

# Application Software Manual

<b>Software Title</b>	<b>F7Z-Electronic Line Shaft (ELS) and MLII</b>
<b>Software No.</b>	<b>VSF108162</b>
<b>Base Software No.</b>	<b>VSZ108958 (VSZ100674_1 w/o Std ELS functionality)</b>
<b>Issued Date</b>	<b>15-May-2006</b>
<b>Product Name</b>	<b>Varispeed F7Z</b>

The software is a final software.

## 1. Overview

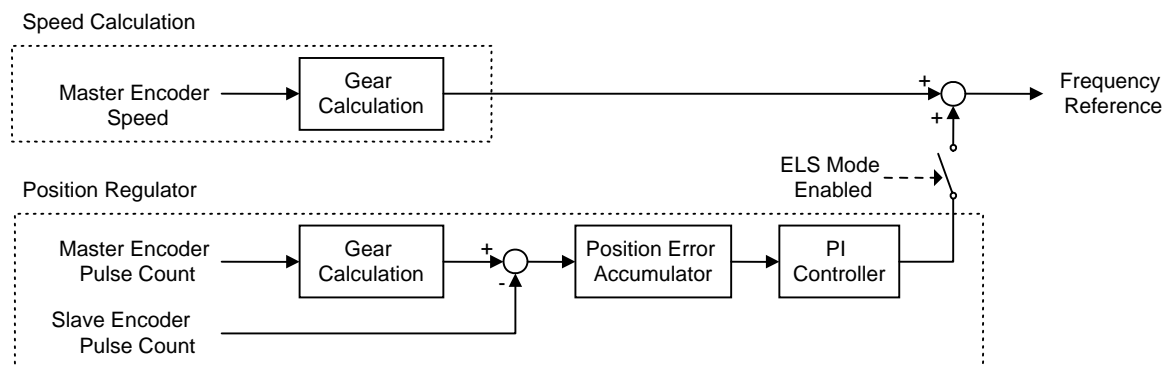
The Electronic Line Shaft (ELS) function allows a drive to precisely follow a master encoder or another drive. The follower can match its position (phase angle) to the master within several quadrature encoder counts. The function is used in applications where the machinery being driven requires two mechanically isolated and motor-driven 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 can be added to the speed reference via parameter, analog input, multi-function input MOP or serial communication. The drive can also be run in a pure speed follower mode for applications which do not require matched position.

From the standard software MLII is supported.

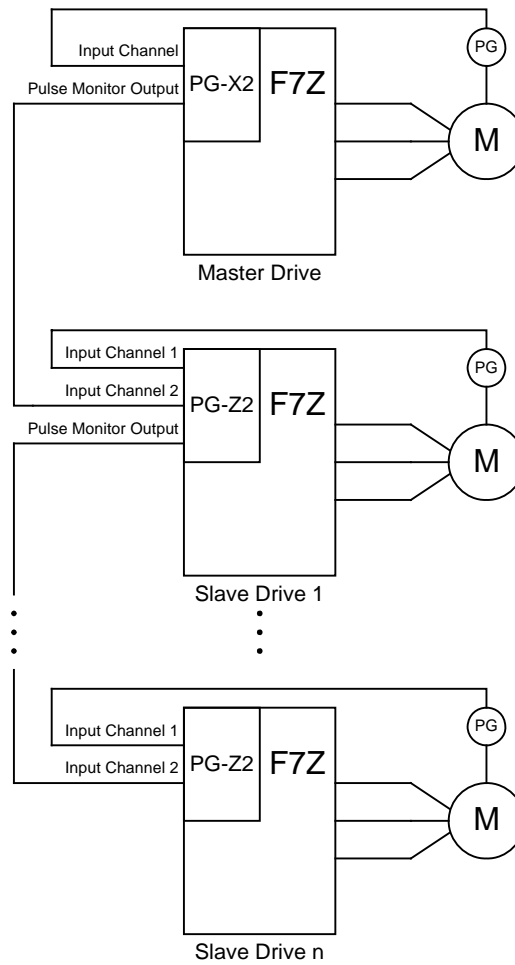
## 2. Basic concept/principle

Both the master and follower encoder signals are fed into the follower drive's dual 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 only as a speed follower, the position regulator is disabled.

*Simplified Block Diagram of Follower Function*



Connection for Typical Configuration



**3. Limitations**

The proper 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. For optimum performance, Flux Vector control mode is recommended.

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

#### 4. Related parameters and functions (including Multi-function selections)

##### (1) Parameters

Parameter No.	Memobus Address	Parameter Name	Description	Range	Default	Change During Run	Control Mode			
		Digital Operator Display					V/f	V/f w/ PG Vector	Open Loop	Flux Vector
P1-01	600H	Follower Mode Selection	<p>Sets the follower operation mode.</p> <p>0: Disabled Follower mode is disabled and the drive runs from the normal frequency reference.</p> <p>1: Speed – Both Dir The drive follows the master encoder speed in both directions.</p> <p>2: Speed – Fwd Dir The drive follows the master encoder speed in the forward direction only.</p> <p>3: Speed – Abs Val The drive follows the master encoder speed but ignores the master encoder direction (motion is always in the forward direction).</p> <p>4: Elec Line Shaft The drive follows the master encoder position (both directions).</p>	0 ~ 4	0	NO	Q	Q	Q	Q
		Follower Mode								
P1-02	601H	Master Encoder PPR	Sets the master drive encoder PPR.	20 ~ 60000	1024	NO	Q	Q	Q	Q
		Master PG PPR								
P1-03	602H	Ratio Numerator (Upper 4 Digits)	Sets the upper 4 digits of the primary gear ratio numerator.	0 ~ 9999	1000	YES	Q	Q	Q	Q
		Ratio Num High								
P1-04	603H	Ratio Denominator (Upper 4 Digits)	Sets the upper 4 digits of the primary gear ratio denominator.	0 ~ 9999	1000	YES	Q	Q	Q	Q
		Ratio Den High								
P1-05	604H	Ratio Numerator (Lower 4 Digits)	Sets the lower 4 digits of the primary gear ratio numerator.	0 ~ 9999	0	YES	A	A	A	A
		Ratio Num Low								
P1-06	605H	Ratio Denominator (Lower 4 Digits)	Sets the lower 4 digits of the primary gear ratio denominator.	0 ~ 9999	0	YES	A	A	A	A
		Ratio Den Low								
P1-07	606H	Ratio 2 Numerator	Sets the numerator of the secondary gear ratio.	1 ~ 65535	1	Yes	A	A	A	A
		Ratio 2 Num								
P1-08	607H	Ratio 2 Denominator	Sets the denominator of the secondary gear ratio.	1 ~ 65535	1	Yes	A	A	A	A
		Ratio 2 Den								
P1-09	608H	Position Error Accumulation Selection	<p>Sets when the position error accumulator is enabled. ELS mode only.</p> <p>0: Only During Run Position error is only calculated when the drive is running.</p> <p>1: Always Position error is calculated whenever power is applied to the drive.</p>	0 ~ 1	0	NO	A	A	A	A
		Pos Accum Select								

Parameter No.	Memobus Address	Parameter Name	Description	Range	Default	Change During Run	Control Mode			
		Digital Operator Display					V/f	V/f w/ PG Vector	Open Loop	Flux Vector
P1-10	609H	Position Units Selection	Sets the units used for the Position Error Monitor (U1-96). ELS mode only. 0: Encoder Counts Position error is displayed in 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).	0 ~ 3	0	YES	A	A	A	A
		Position Units								
P2-01	60AH	Digital Ratio Adjustment	Sets the digital gear ratio adjustment. The gear ratio adjustment is also influenced by the analog and communication gear ratio adjustments.	-99.99 ~ 99.99	0.00%	YES	A	A	A	A
		Digital RatioAdj								
P2-02	60BH	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 inputs are closed.	0 ~ 6000.0	50.0sec	YES	A	A	A	A
		MOP Adjust Time								
P2-03	60CH	Gear Ratio Adjustment Ramp Time	Sets the time for the composite gear ratio adjustment to change by 100.00%.	0 ~ 6000.0	10.0sec	YES	A	A	A	A
		Ratio Adj Ramp								
P2-04	60DH	Advance/Retard Mode Selection	Selects the advance/retard functionality. ELS mode only. 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.	0 ~ 1	0	NO	A	A	A	A
		Adv/Ret Mode Sel								
P2-05	60EH	Advance/Retard Amount	Sets the number of 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. ELS mode only. <b>Note:</b> An 1024PPR encoder is considered to have 4096 counts per revolution.	0 ~ 65535	2048cts	YES	A	A	A	A
		Adv/Ret Amount								
P2-06	60FH	Follower Deviation Level	Sets the amount of position error that will activate follower deviation detection. Also sets the scaling for the Position Error analog output selection (H3-09 = 94). ELS mode only. <b>Note:</b> An 1024PPR encoder is considered to have 4096 counts per revolution.	0 ~ 65535	4096cts	NO	A	A	A	A
		Follower Dev Lvl								

Parameter No.	Memobus Address	Parameter Name	Description	Range	Default	Change During Run	Control Mode			
		Digital Operator Display					V/f	V/f w/ PG	Open Loop Vector	Flux Vector
P2-07	610H	Follower Position Fault Stop Selection	<p>Selects the drive action when the position error exceeds the P2-06 setting.</p> <p>0: No Detection The drive continues to run.</p> <p>1: Alarm Only The drive continues to run and an FPA alarm flashes on the digital operator.</p> <p>2: Coast to Stop The FPF fault is displayed, the drive fault contact is activated, and the motor coasts to a stop.</p>	0 ~ 2	2	NO	A	A	A	A
		Flt Stop Sel								
P2-08	611H	PG Monitor Channel Selection	<p>Selects which PG channel is sent to the PG monitor outputs when using a dual channel PG option card (PG-Z2).</p> <p>0: Channel 1 (Slave's PG) PG Channel 1 is sent to the monitor outputs.</p> <p>1: Channel 2 (Master's PG) PG Channel 2 is sent to the monitor outputs.</p>	0 ~ 1	1	YES	A	A	A	A
		PG Mon Ch Select								
P2-09	612H	MOP Adjustment Memorization at Power Off	<p>Determines if the MOP gear adjustment is memorized when the drive loses power.</p> <p>0: Disabled MOP adjustment is not memorized at power down.</p> <p>1: Enabled MOP adjustment is memorized at power down.</p>	0 ~ 1	0	NO	A	A	A	A
		MOP Mem @Pwr Off								
P3-01	614H	Position P Gain	<p>Sets the proportional gain of the position control. ELS mode only.</p>	0 ~ 100.00	5.00	YES	A	A	A	A
		Position P Gain								
P3-02	615H	Position I Time	<p>Sets the integral time of the position control. ELS mode only.</p>	0 ~ 50.00	0.00sec	YES	A	A	A	A
		Position I Time								
P3-03	616H	Position Control Filter Time	<p>Sets the filter time of the position control. ELS mode only.</p>	0 ~ 1.50	0.00sec	YES	A	A	A	A
		Pos Filter Time								
P3-04	617H	Position PI Limit	<p>Sets the bipolar limit of the position PI control output. Set as a percentage of maximum frequency E1-04. ELS mode only.</p>	0 ~ 10.00	8.00%	YES	A	A	A	A
		Pos PI Limit								
P3-05	618H	Position Control Trim Mode	<p>Selects how the position control is used to trim the master encoder speed reference. ELS mode only.</p> <p>0: Constant The position control output is independent of the master encoder speed reference.</p> <p>1: Speed Prop The position control output is proportional to the master encoder speed reference.</p>	0 ~ 1	0	YES	A	A	A	A
		Pos Trim Mode								

Parameter No.	Memobus Address	Parameter Name	Description	Range	Default	Change During Run	Control Mode			
		Digital Operator Display					V/f	V/f w/ PG	Open Loop Vector	Flux Vector
P3-06	619H	Speed Proportional Position Control Trim Lower Limit	Sets the lower limit of the position control trim when P3-05 = 1.	0 ~ 100.00	10.00%	YES	A	A	A	A
		SpdProp LowerLim								
P3-07	61AH	Ratio Change Speed Agree Width	Sets the frequency width used to determine a speed agree condition when the drive is accelerating or decelerating due to one of the following: <ul style="list-style-type: none"> <li>▪ Gear ratio change</li> <li>▪ Change in state of the Follower Disable multi-function input</li> </ul> Change in state of the run command	0 ~ 20.0	0.5Hz	YES	A	A	A	A
		RatioChg SpdAgrF								

## (2) Memobus Registers

Memobus Address	Description	Scaling
61CH	Communication Gear Ratio Adjustment Allows gear ratio adjustment via serial communication. The total gear ratio adjustment is the sum of the analog, digital, MOP and communication ratio adjustments. Data is interpreted as signed, so the adjustment can be set from -327.68% ~ 327.67%.	1 = 0.01%
61DH	Communication Advance/Retard Counts Allows advance/retard of the follower drive via serial communication. Data is interpreted as signed, so the advance/retard counts can be set from -32768 ~ 32767. <b>After this register is set, its data returns to 0.</b> ELS mode only.	1 = 1 encoder count

Note: The ENTER command is not required when writing to these registers.

## (3) Monitors

Monitor No.	Memobus Address	Monitor Name	Description	Scaling for Multi-function Analog Output (H4-01/H4-04)	Unit	Control Mode			
		Digital Operator Display				V/f	V/f w/ PG	Open Loop Vector	Flux Vector
U1-90	720H	Master Encoder Reference	Displays the frequency reference from the master drive before gear ratios and gains are applied.	10V: Maximum Frequency (E1-04)	0.1 Hz	A	A	A	A
		Master PG Fref							
U1-91	721H	Follower Reference After Gear Ratio	Displays the frequency reference from the master drive after the gear ratio (P1-03 ~ P1-06) is applied.	10V: Maximum Frequency (E1-04)	0.1 Hz	A	A	A	A
		Fref After Gear							
U1-92	722H	Gear Ratio Adjustment	Displays the total gear ration adjustment (sum of digital, analog, MOP and communication adjustments).	10V: 100.00%	0.01%	A	A	A	A
		Gear Ratio Adj							
U1-93	723H	Follower Reference After Gear Ratio Adjustment	Displays the frequency reference from the master drive after the digital, analog, MOP and communication gear ratio adjustments are applied.	10V: Maximum Frequency (E1-04)	0.1 Hz	A	A	A	A
		Fref After Adj							

Monitor No.	Memobus Address	Monitor Name	Description	Scaling for Multi-function Analog Output (H4-01/H4-04)	Unit	Control Mode			
		Digital Operator Display				V/f	V/f w/ PG	Open Loop Vector	Flux Vector
U1-94	724H	Master Counts/5ms	Displays the quadrature encoder counts per 5ms for the master drive (after gear ratio and digital, analog, MOP and communication ratio adjustments). Active in ELS mode only.	10V: Counts/5ms at Maximum Frequency (E1-04)	-	A	A	A	A
		Master Cts/5ms							
U1-95	725H	Slave Counts/5ms	Displays the quadrature encoder counts per 5ms for the follower drive. Active in ELS mode only.	10V: Counts/5ms at Maximum Frequency (E1-04)	-	A	A	A	A
		Slave Cts/5ms							
U1-96	726H	Position Error	Displays the position error between the master and slave drives in encoder counts. Active in ELS mode only.	10V: Maximum Frequency (E1-04)	cts*	A	A	A	A
		Position Error							
U1-97	727H	Position Control P Output	Displays the output of the proportional part of the position PI control. Active in ELS mode only.	10V: Maximum Frequency (E1-04)	0.01%	A	A	A	A
		Position P Out							
U1-98	728H	Position Control I Output	Displays the output of the integral part of the position PI control. Active in ELS mode only.	10V: Maximum Frequency (E1-04)	0.01%	A	A	A	A
		Position I Out							
U1-99	729H	Position Control PI Output	Displays the output of the position PI control. Active in ELS mode only.	10V: Maximum Frequency (E1-04)	0.01%	A	A	A	A
		Position PI Out							

\* Unit is dependent on the setting of 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.

Note: When reading U1-96 by Memobus communication (register 726H) the unit is fixed at encoder counts.

#### (4) Multi-function input settings (H1-XX)

Setting	Description	Control Mode			
		V/f	V/f w/ PG	Open Loop Vector	Flux Vector
80	Follower Disable Closed: Follower mode is disabled and the drive will follow the normal frequency reference (based on B1-01 setting) and use the normal accel/decel times.	X	X	X	X
81	Position Control Integral Reset Closed: Position control integral is reset. ELS mode only.	X	X	X	X
82	Advance Follower Closed: Follower position is advanced relative to the master. No additional position error is accumulated. ELS mode only.	X	X	X	X
83	Retard Follower Closed: Follower position is retarded relative to the master. No additional position error is accumulated. ELS mode only.	X	X	X	X
84	MOP Adjust Increase Closed: The MOP ratio adjustment is increased.	X	X	X	X
85	MOP Adjust Decrease Closed: The MOP ratio adjustment is decreased.	X	X	X	X
86	MOP Adjust Reset Closed: The MOP ratio adjustment is reset to 0.	X	X	X	X
87	Position Error Reset Closed: Position error is reset when in ELS mode.	X	X	X	X

Setting	Description	Control Mode			
		V/f	V/f w/ PG	Open Loop Vector	Flux Vector
88	Ratio 2 Select Closed: Gear Ratio 2 (P1-07, P1-08) is selected. When in ELS mode, 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 become enabled again.	X	X	X	X

(5) Multi-function output settings (H2-XX)

Setting	Description	Control Mode			
		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. ELS mode only.	X	X	X	X

(6) Multi-function analog input settings (H3-09)

Setting	Description	Scaling	Control Mode			
			V/f	V/f w/ PG	Open Loop Vector	Flux Vector
20	Analog Ratio Adjustment Added to the digital, MOP and communication ratio adjustment to form the total gear ratio adjustment.	10V = 100.00%	X	X	X	X

(7) Faults

Fault Display	Description	Causes	Countermeasures
OPE12 Follower Sel Err	There is a problem with the configuration of the Follower function.	<ul style="list-style-type: none"> <li>▪ P1-01 = 4 (ELS mode) and one of the following option cards is not installed: PG-Z2.</li> <li>▪ P1-01 = 1,2,3 (Speed Follower mode), the control mode is V/f w/ PG or Flux Vector and one of the following option cards is not installed: PG-Z2.</li> <li>▪ P1-01 = 1,2,3 (Speed Follower mode), the control mode is V/f or Open Loop Vector and one of the following option cards is not installed: PG-B2, PG-X2.</li> </ul>	Install the appropriate PG option card for the control mode and follower mode selection.

<p>FDEV Follower Pos Dev</p>	<p>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).</p>	<ul style="list-style-type: none"> <li>▪ Mechanical binding of the follower motor.</li> <li>▪ The Follower Deviation Level (P2-06) is set too low.</li> <li>▪ The master drive is running, the follower drive is stopped, and the Position Error Accumulation Selection (P1-09) is set to 1 (position error is always accumulated).</li> </ul>	<ul style="list-style-type: none"> <li>▪ Confirm the machinery is operating correctly and the follower motor is not binding.</li> <li>▪ Increase the setting of P2-06.</li> <li>▪ If the application requires that the master drive runs while the follower drive is stopped, set P1-09 = 0 (position error only accumulated during run).</li> </ul>
<p>PL Loss of Position</p>	<p>The follower drive has lost its position information. This has occurred because one of the following conditions exist:</p> <ul style="list-style-type: none"> <li>▪ The position error has exceeded 268.435.456 counts.</li> <li>▪ The pulse frequency after the gear ratio is so high that the follower cannot run at this speed without exceeding the PG option card hardware limitation (300kHz).</li> </ul>	<ul style="list-style-type: none"> <li>▪ Mechanical binding of the follower motor.</li> <li>▪ The master drive is running, the follower drive is stopped, and the Position Error Accumulation Selection (P1-09) is set to 1 (position error is always accumulated).</li> <li>▪ The desired follower speed is too high for the PPR of the installed encoder.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Confirm the machinery is operating correctly and the follower motor is not binding.</li> <li>▪ If the application requires that the master drive runs while the follower drive is stopped, set P1-09 = 0 (position error only accumulated during run).</li> <li>▪ Replace the follower motor's encoder with a lower PPR model.</li> </ul>

### (8) Alarms

Alarm Display	Description	Cause	Countermeasures
<p>FDEV Follower Pos Dev</p>	<p>The position error has exceeded the Follower Deviation Level (P2-06) and the Follower Deviation Selection (P2-07) is set to 1 (Alarm Only).</p>	<ul style="list-style-type: none"> <li>▪ Mechanical binding of the follower motor.</li> <li>▪ The Follower Deviation Level (P2-06) is set too low.</li> <li>▪ The master drive is running, the follower drive is stopped, and the Position Error Accumulation Selection (P1-09) is set to 1 (position error is always accumulated).</li> </ul>	<ul style="list-style-type: none"> <li>▪ Confirm the machinery is operating correctly and the follower motor is not binding.</li> <li>▪ Increase the setting of P2-06.</li> <li>▪ If the application requires that the master drive runs while the follower drive is stopped, set P1-09 = 0 (position error only accumulated during run).</li> </ul>

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## 5. Function description

When Follower Mode Selection **P1-01 = 1 ~ 3 (speed follower mode)** the drive will follow the speed of the master encoder signal. Using the gear ratio parameters P1-03 ~ P1-06, the drive can be made to run at a ratio of the master speed.

The ratio can be further adjusted using the Digital Ratio Adjustment, the Analog Ratio Adjustment (H3-09 = 20), the MOP Adjust multi-function inputs (H1-0X = 84 ~ 86) and the Communication Ratio Adjustment (register 612H). These adjustments are summed and then added to 100% to produce the total gear ratio adjustment, which is multiplied by the incoming speed reference (after gear ratio calculation).

When Follower Mode Selection **P1-01 = 4 (ELS mode)**, the drive will track follower position relative to the master. A PI controller is applied to the position error. The output of the PI controller 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. The Advance Follower (H1-0X = 82) and Retard Follower (H1-0X = 83) multi-function inputs and the Communication Advance/Retard Follower (register 61DH) can be used to change the position of the follower relative to the master.

When in ELS mode and the gear ratio of the drive is changed instantaneously (by changing the gear ratio parameters during run) the drive will ramp to the new ratio using Accel/Decel Time 2 (C1-03/C1-04). If ELS mode is selected the position error will be held to 0 until the drive re-enters speed agree (based on the Ratio Change Speed Agree Width P3-07).

### Notes:

- In speed follower mode, the drive run direction is determined based on the run command direction and the master encoder direction, in the same manner as when the drive operates from a bipolar analog frequency reference. In ELS mode, the run direction is solely based on the master encoder direction – forward and reverse run commands are treated identically.
- Parameter F1-05 (PG Rotation) only affects encoder input channel 1 (feedback channel) when the dual PG feedback option (PG-Z2) is used. It does not affect the pulse monitor output.
- In ELS mode, the Position P Gain setting (P3-01) is scaled in relation to the drive Max Frequency (E1-04), so if the E1-04 setting is changed the proportional contribution of the position controller will be influenced.
- The Speed Follower and ELS function is only for first motor.

## 6. Frequency Reference Block Diagram (next page)

