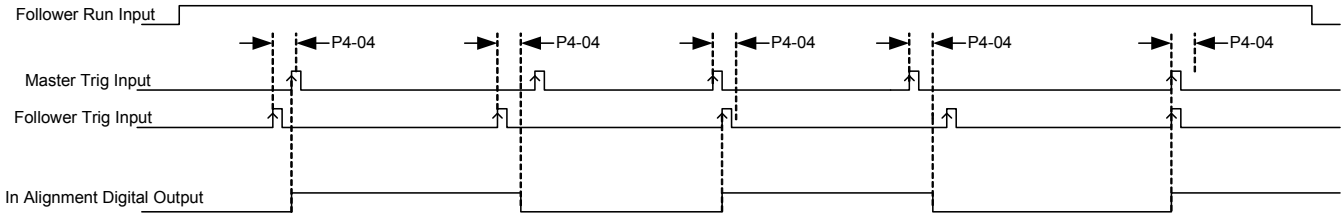


Reverse Run - Alignment - Follower Before Master

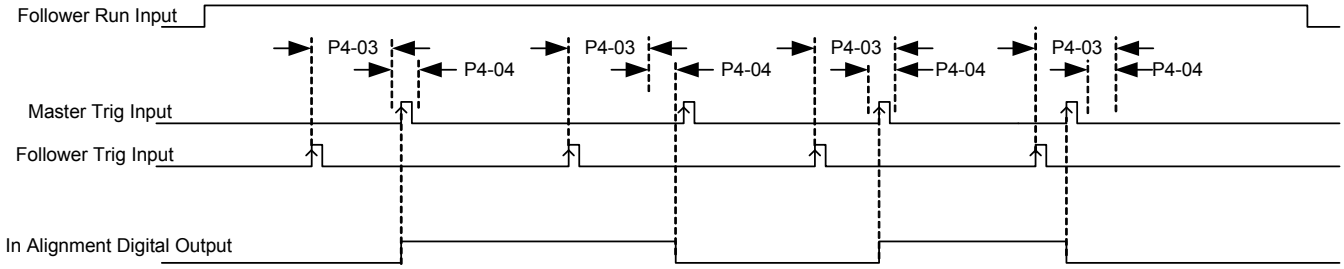


Note: The "Align Input" is edge triggered. It doesn't matter whether the input is maintained or momentary.

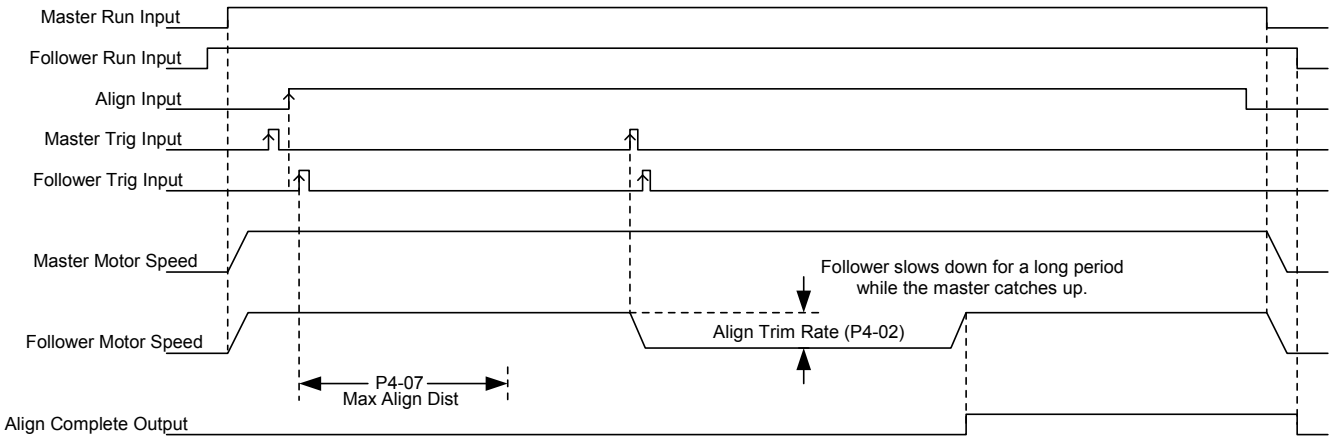
In Alignment (Digital Output) Function , no offset (P4-03 = 0.00 revs)
(P4-04 = 4096 cts)



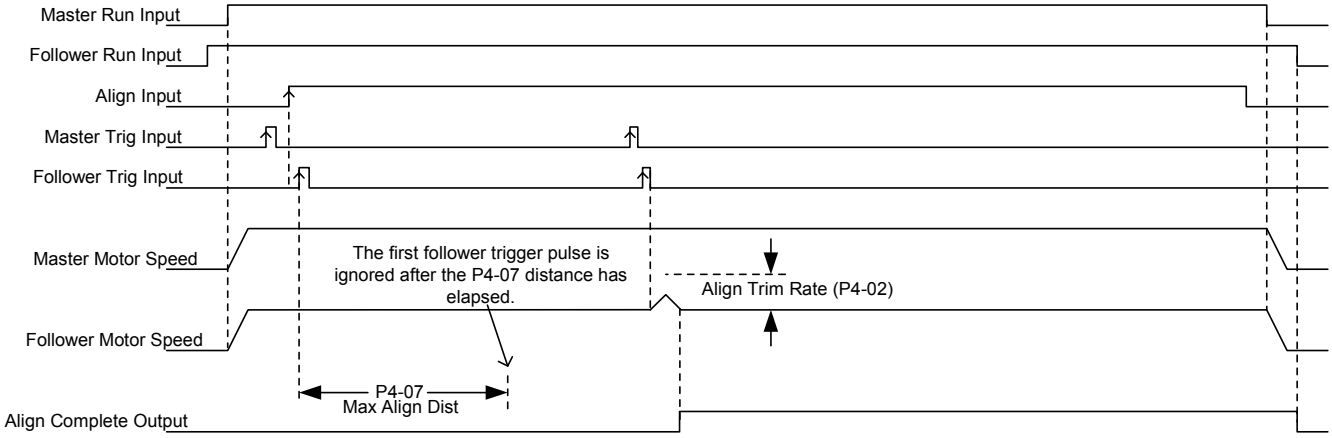
In Alignment (Digital Output) Function , w/offset (P4-03 = +3.00 revs)
(P4-04 = 4096 cts)



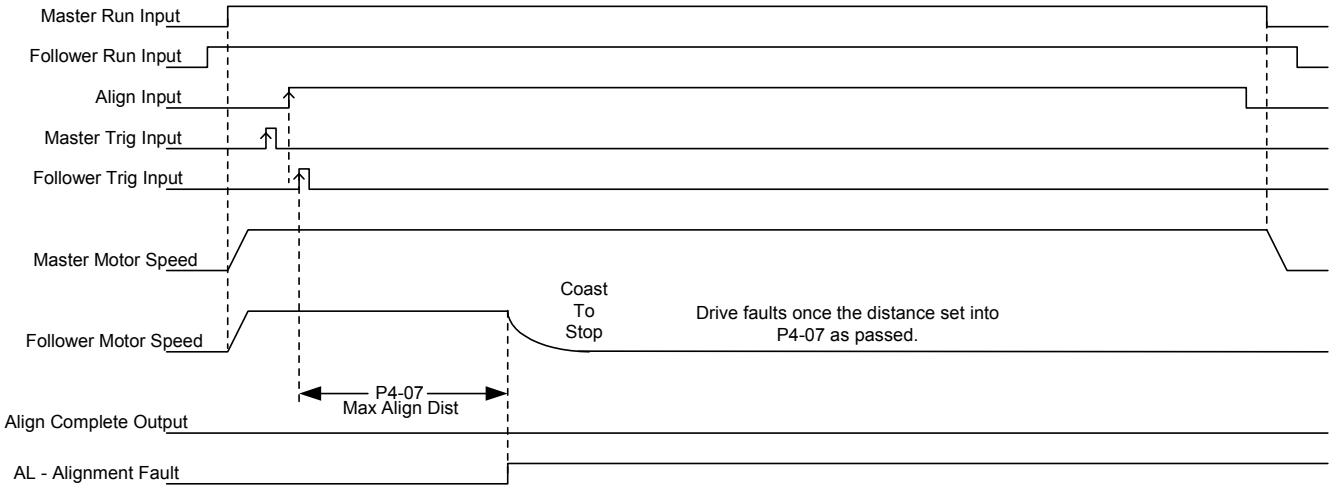
Alignment Fault Select = Disabled (P4-06 = 0)



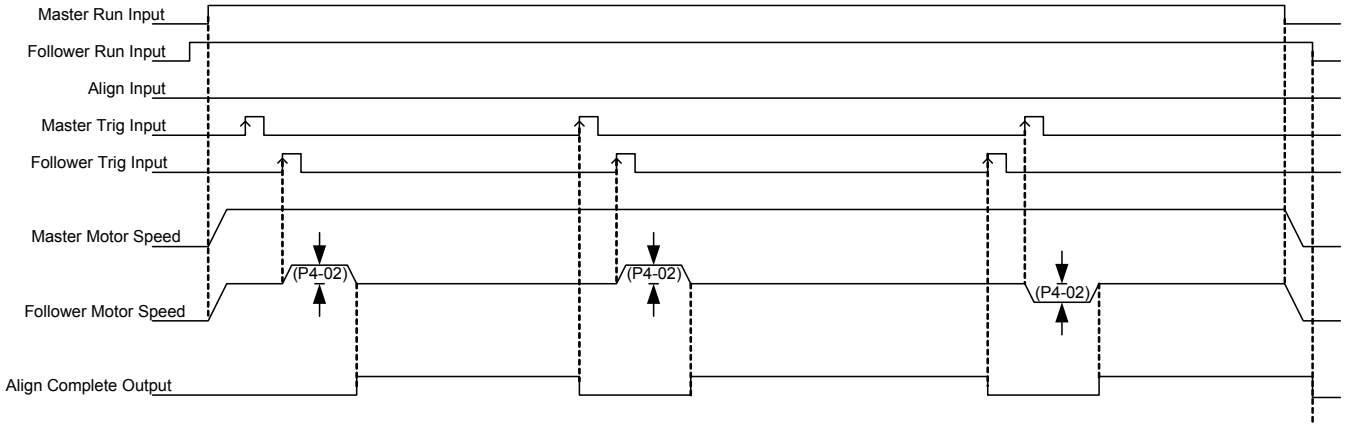
Alignment Fault Select = Ignore 1st Pulse (P4-06 = 1)



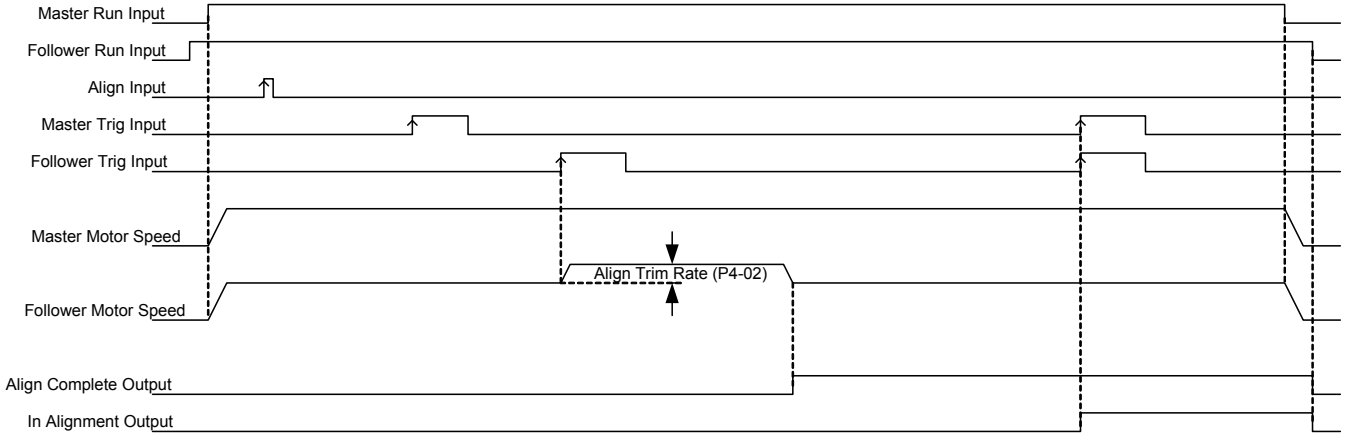
Alignment Fault Select = Fault (P4-06 = 2)



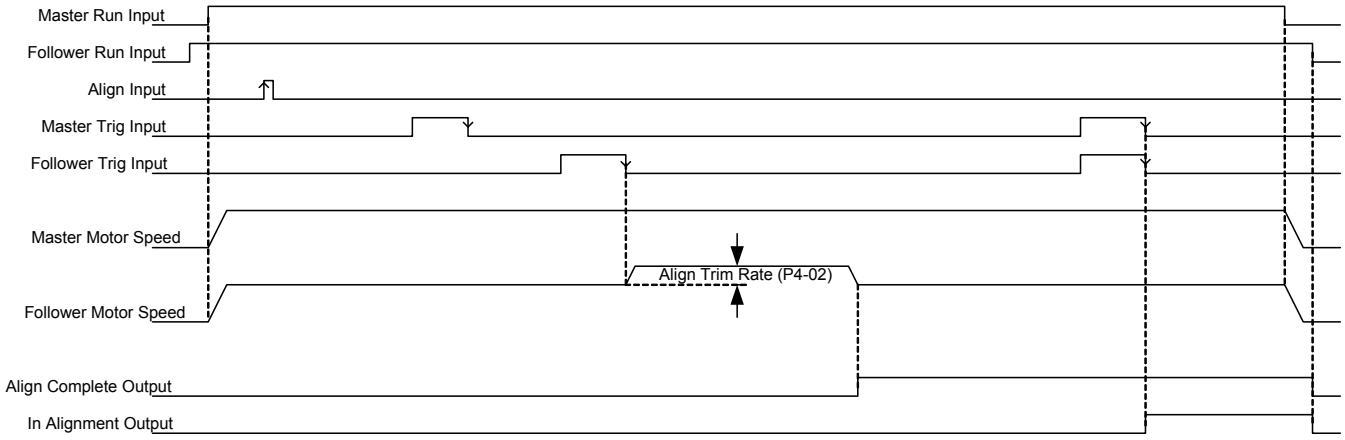
Continuous Alignment (P4-01 = 3)



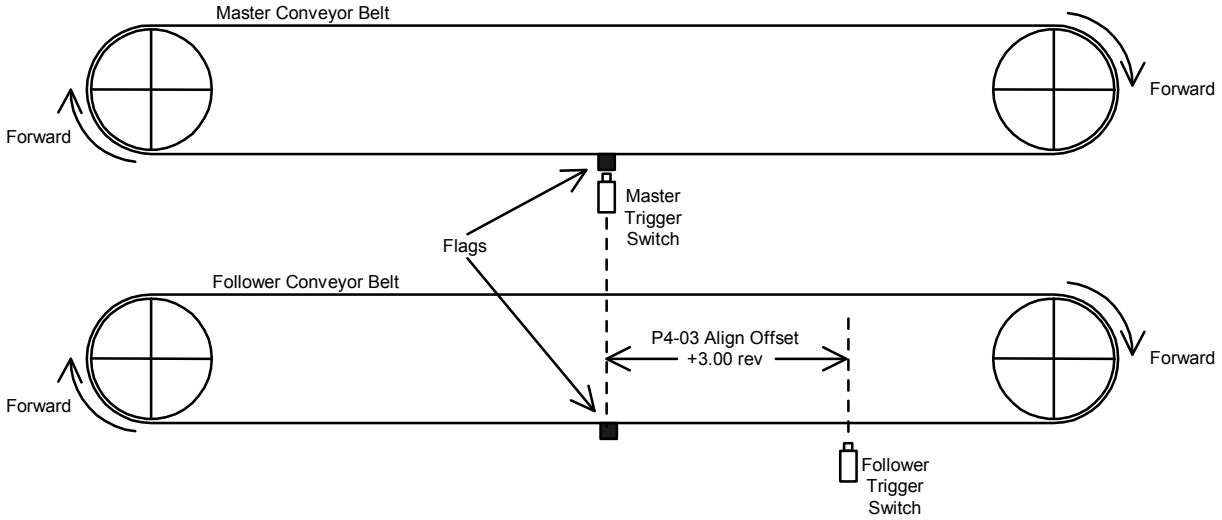
Normally Open Trigger Inputs (P4-05 = 0)



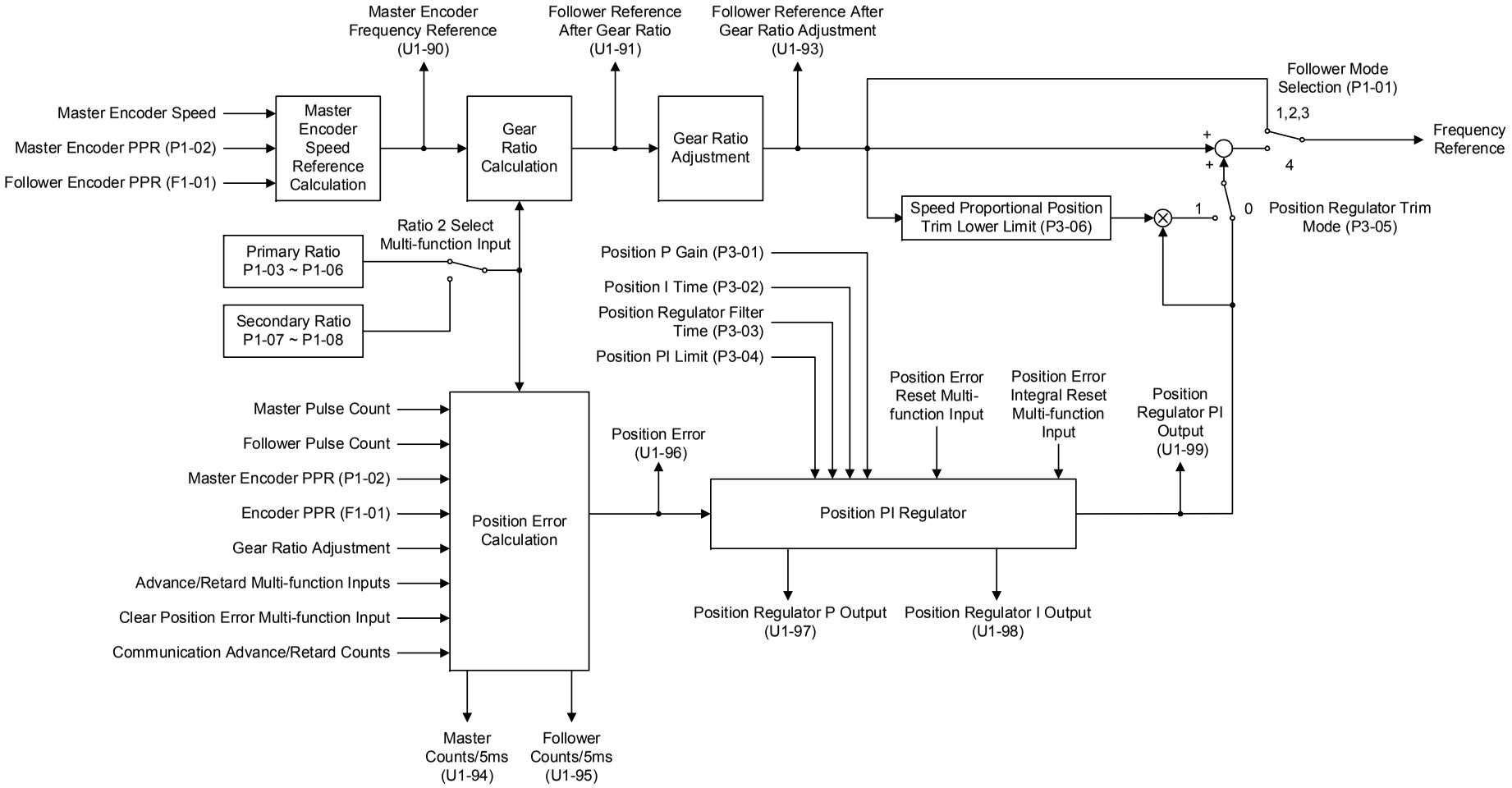
Normally Closed Trigger Inputs (P4-05 = 3)



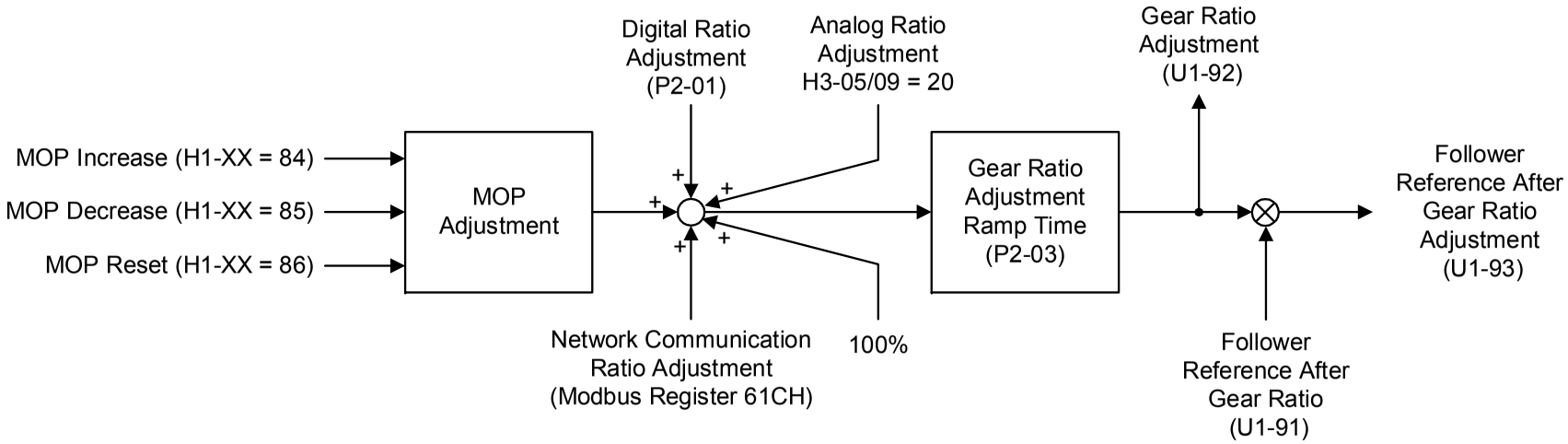
Two conveyor belts shown aligned but with different trigger switch positioning (corrected with the Align Offset parameter P4-03).



6.0 Block Diagrams



Software Overview Diagram



Composite Gear Ratio Diagram