

Objective

690+ Phase Control

The 690+ drive version 2 or greater firmware supports Phase Control with the use of the Encoder Function blocks.

Phase Control or Phase Lock, sometimes referred to as electronic lineshaft or electronic gearbox, is a position trim of a slave drive speed to maintain the relative position between the master and slave shafts or a precision ratio between the two shafts. The slave speed demand comprises the Master speed demand and the position trim from a counter of the accumulated differences between the Master and Slave encoders.

Equipment

690+ drive equipped with the “Systems Board” option, an external 24 VDC power supply to power the Systems Board, a Reference Encoder Input from a Master encoder, a Slave encoder which will be mounted to the 690+ Slave motor and the software DSELite. The “Systems Board” option is required to do Phase Control.

Systems Board

The Systems Board is an option board that is fitted to the 690+ drives and provides the following features: Master Encoder Input, Slave Encoder Input, Retransmit Slave Encoder Output, adds 5 Configurable Digital I/O (Inputs or Outputs) and increased Analog Input resolution, 12bit plus sign.

Description of the 690+ System Blocks

ENCODER SPEED 1

This block provides the ‘feed forward’ speed demand from the Reference / Master encoder. This is the Master/Reference encoder signal, that the Slave drive will follow.

Source: Selects either the Master or Slave encoder “hardware” input for the speed reference. The signal is generated from the Systems Board, terminal connector “B” for the *Master* encoder. For this application select *Master*.

Lines: Set this to match the PPR (Pulses Per Revolution) of the Master encoder.

Invert: Inverts the polarity of the speed output . Do not use. (swap encoder wires to invert polarity)

Max Speed: Sets the RPM of the Master encoder which will equal 100% at the *Speed* output of this block.

Filter Time: Sets the time constant of the speed filter. Useful for removing ripple on the reference encoder; but, any filter will produce a transient lag in the speed signal which will cause a following error during acceleration or deceleration. Set to zero to remove filter. The default value of 0.5s or less would be a typical value.

Speed: Encoder *Speed* output, connect to PHASE CONTROL::SPEED INPUT for this application. This output will have a range of 0 to 100% Speed, where 100% will be the Master Encoder max speed.

If you have questions, please call the Product Support Group at (704) 588-3246.

PHASE CONFIGURE

Slave Cnt Source: Selects either the TechBox or System Board Slave encoder, for the *Slave* input to the counter. For this application, set it to *Slave Encoder*. The *Slave Encoder* input will be taken from terminal block “C” of the Systems Board.

Speed Loop Speed feedback: Selects either the Encoder TechBox or System Board Slave / Feedback encoder as the speed feedback for the 690+ drive. For this application, select *Slave Encoder*. The encoder input will be taken from terminal block “C” of the Systems Board.

Note: The encoder TechBox is not required for speed feedback when the System Board is used.

Counts Per Unit: Normalizes the encoder counts, e.g. if the encoder is 2048ppr, counting rising and falling edges on A & B inputs, it produces 2048*4 counts in every rev. Setting the Counts per unit to 8192 produces a position value of 1.00 per rev. Set this parameter to 4 times the encoder ppr.

1 ms Cycle Rate: . In drive firmware version 5, setting this to True boosts the execution rate of the phase loop to 1ms, thus improving response. For drive firmware version 5, this parameter is usually set to False.

Max Speed: This scales the speed feed forward for Phase Inch, Phase Move and Phase Register. For this application, this parameter is connected to the *Max Speed* in the *Setpoint Scale* block.

Master Scale A & Master Scale B: These are used to scale the Master encoder input. A is the multiplier and B the divider. E.g. In this example, if the Master encoder is 1024ppr and the Slave encoder 5000pp and the requirement is for 1:1 phase lock, set the *Master Scale A* to 5000 (representing the Slave encoder) and *Master Scale B* to 1024 (representing the Master encoder) so that one revolution of the master encoder produces the same number of counts as the Slave. Set these parameters accordingly to match the Master and Slave encoders ppr.

Master Position: Diagnostic output in encoder counts from the master quadrature encoder. This is the raw counter value and will wrap around from maximum positive to maximum negative through 0, if the counter overflows. With the *Counts per Unit* set to 8192, and with 1 revolution of the encoder, the *Master Position* would be 8192.

Slave Position: Same as the *Master Position*, except for the slave encoder.

Fault: This is a general error flag. The phase accumulator is 32bit. If the *Position Error* counter exceeds the 32bit register, the *Overflow* flag will be set and the phase information will be lost.

PHASE CONTROL

The Phase Control includes the position counter, feed forward speed demand and gearing.

Speed Input: This is the input for the Master Speed demand. For this application this Speed Input is connected to the ENCODER SPEED 1::SPEED.

Gearing A and Gearing B: These scale both the Master Speed and the Master Count for ratioing the Slave speed to the Master speed. A is the multiplier and B the divider. If this ratio is 1:1, the Slave will follow the Master exactly. If Gearing A=100 and Gearing B = 50, the ratio is $(100/50) = 2$. Thus the slave will run at 2x speed of the master. If Gearing A=1100 and Gearing B = 1000, the ratio is $(1100/1000) = 1.1$ Thus the slave will operate at 10% faster speed, than the master. Use Integer numbers for Gearing A&B.

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Position Enable: Enables the position counter, disabling resets the Phase CONTROL::OUTPUT to zero. This parameter is usually connected to a Digital Input or to *Running* parameter in the *Sequence Logic block*.

Output: Output of the position counter scaled by *Output Scale* and sign set by *Invert Output*. This Output is the error between the Master encoder and Slave encoder pulses. If the *Counts Per Unit* in *Phase Configure* is set to 8192, for 1 revolution of the encoder, the *Output* will be 1.00. When the system is running in a steady state condition the *Output* should be hovering around zero if the system is set up properly.

Speed Output: Master encoder speed demand scaled by *Gearing A & Gearing B*.

Master Position: Master position scaled in encoder counts. If the *Counts Per Unit* in *Phase Configure* is set to 8192, for 1 revolution of the Master encoder, the *Master Position* will be 1.00

Master Position INT: Position error in actual counts. If the *Counts Per Unit* in *Phase Configure* is set to 8192, for 1 revolution of the encoder, the *Master Position INT* will be 8192.

Position Error: Normalized position error in encoder units. If the *Counts Per Unit* in *Phase Configure* is set to 8192, for 1 revolution of the encoder, *Position Error* will be 1.00

PHASE PID

This is a dedicated PID for the Phase Control. It includes a Feed forward (*Feed Fwd*) input and Scaling (*Feed Forward Gain*) for the Master Speed demand. The *Limit* can be used to set the trim range, it operates only on the PID output. The *P Gain* and *I Gain* should be set much higher than usual as the normalized position error typically reduces the gain by a factor of 10 to 100. The *Integral* can be disabled by setting the *I Gain* to zero. Without *Integral* the speed will be correct but with a possible position error. Integral control will provide zero position error in steady state.

Output: This is the feed forward speed demand and it should be connected to the *Speed Trim* in the *Reference* block in drive firmware version 4 & 5. This *Output* will generate a 0 to 100% speed demand to the drive. The *Speed Trim* input will accept a speed signal to 100% and it will bypass all of the ramps in the drive.

PID Output: Output of the PID without the feed forward. No connection is made to this parameter. In firmware version 4 & 5, an internal connection is made from this parameter to the *Speed Loop // Phase Input*.

Enable PID: Globally resets the PID output and *Integral* term when false. This parameter must be true for the PID to operate. This parameter should be connected to PHASE CONTROL::POSITION ENABLE for this application.

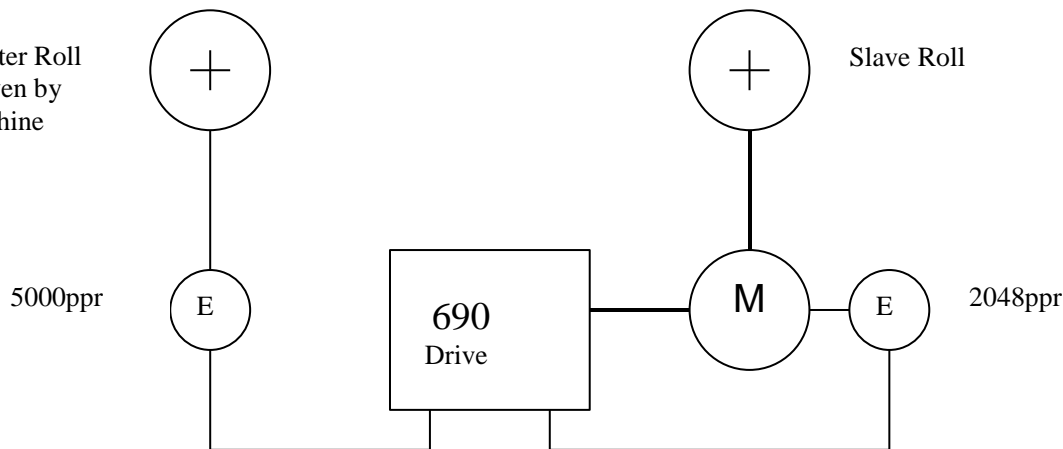
If you have questions, please call the Product Support Group at (704) 588-3246.

Different Types of Phase Configure Applications

PHASE CONTROL WITH FIXED 1:1 RATIO

This is the simplest phase control configuration. The master encoder is driven by the previous section and the slave drive section follows in phase.

In this example, the master encoder has 5000 pulses per revolution and the slave encoder has 2048 pulses per revolution.



Phase Configure block

The *Counts Per Unit* sets the global scaling of position setpoint and feedback. It is 4 times the ppr of the slave encoder for 1 revolution of the slave encoder. This is because there are 2 edges (1 rising and 1 falling) from both A and B inputs of a quadrature encoder. Thus since the slave encoder has 2048 pulses / revolution, the counts Per Unit will be set to $(4 * 2048) = 8192$.

Max Speed block: Set to 1800 rpm the same as the Drive *Max Speed* in the *Quick Set* up menu.

Master Scale A and *Master Scale B*, provide the same counts per unit for the master position. The master encoder counts are scaled by Master Scale A & B, where A is the multiplier and B is the divisor. Set *Master Scale A* to the slave encoders ppr. Set *Master Scale B* to the master encoders ppr.

Encoder Speed 1 block

This provides the feed forward speed demand.

Source Set to *Master Encoder*

Lines Set to 5000

Max Speed Set to 1800 rpm which will equal 100% at the *Speed* out of this block.

Phase Control block

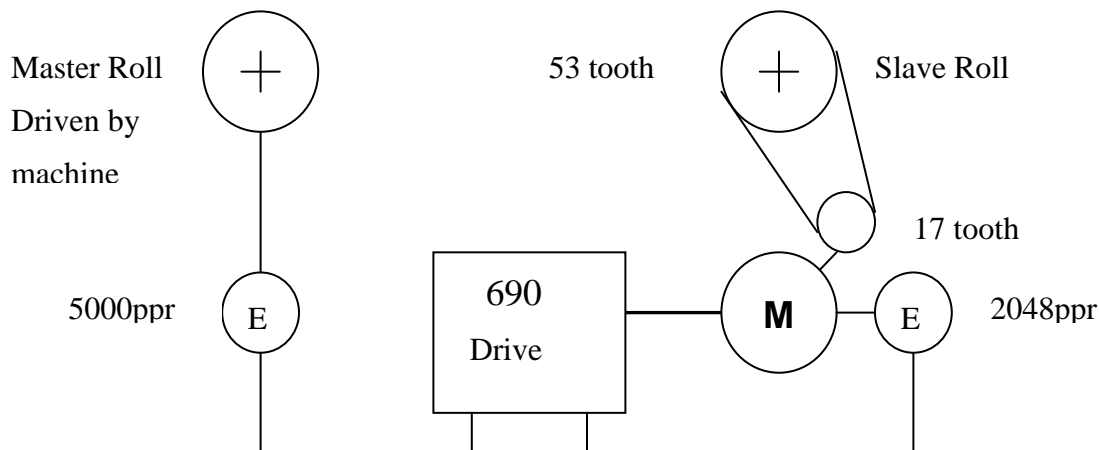
Set *Gearing A* & *B* so both are 1000 for 1:1 ratio.

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PHASE CONTROL WITH FIXED RATIO OTHER THAN 1:1

This is a more typical case where the master encoder is directly connected to a roll turning at a low speed and the slave has a pulley ratio to increase the motor speed. The slave roll must rotate in phase with the master.

The 17 and 53 tooth pulleys give a ratio of $53/17 = 3.117647\dots$



Phase Configure block

Integer ratios must be used which can easily be achieved by setting *Gearing A* = 53 and *Gearing B* = 17

If the Gearing is not an Integer ratio, i.e. *Gearing A* = 31176 and *Gearing B* = 10000, the speed will be correct within the drive resolution but the slave will slowly move out of phase with the master because the ratio is not exact. If this, for example were a print section following a main press with a compensator for register control, the compensator would slowly move and eventually reach the end of its travel.

Max Speed: Set to 1800 rpm the same as the Drive *Max Speed* in the *Quick Set* up menu.

Encoder Speed 1 block

This provides the feed forward speed demand.

Source Set to *Master Encoder*

Lines Set to 5000

Max Speed Set to 1800 rpm.

If the Master Roll speed is 500 rpm the Slave Roll must run at $500 * 53/17 = 1559$ rpm.

Checking the speed feedforward:

Encoder Speed 1 O/P is $500/1800 * 100 = 27.78\%$, multiplied by the gearing of $53/17 = 86.6\%$ of 1800 = 1559rpm.

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Procedure

1. Determine which version of the 690+ drive firmware is being used. Different versions have different connections and set up parameters.
2. Using DSELite, open a “default*.690” template, which matches the drive firmware version. Configure this template per the different versions as shown in FIGURE 3x.
3. In the PHASE CONFIGURE block set SLAVE CNT SOURCE & SPD LOOP SPD FBK to SLAVE ENCODER. This will use the Slave Encoder Feedback from the Systems Board terminal “C” block. Enter the required data for the PHASE CONFIGURE block. I.e. Counts Per Unit, Max Speed, Master Scale A and Master Scale B. See page 2 for information on this block.
4. In the ENCODER SPEED 1 block, set SOURCE to MASTER ENCODER. Enter the LINES and the MAX SPEED data.
5. Using DSELite download the template to the 690+ Slave drive. When installing this template make sure that PARTIAL INSTALL is performed under the COMMAND menu. Do NOT do a COMMAND::FULL INSTALL.
6. Connect the (Feedback) Slave Encoder to terminal block “C” on the Systems Board, as shown in FIGURE 2. This is the encoder that is mounted to the Slave drive motor. See FIGURE 2.
7. Connect the (Master) Reference Encoder to terminal block “B” of the Systems Board.
8. Connect an External 24 VDC power supply to the Systems Board, as shown in FIGURE 2. An external 24Vdc, 1 amp power supply is required for the systems board to operate and supply the digital I/O and encoder power supply at maximum loading.
9. Set up the slave drive via the 690+ MMI keypad (motor data, max speed, encoder data & etc) using the QUICK SETUP menu. Also set the CONTROL MODE for VOLTS / HZ and the VIEW LEVEL to ADVANCED.
10. Run the Slave drive in the Local Mode via the MMI Keypad on the drive and in the forward direction. Verify that the Slave motor is rotating in the correct direction as required for the application. If the motor rotation is wrong, swap any 2 motor leads. Run the motor up to 100% speed to make sure that max speed can be obtained.
11. Run the drive in the Local Mode via the MMI Keypad with a speed SETPOINT of 50%. Make sure the drive is operating in the forward direction. (The right hand arrow > LED will be illuminated). Go to the menu SETUP: MOTOR CONTROL::FEEDBACKS::ENCODER FBK %. Verify that there is a valid number in this ENCODER FBK % window. I.e.: If the Speed Demand of the drive is 50%, the ENCODER FEEDBACK % should be 50%. Also verify that the polarity of this number is positive. If it is NOT positive, reconnect the encoder wiring to make it positive. **Do NOT change the parameter ENCODER INVERT. This parameter must be FALSE for the Phase Control to operate properly.**
12. Set the CONTROL MODE to CLOSED LOOP VEC and perform an Autotune. When finished save the parameters in the drive.

Phase Control setup procedure:

13. In the Slave drive, set the ENCODER SPEED 1::MAX SPEED to 0. (Record the original MAX SPEED value which will be needed in step 16). Also set the SYSTEM BOARD::PHASE PID ::LIMIT to 100%.
14. Run the Master drive or the piece of equipment that the “controls / turns” the Master / Reference encoder. Run this Master Encoder at 10% speed.

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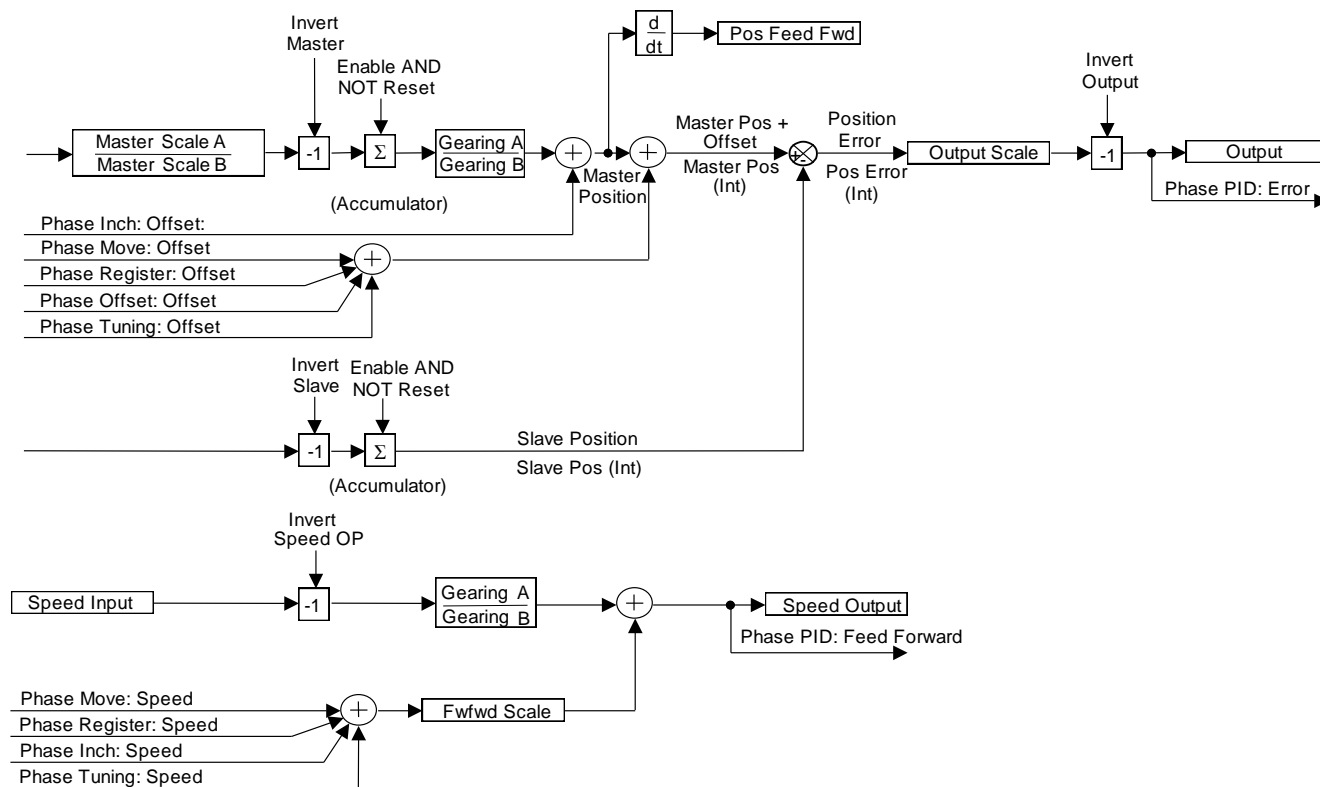
15. Run the Slave drive in the remote mode and enable the SYSTEM BOARD:: POSITION CONTROL::POSITION ENABLE. Verify that the Slave drive motor is operating in the correct direction and is under control. If the Slave motor is rotating in the wrong direction, change the Master / Reference Encoder wiring on terminal strip B, and repeat this step. **Do NOT change the PHASE CONTROL:: INVERT OUTPUT to change rotation of the motor.**
16. Monitor the parameter DIAGNOSTIC::TOTAL SPD DMD %, it should be 10% and a positive number.
17. Slowly increase the speed of the Master / Reference encoder up to 100% speed. The Slave drive should now be running a 100%. Monitor the DIAGNOSTIC::TOTAL SPD DMD %. It should be 100%. Verify that the Slave drive is operating at 100% speed. If it is not, there is a set up problem, possibly with GEARING A or GEARING B set up, in the Phase Control block. If the slave drive is not operating at 100% speed, do not proceed any further until this problem is resolved.
18. Stop the Master and Slave drive. In the Slave drive, set the PHASE PID::LIMIT to 0. (record the original value)
19. In the Slave drive, set the ENCODER SPEED CALC 1::MAX SPEED from 0 to the correct max speed for the application which was recorded in step 13.
20. Run the Master drive or the piece of equipment that the “controls / turns” the Master / Reference encoder. Run this Master Encoder at 10% speed.
21. Run the Slave drive in the remote mode and enable the POSITION CONTROL::POSITION ENABLE. Verify that the Slave drive motor is operating in the correct direction. Go to DIAGNOSTIC::TOTAL SPD %, it should be 10% and a positive number. If it is not the ENCODER SPEED CALC 1::MAX SPEED may be incorrect
22. Slowly increase the speed of the Master / Reference encoder up to 100% speed. The Slave drive should now be running a 100%. Go to DIAGNOSTIC::TOTAL SPD DMD %, it should be 100% and a positive number. Verify that the Slave drive is operating at 100% speed. Stop the Master & Slave drives.
23. Set the PHASE PID::LIMIT to the original value (recorded in step 15). Typically this value is in the range of 3 to 10%.
24. Run the Slave drive and monitor the PHASE PID::PID OUTPUT. This PID OUTPUT is the trim signal and it should be a very small number or dithering around zero, if the drive is set up properly,
Phase Tuning procedure: This procedure is optional, but to optimize the drive speed loop and phase loop it should be performed.
25. The Phase Tuning function block can now be used to optimize the drive speed loop. To set up the Speed Loop:
 - a) Disable the phase loop by setting the: PHASE CONTROL::GEARING A to 0.0. Record the original value of GEARING A as it needs to be re entered in step 22e.
 - b) In the PHASE TUNING block, set PERIOD to 1.0s, SPEED OFFSET to 10% and set ENABLE SPEED to True.
 - c) Monitor speed feedback with an oscilloscope via an Analog Output.
 - d) Start the drive in the remote mode. Make sure that the PHASE CONTROL:: POSITION ENABLE is True. The speed will step between 0 and 10%. Adjust the MOTOR CONTROL::SPEED LOOP :: SPEED PROP GAIN & SPEED INT. TIME for optimum response. A typical value for the Prop Gain is 75 -90 and a typical value for the Int. Time is 75 to 200ms.
 - e) Stop the drive, set PHASE TUNING::ENABLE SPEED to false and set the PHASE CONTROL::GEARING A to the correct value which was recorded in step 22a.

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26. The Phase Tuning function block can now be used to optimize the drive Phase loop. To Set up the Phase Loop:

- Disable the phase loop by setting the: PHASE CONTROL::GEARING A to 0. Record the original value of GEARING A as it needs to be re entered in step 23e.
- Monitor SLAVE POSITION in the PHASE CONTROL block with an oscilloscope, via an Analog Output (set the Analog Output Scale to 300% for more scale).
- Set the PHASE TUNING block set, PERIOD to 4s, PHASE OFFSET to 0.3, and ENABLE PHASE to True.
- Start the drive in the remote mode. Make sure that the PHASE CONTROL:: POSITION ENABLE is TRUE. The motor should step forward and backwards 1/3 or a revolution. Adjust the PHASE PID || P GAIN and I GAIN for optimum response. With a square wave phase input, there will be no effective speed feedforward, so only small Phase Offsets should be used. A typical value for the P GAIN would be 30 to 75 and the I GAIN between 5 to 10.
- Stop the drive, set the ENABLE PHASE to False, and restore GEARING A to the original value that was recorded in step 23a and save the drive parameters.

27. The drive is now optimized for Phase Control.



Phase Control internal diagram

Figure 1

If you have questions, please call the Product Support Group at (704) 588-3246.

Switch Settings

	SW2	OFF	ON
SW1		OFF	ON
OFF		24V	18V
ON		12V	5V

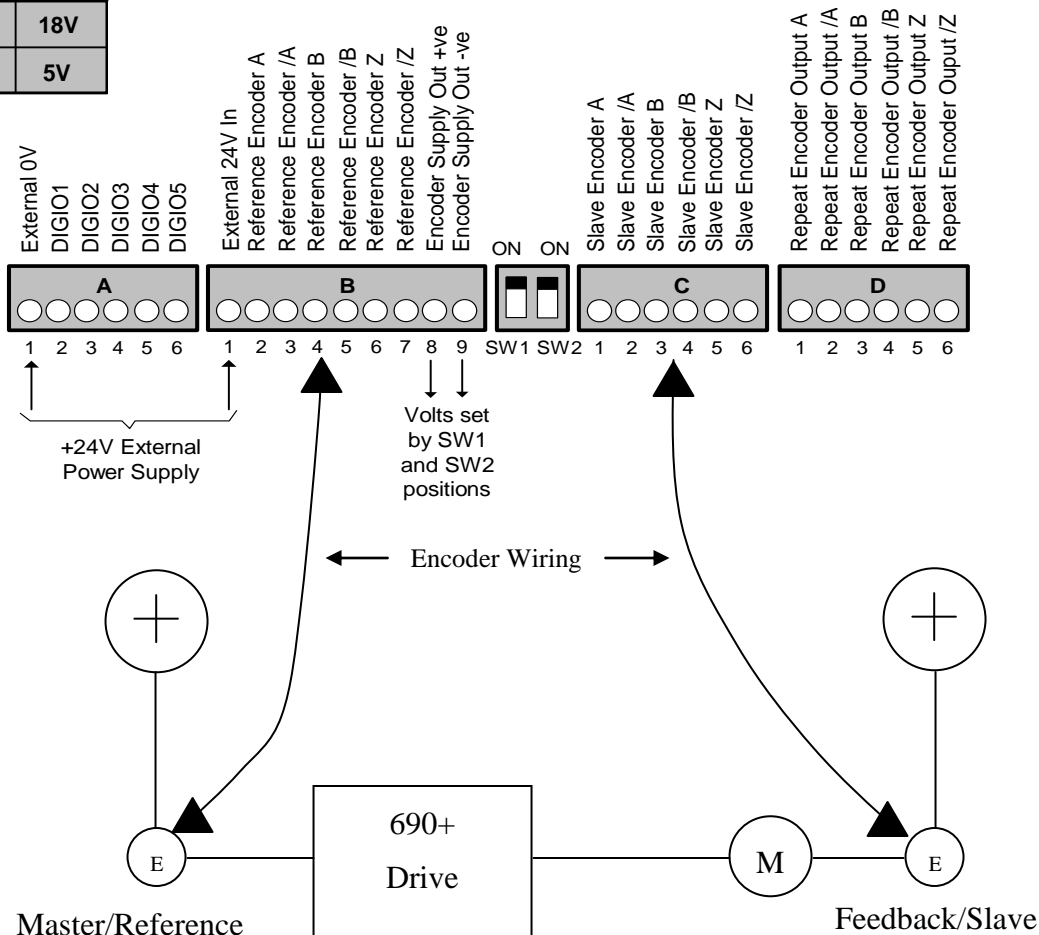
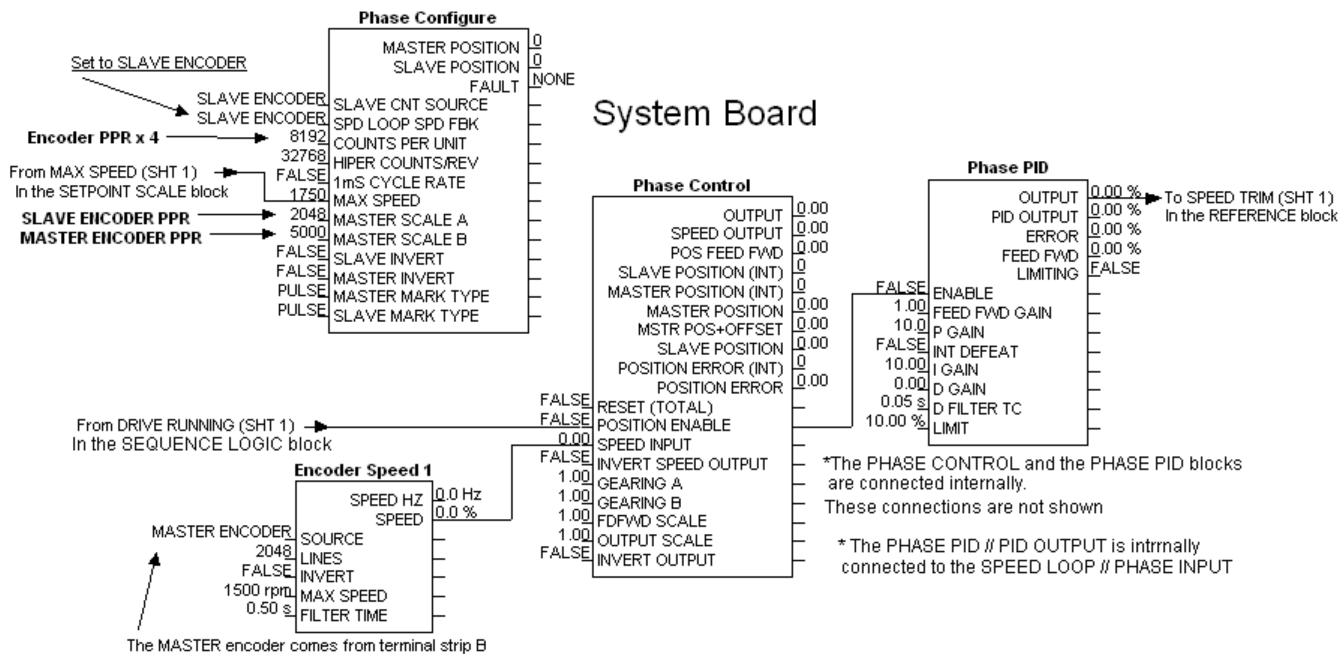


Figure 2 – Wiring Diagram

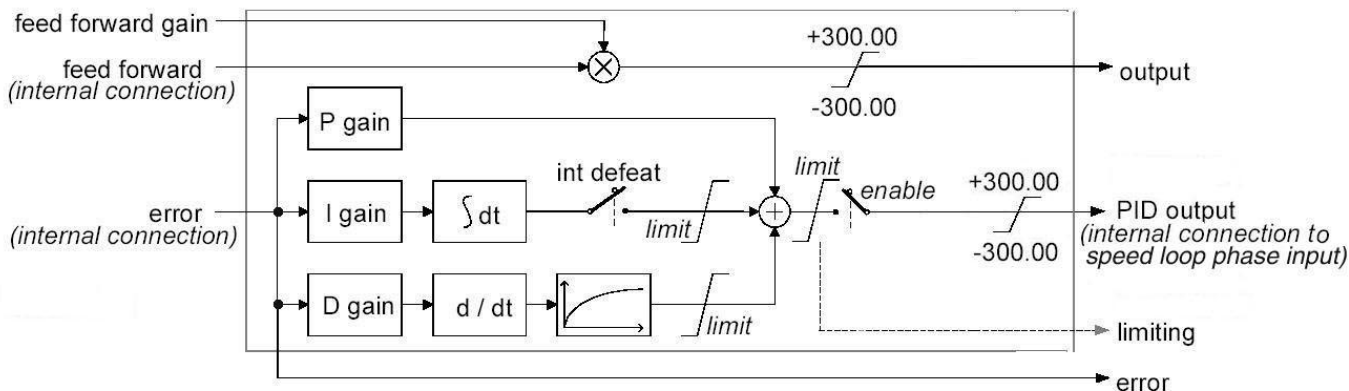
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Phase Control Configuration for firmware version 5.x drive

Figure 3



Configuration for version 5.x drive

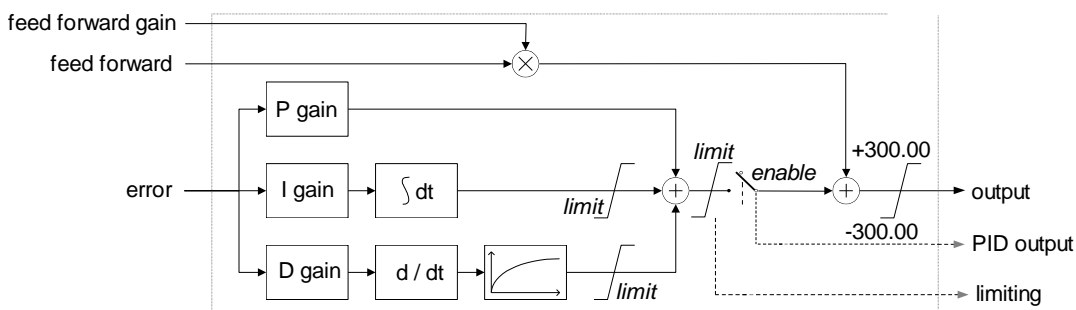
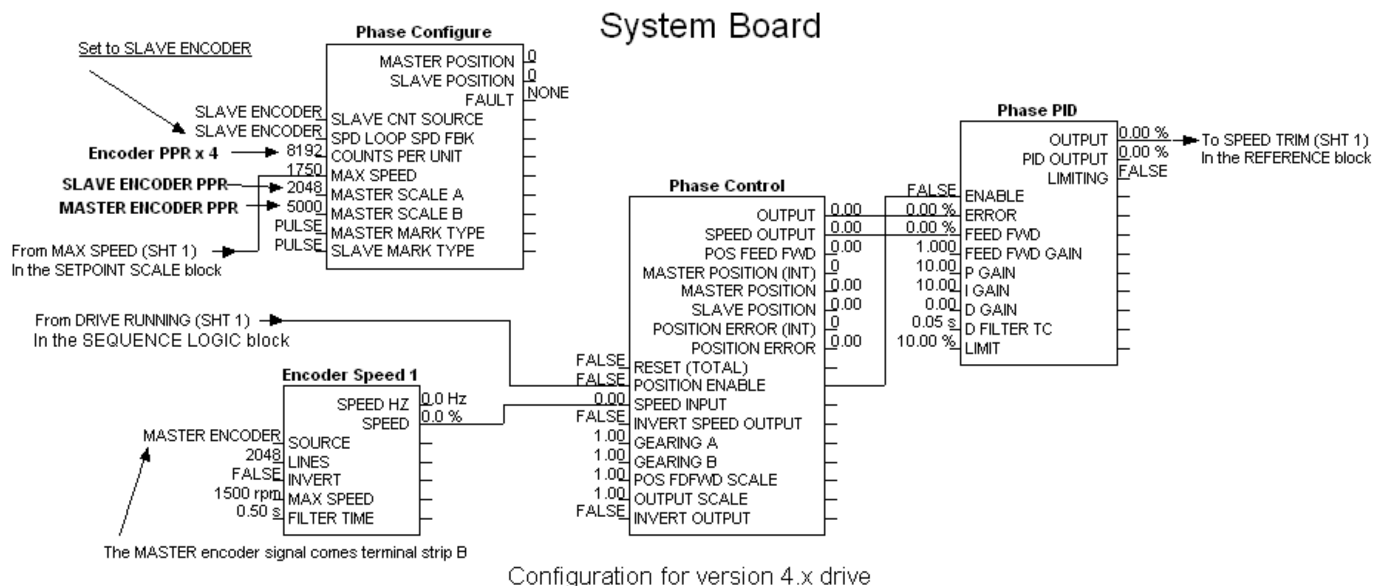


Phase PID internal block diagram for firmware version 5.x drive

If you have questions, please call the Product Support Group at (704) 588-3246.

Phase Control Configuration for firmware version 4.x drive

Figure 3



Phase PID internal block diagram for firmware version 4.x drive

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