YASKAWA

Electronic Lineshaft with Alignment G7 Drive Software Technical Manual

Software Number: VSG13311X, Drive Models: CIMR-G7UXXXXXX-064, CIMR-G7UXXXXXX-065
Document Number: TM.G7SW.064, Date: 03/31/09, Rev: 09-03

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.

The Alignment function allows the follower drive to maintain a phase angle with respect to 2 alignment inputs (can be sensors or encoder marker pulses). The phase angle, quantified as the Displacement in follower encoder counts, can be adjusted during run either through keypad, digital multi-function inputs, or network communication. The phase angle is maintained by monitoring alignment inputs (pulses) from both the master alignment input and follower alignment input and then measuring the follower encoder counts received between the two alignment pulses.

The Alignment function is enabled through the Align by Pulse multi-function digital input. When enabled, the drive will monitor the Z (marker) channel inputs on any of the dual channel encoder option cards.

Please note that the alignment inputs need not come directly from encoder marker pulse channels. However, special external circuitry may be required to support other input types, such as proximity sensors. Also, the inputs do not have to be of the same type. Refer to Section 3.0 (Limitations) for application details.

Figures 1 ~ 3 below give overview to the Electronic Lineshaft and Alignment functions.

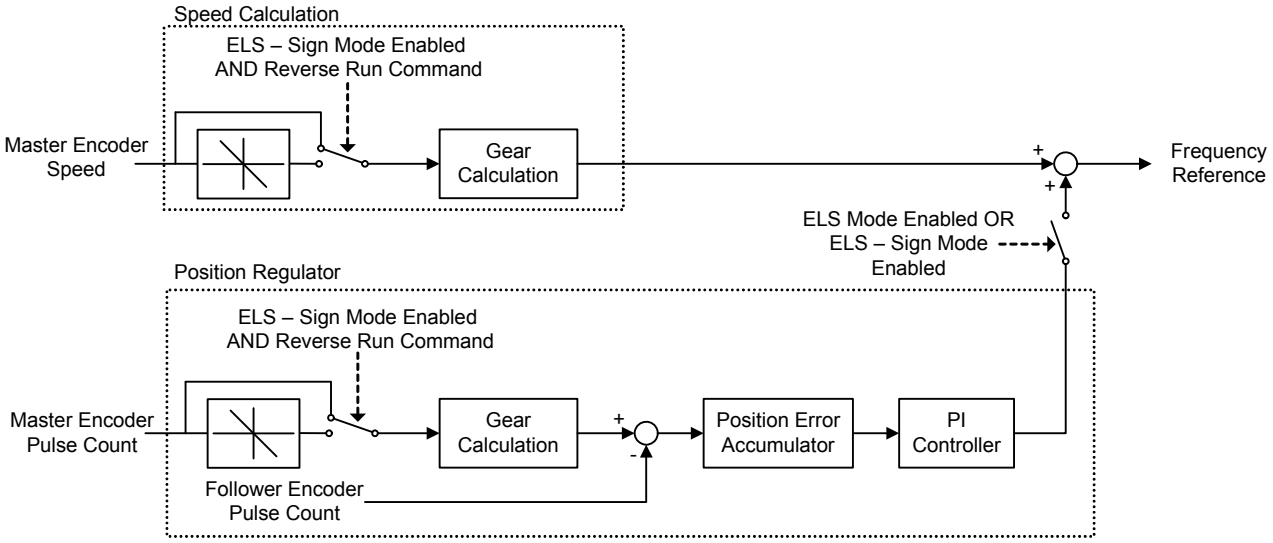

Figure 1: Simplified Block Diagram of the Electronic Lineshaft Function

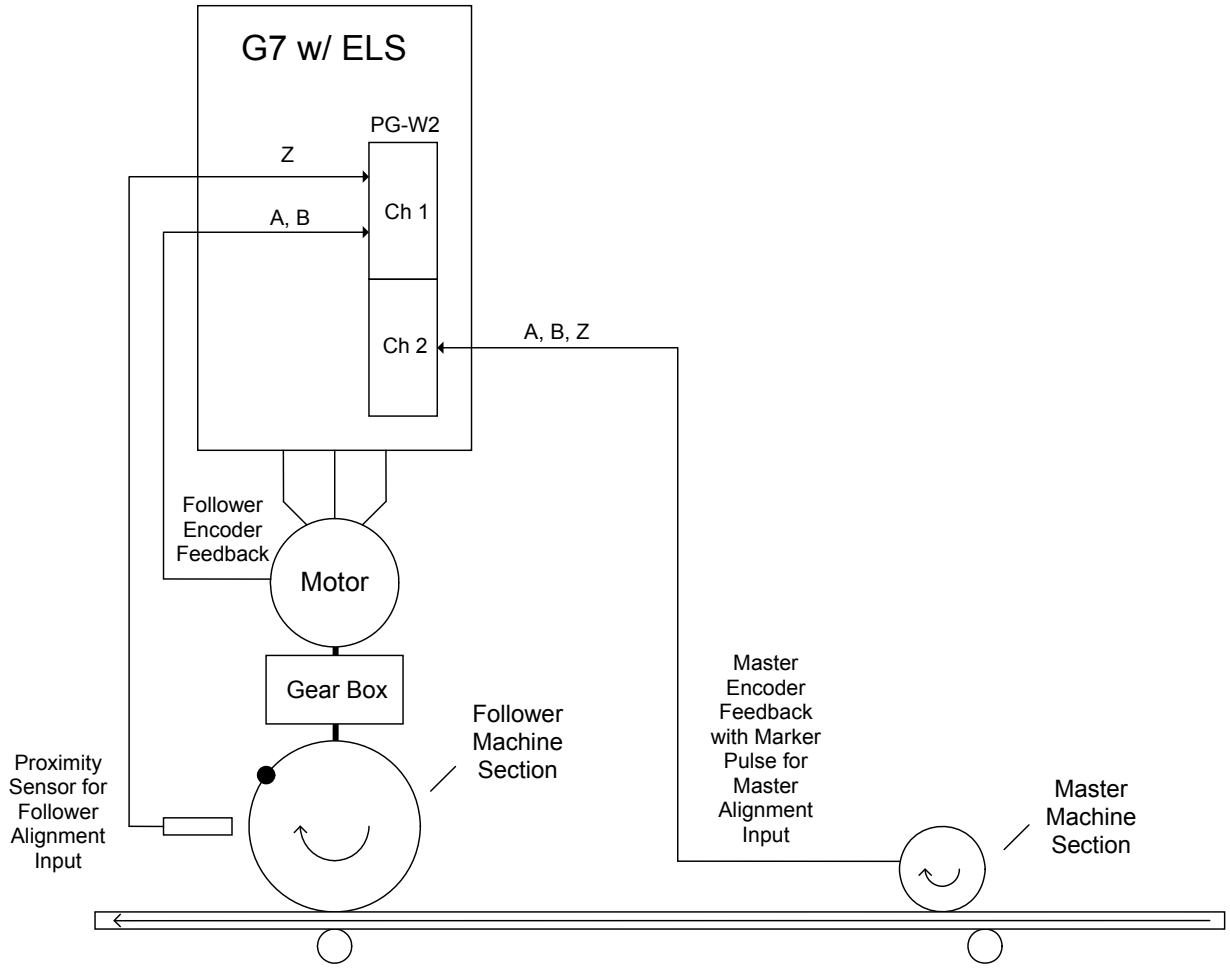

Figure 2: Typical Connection Diagram of the Alignment Function

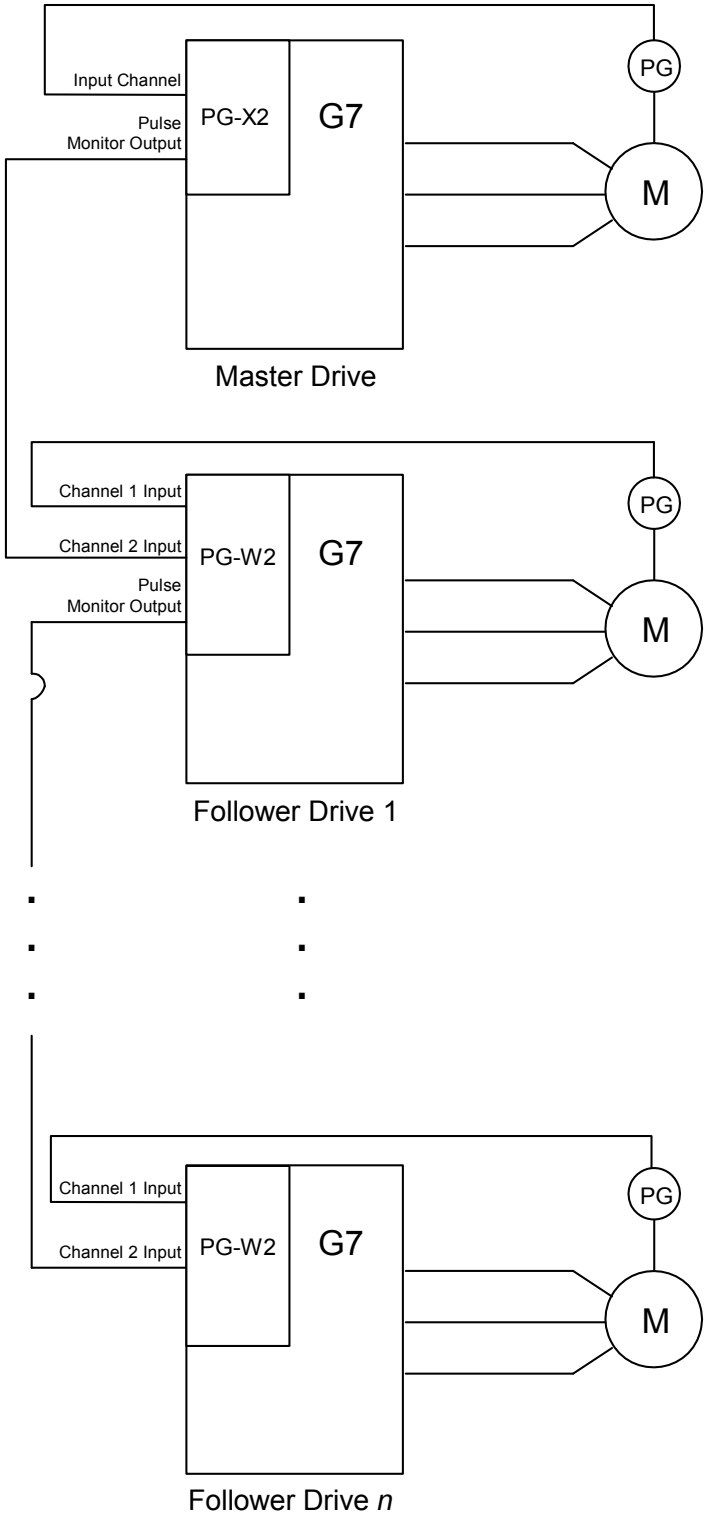

Figure 3: Typical Connection Diagram for Basic Electronic Lineshaft

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 "User" access level and all of the associated "A2" parameters are deleted.
e. The follower drive uses acceleration and deceleration times of zero during standard Electronic Line Shaft (P1-01 = 4, 5) and the Alignment function.

3.0 Limitations

a. For ELS modes (P1-01 = 4, 5), Flux Vector control mode must be used (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 Alignment function is available in Flux Vector control mode only (A1-02 = 3) and when P1-01 = 4 or 5 (ELS modes).
d. The Alignment function is only available in the forward direction.
e. The Alignment function is disabled when the motor speed is less than the DC Injection Frequency (B2-01).
f. The alignment pulse from the master and the alignment pulse from the slave must be at a 1:1 ratio (the software requires one follower alignment pulse for every one master alignment pulse).
g. The master alignment pulse must occur exactly once per master encoder revolution.
h. 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.

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 "top" position (using the 2 pins closest to the 4CN connector).

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 1, 2	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. *Note: Settings 4 and 5 are available only in the Flux Vector Mode (A1-02 = 3).*	0 ~ 5	0	No	Q	Q	Q	Q

*1: Access Level (A1-01): Q = “Quick Start”, A = “Advanced”, F = “Factory”, – = Not Available.

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 1, 2	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***	Selects 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. 1: Always Position error is calculated whenever power is applied to the follower drive. *Note: ELS modes only.*	0 ~ 1	0	No	–	–	–	A

*1: Access Level (A1-01): Q = “Quick Start”, A = “Advanced”, F = “Factory”, – = Not Available.

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 1, 2	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
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”, – = Not Available.

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 1, 2	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
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
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

*1: Access Level (A1-01): Q = “Quick Start”, A = “Advanced”, F = “Factory”, – = Not Available.

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 1, 2	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
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 follower 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
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

*1: Access Level (A1-01): Q = “Quick Start”, A = “Advanced”, F = “Factory”, – = Not Available.

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 1, 2	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
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
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
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
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

*1: Access Level (A1-01): Q = “Quick Start”, A = “Advanced”, F = “Factory”, – = Not Available.

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 1, 2	Flux Vector
P4-01	106H	Initial Alignment Displacement ***Init Align Displ***	Sets the initial value that will be loaded into the Displacement Reference Register. This is set in quadrature follower encoder counts. The value of this parameter will be loaded into the register on drive power up and anytime this parameter is changed. This value is ignored when a non-zero value is written to the Displacement network communication register. See section 4.6. *Note: ELS modes only.*	1 ~ 65,535 Counts	1	Yes	–	–	–	A
P4-02	107H	Alignment Tolerance ***Align Tolerance***	Sets the amount the amount of displacement error (U1-94 minus U1-95) and position error (U1-96) that constitutes being in alignment. This is set in quadrature follower encoder counts. The "In Alignment" multi-function digital output (H2-0X = 41) will close when the displacement error and the position error is less than P4-02. *Note: ELS modes only.*	0 ~ 65,535 Counts	20	Yes	–	–	–	A
P4-03	108H	Max Corrections per Revolution ***Max Correctn/Rev***	Sets the maximum amount of displacement error that can be corrected by the follower drive each time the master and follower alignment pulses are read. This is set in quadrature follower encoder counts. *Note: ELS modes only.* *Note: Setting this parameter to a large value could result in possible machine damage.*	0 ~ 65,535 Counts	40	Yes	–	–	–	A

*1: Access Level (A1-01): Q = "Quick Start", A = "Advanced", F = "Factory", – = Not Available.

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 1, 2	Flux Vector
U1-56	079H	Master Marker Frequency ***Master Marker Fq***	Displays the frequency of the master alignment input pulse. *Note: This monitor should be used for testing and debugging only, not for measurement.* *Note: ELS modes only.*	N/A	Hz	–	–	–	Q
U1-57	07AH	Slave Marker Frequency ***Slave Marker Fq***	Displays the frequency of the follower marker alignment input pulse. *Note: This monitor should be used for testing and debugging only, not for measurement.* *Note: ELS modes only.*	N/A	Hz	–	–	–	Q
U1-58	079H	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 should be used only to confirm that encoder counts are being received.*	100% = Counts/5ms at Maximum Output Frequency (E1-04)	Counts	-	-	-	Q
U1-59	07AH	Slave Counts/5ms ***Slave Cts/5ms***	Displays the number of quadrature encoder counts per 5ms scan from the follower drive. *Note: ELS modes only.* *Note: This monitor should be used only to confirm that encoder counts are being received.*	100% = Counts/5ms at Maximum Output Frequency (E1-04)	Counts	-	-	-	Q

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 1, 2	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 ratio adjustment (sum of digital, analog, MOP and communication adjustments).	100% = 100.00%	0.01%	Q	Q	Q	Q
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	Displacement Reference ***Displacement Ref***	Displays the current Displacement Reference value in quadrature follower encoder counts. *Note: ELS modes only.*	N/A	Counts	–	–	–	Q
U1-95	725H	Displacement Feedback ***Displacement Fb***	Contains the last displacement measured between the master and follower alignment inputs in quadrature follower encoder counts. Updated once per master alignment input after the follower alignment input has been detected. *Note: ELS modes only.*	N/A	Counts	–	–	–	Q

*1: Access Level (A1-01): Q = “Quick Start”, A = “Advanced”, F = “Factory”, – = Not Available.

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 1, 2	Flux Vector
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

*1: Access Level (A1-01): Q = "Quick Start", A = "Advanced", F = "Factory", – = Not Available.
*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 1, 2	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
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
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

*1: Access Level (A1-01): Q = "Quick Start", A = "Advanced", F = "Factory", – = Not Available.

4.3 Multi-function Digital Input Settings (H1-XX)

Setting	***Name*** Description	Control Mode *1			
		V/f	V/f w/ PG	Open Loop Vector 1, 2	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.*	√	√	√	√

*1: √ = Available, – = Not Available.

4.3 Multi-function Digital Input Settings (H1-XX) (continued)

Setting	***Name*** Description	Control Mode *1			
		V/f	V/f w/ PG	Open Loop Vector 1, 2	Flux Vector
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 regulator error is reset to zero. *Note: ELS modes only.*	√	√	√	√
88	***Position Regulator Integral Reset*** Closed: Position regulator integrator is reset to zero. *Note: ELS modes only.*	√	√	√	√
89	***Align by Pulse (Alignment)*** Closed: Alignment function is enabled and the drive will keep the number of quadrature follower encoder counts (displacement) between the master and follower alignment inputs equal to the displacement reference. *Note: ELS modes only.*	–	–	–	√
8A	***Save Displacement*** Closed: At the transition from open to closed, the current Displacement Reference value (which can be seen in the Displacement Reference monitor U1-94) will be saved to the Initial Alignment Displacement Parameter (P4-01). The data will survive a power loss. *Note: ELS modes only.* *Note: Since this command saves the data into non-volatile RAM, do not continuously use this function. The drive's storage RAM could fail causing drive failure.*	–	–	–	√
8B	***Disable Displacement Error*** Closed: Displacement error will not be corrected. However, if the Align by Pulse (Alignment) digital input (H1-XX = 89) is closed, the displacement feedback will still be calculated and displayed (U1-95), but the follower drive will not correct for any displacement error. This input is useful for troubleshooting and testing. *Note: ELS modes only.*	–	–	–	√

*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 1, 2	Flux Vector
40	***Follower Position Deviation*** Closed: The position regulator error has exceeded the Follower Deviation Level (P2-06). *Note: ELS modes only.*	√	√	√	√
41	***In Alignment*** Closed: The displacement (Alignment) error and the position regulator error are within the Alignment Tolerance (P4-02). *Note: ELS modes only.*	–	–	–	√

*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 1, 2	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 follower encoder count
Hi-Speed Communication Option Card Frequency Reference Register	***Displacement Reference*** Sets the number of quadrature follower encoder counts the follower alignment sensor is expected to be behind the master alignment sensor. This value can also be adjusted by the advance/retard follower digital inputs. The value can be set from 0 ~ 65,535 counts. Setting to a value of 0 will give control of the Displacement Reference to the P4-01 parameter. *Note: ELS modes only.* *Note: The ENTER command is not required when writing to this register.*	1 = 1 quadrature follower 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. ▪ P1-01 = 4, 5 (ELS modes) and the control mode is not Flux Vector.	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.

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 and 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 the 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 the 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 encoder signal.

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 in Figure 4.

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[b]	FWD	NONE[b]
	REV	NONE	NONE	NONE	NONE	NONE	NONE	NONE[a]	NONE[b]	NONE[a]	NONE[b]

a: Inability to follow causes position error accumulation and potential FDEV faults in these conditions.
b: Inability to follow does not cause position error accumulation in these conditions unless P1-09 = 1, due to the way the drive handles the B1-04 = 1 condition.

Figure 4 below outlines the follower direction and Advance/Retard behavior for P1-04 settings and forward / reverse run command selections.

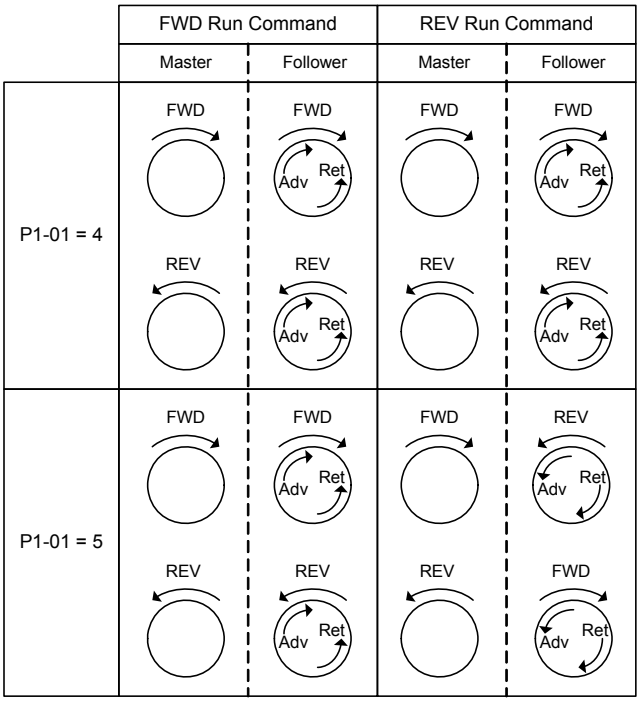

Figure 4: Follower Direction and Advance/Retard Behavior

5.3 Alignment

The Alignment function builds off of the existing Electronic Line Shaft functionality, and is identical to ELS except where noted below. In order to use Alignment, the following conditions must be met: the Follower Disable digital input must be open (H1-XX = 80), the Align by Pulse input must be closed (H1-XX = 89), the drive must also be in closed loop vector control (A1-02 = 3), and either ELS mode (P1-01 = 4, 5) must be selected.

Also, if the follower drive is traveling at a speed less than the DC Injection frequency (B2-01) or is traveling in the negative direction, the Alignment function will be disabled, but standard ELS will continue to function. Any conditions that cause the ELS position error to be cleared (held at zero) will also disable Alignment.

Alignment is maintained by adding the Displacement Error (difference between the Displacement Reference U1-94 and the Displacement Feedback U1-95) into the same position error that is used by both ELS modes. This difference is added only once each time it is measured (once for each master/follower alignment pulse combination received). If the Disable Alignment Error digital input is closed (H1-XX = 91), the system will calculate Displacement Feedback, but the Alignment Error will not be summed into the position error.

The In Alignment multi-function digital output will close when the magnitudes of the Position Error and the Displacement Error are both less than the Alignment Tolerance (P4-02). The In Alignment digital output can only be set after making a Displacement Error calculation; therefore the Position Error must be within range at the moment the Displacement Error is calculated. If the magnitudes of either the Position Error or the Displacement Error are greater than the Alignment Tolerance, the In Alignment digital output will open. The In Alignment output will function even if the Disable Displacement Error multi-function digital input is closed.

The In Alignment output will be reset if the Master or Follower Marker signal is lost. If the master encoder travels more than 1.5 master revolutions since the last Master Marker Pulse, the In Alignment output will be reset (opened). If the Follower Marker Pulse is not seen for two consecutive Master Marker Pulses, the In Alignment output will be reset (opened). The In Alignment output will function even if the Disable Displacement Error input is closed.

When the drive powers up, the Displacement Reference value is loaded from the Initial Displacement Reference parameter (P4-01). P4-01 will serve as the Displacement Reference as long as the Displacement Reference network communications register value is at zero (see Section 4.6). When a non-zero value is written to the Displacement Reference register, this value will become the Displacement Reference. P4-01 will resume as the Displacement Reference when a zero is written to the Displacement Reference register.

While P4-01 has control over the Displacement Reference and the Align by Pulse multi-function digital input is closed, the Advance/Retard Follower inputs will have a second effect of adjusting the Displacement Reference along with adjusting the current position of the follower motor. The Advance follower input will move the follower motor forward and will reduce the Displacement Reference by an equal amount. The Retard follower input will move the follower motor backwards and will increase the Displacement Reference by an equal amount. This change will only affect the Displacement Reference value, not the actual P4-01 parameter. The Advance/Retard follower inputs will have no affect on the Displacement Reference while the Displacement Reference register has control. If the P4-01 parameter is changed while it has control over Displacement Reference, the new P4-01 value will be loaded into the Displacement Reference.

Two parameters are used to ensure that the follower drive is not too reactive when correcting alignment errors. The first parameter is the Maximum Correction per Revolution (P4-03). This limits the number of counts of Displacement Error that can be added to the Position regulator each time the master and follower alignment pulses are read. This value can also help limit Displacement Feedback overshoot and oscillation issues when bringing the follower into alignment from an initial large Displacement Error. The second parameter is P3-04 (Position PI Limit), which has the effect of regulating the maximum delta speed with respect to master speed the follower will travel at to correct alignment errors.

5.4 Wiring Electronic Lineshaft and the Alignment Inputs

The two alignment inputs can each come from either the marker pulse from an encoder or from an external sensor. The alignment inputs need to be wired to the marker (Z) pulse inputs of the dual input encoder card (ex. PG-W2). Marker pulse input channels require a line driver type circuit. Wire the master alignment input into terminals 14 and 15 of the PG-W2. Wire the follower alignment input into terminals 7 and 8 of the PG-W2. For other dual input encoder cards, consult their installation guide for exact terminals. Figure 5 below details the wiring of the PG-W2 option card.

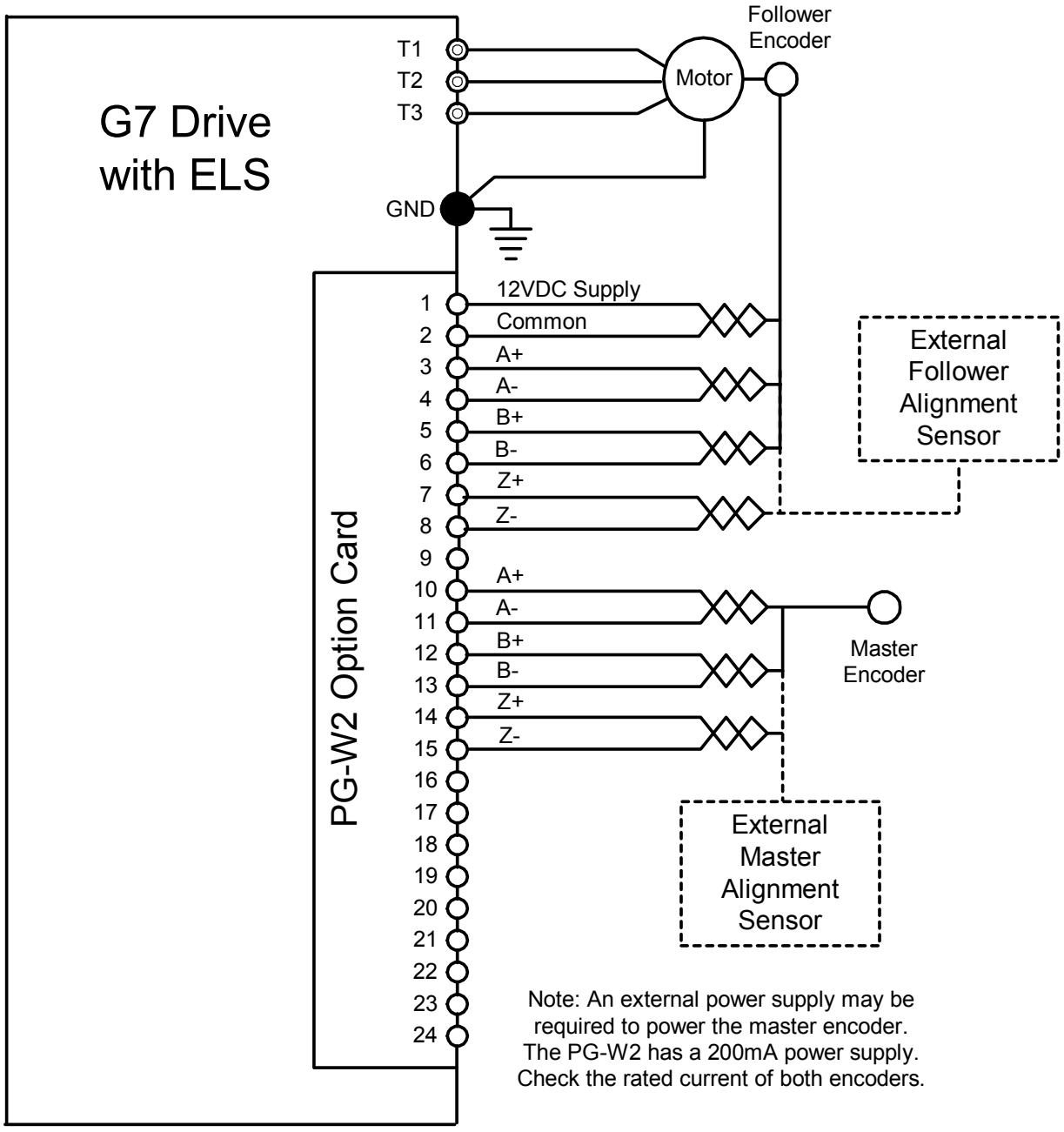

Figure 5: Wiring Example of ELS with Alignment

Figure 6 below shows an example of how a +12VDC current sinking (open collector NPN) sensor can be used to trigger the marker pulse input (alignment input) of the encoder feedback card. An external power supply may be required. For best noise immunity, locate the resistor network at the switch, not at the encoder feedback card. Please note that the switch must be able to handle at least 22mA of current draw. For exact application wiring, consult Yaskawa Application Engineering with the exact sensor specifications.

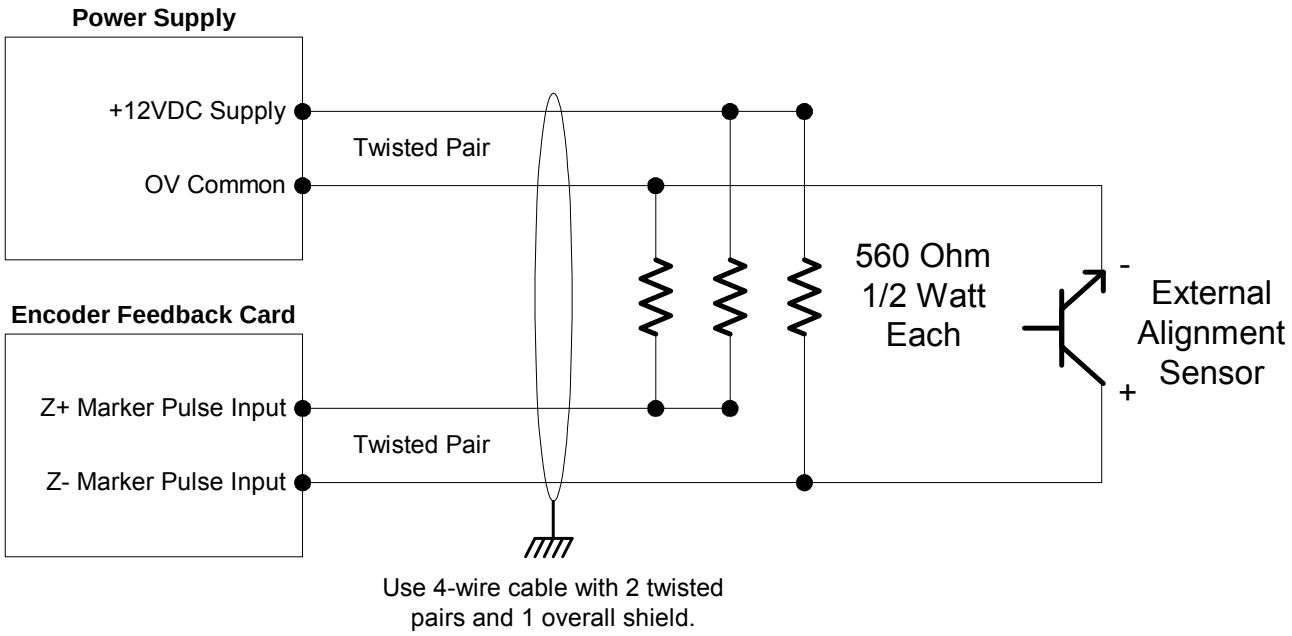

Figure 6: Wiring Example of External Alignment Sensor

6.0 Block Diagrams

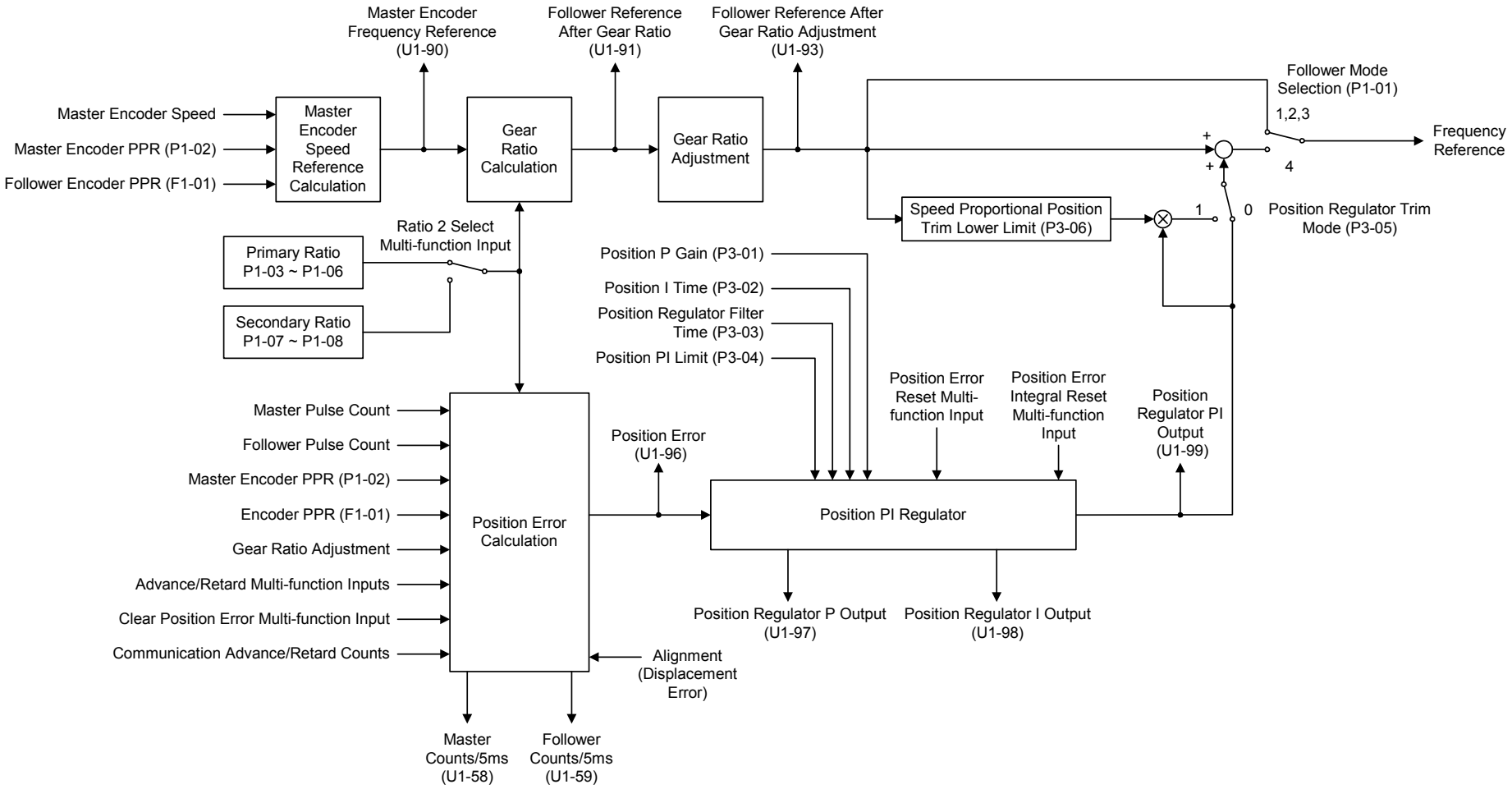

Figure 7: Software Overview Diagram

6.0 Block Diagrams (continued)

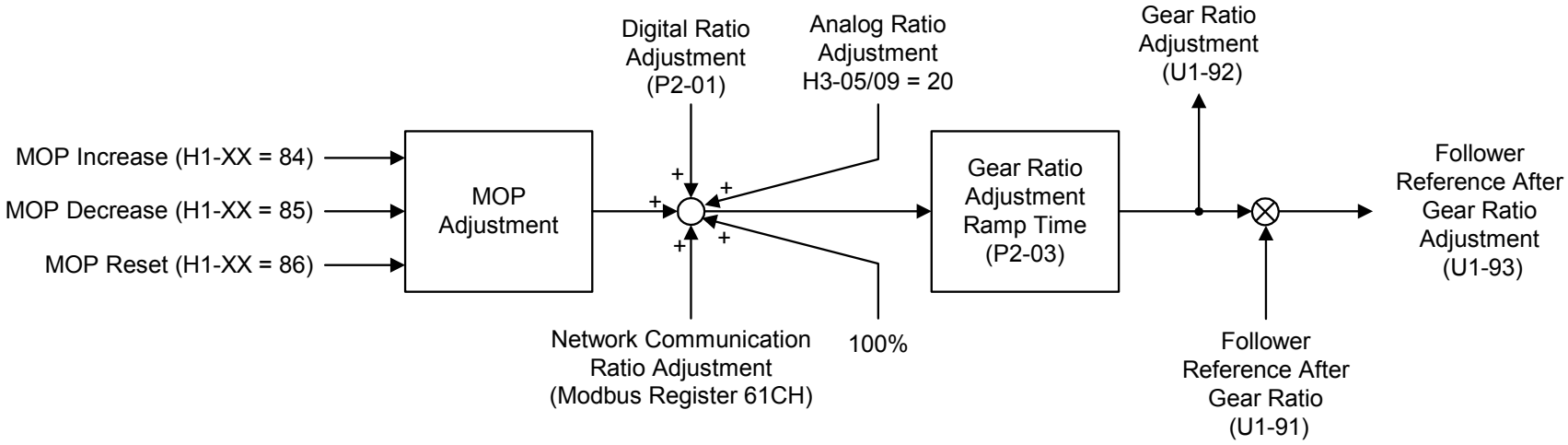

Figure 8: Composite Gear Ratio Diagram

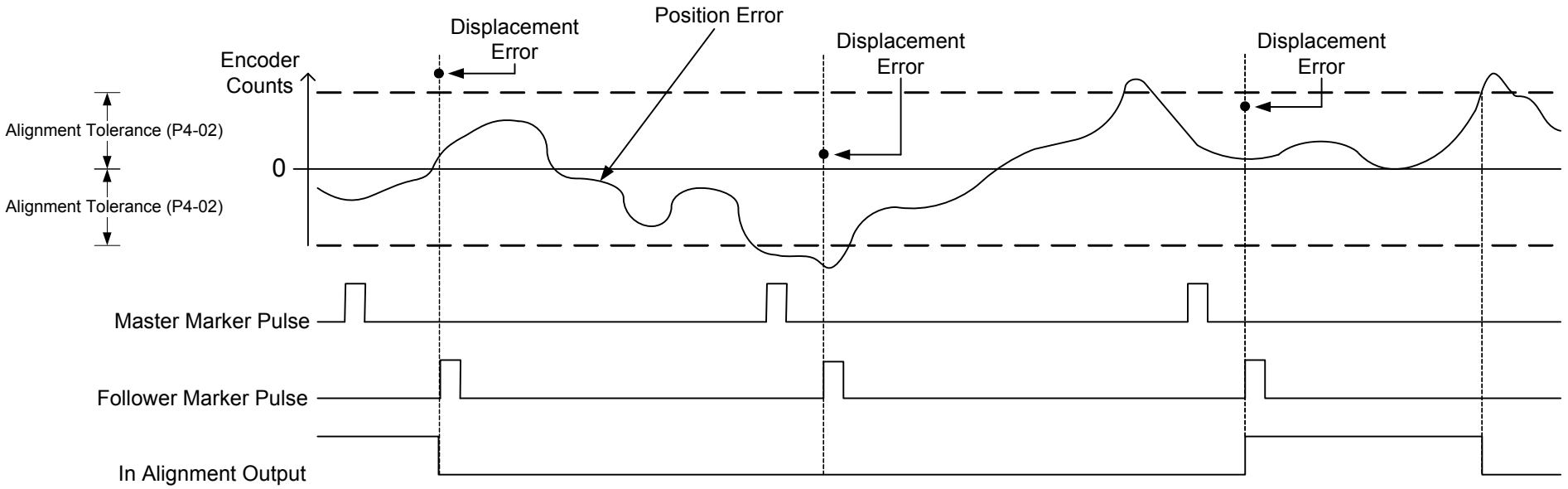

Figure 9: In Alignment Digital Output Diagram

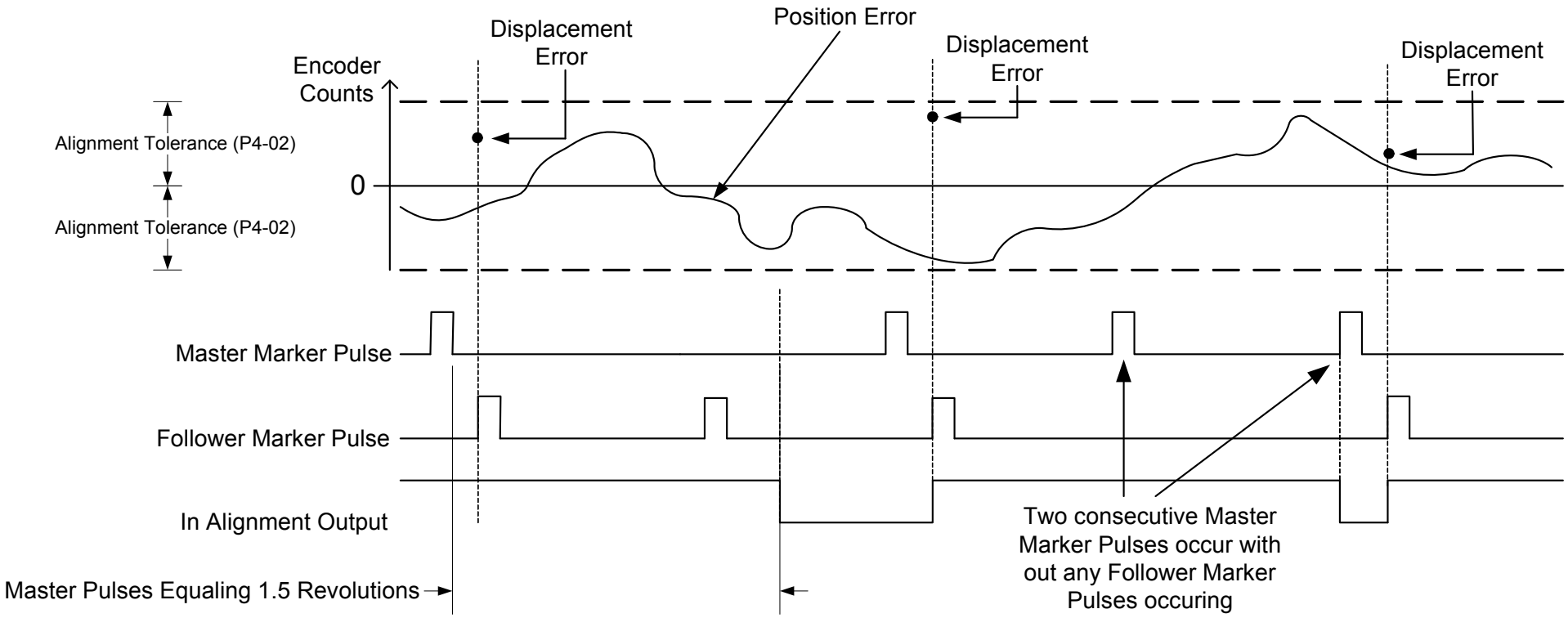

Figure 9: In Alignment Function When the Master or Follower Marker Pulse is Lost