Application Note **Product: 690+**
Document Number: 34205 **Keywords: Phase Control**

EUROTHERM DRIVES

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 ConfigEd Lite. 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+ Encoder Blocks

ENCODER SPEED 1

This block provides the feed forward speed demand from the reference encoder.

Source: Selects either the Master or Slave encoder input for the speed reference. The signal is generated from the Systems Board, terminal connector "B" for the *Master*. For this application *Master*, will be selected.

Lines: PPR (Pulses Per Revolution) of the Master encoder.

Invert: Inverts the polarity of the speed output (to avoid changing the encoder leads).

Max Speed: Sets the rpm of the Master encoder for 100% Speed output.

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.

Speed: Encoder speed output, connect to PHASE CONTROL::SPEED INPUT for this application.

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.*

Speed Loop Speed feedback: Selects either the TechBox or System Board Slave encoder as the speed feedback for the 690. For this application, select *Slave Encoder.* The 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.

Max Speed: This scales the speed feed forward for Phase Inch, Phase Move and Phase Register. It should be set the same as the drive *Max Speed* located in the *Quick Setup* menu.

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. if the master encoder is 1024ppr and the Slave encoder 5000ppr and the requirement is for 1:1 phase lock, Set the *Master Scale A* to 5000 and *Master Scale B* to 1024 so that one revolution of the master encoder produces the same number of counts as the Slave.

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. I f 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, it can be inverted by *Invert Speed Output.*

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 at a 1:1 ratio. If Gearing A=100 and Gearing B = 50, the ratio is 0.5 (100/50). Thus the slave will run at 50% speed of the master.

Position Enable: Enables the position counter, disabling sets the 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.* If the *Counts Per Unit* in *Phase Configure* is set to 8192, for 1 revolution of the encoder, the *Output* will be 1.00. Connect to PHASE PID::ERROR for this application.

Speed Output: Master encoder speed demand scaled by *Gearing A* & *Gearing B.*
Connect to PHASE PID::FEED FWD for this application.

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

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.

The *Output*, including the feed forward speed demand should be connected to the *Speed Trim* in the *Reference block*. 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.

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.

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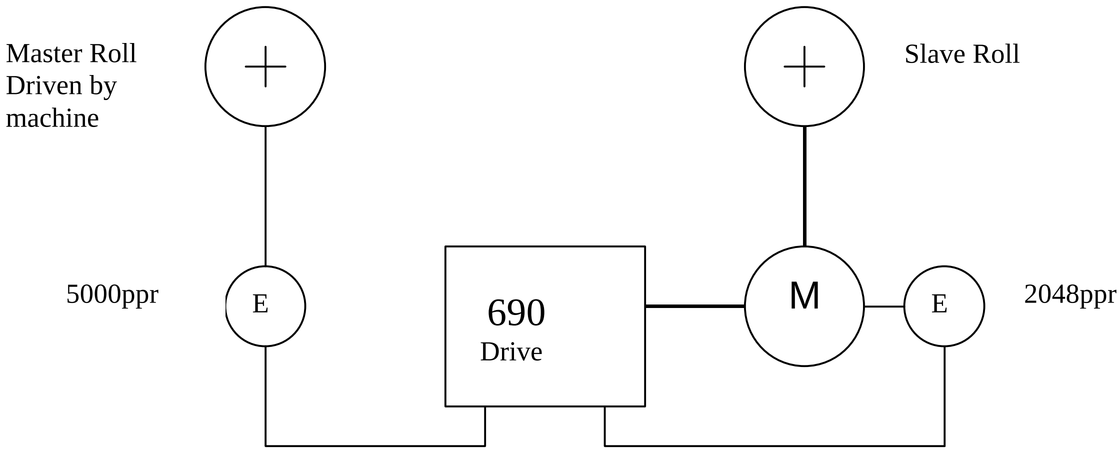
Different Types of Phase Configure Applications

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 to1800 rpm which will equal 100% at the *Speed* out of this block.

Phase Control block

Set *Gearing A & B* so both are1000 for 1:1 ratio.

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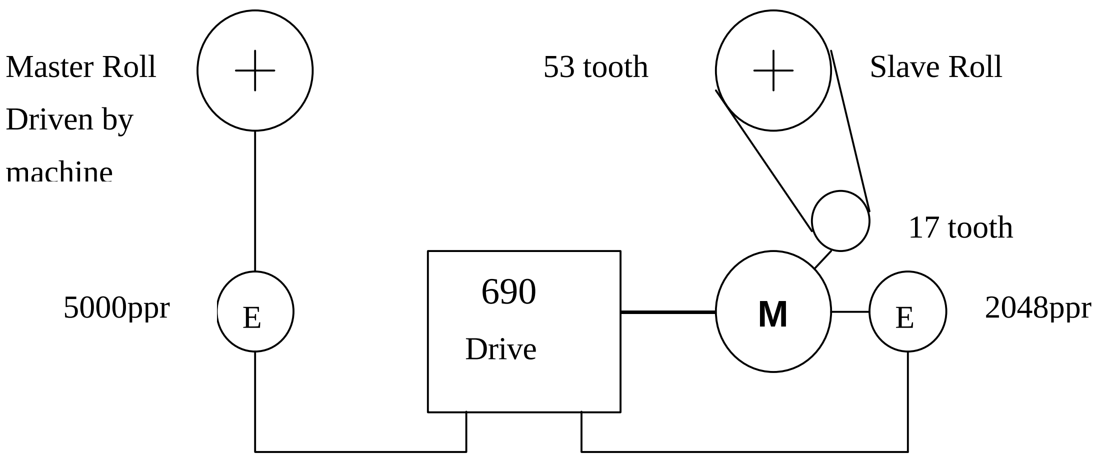
PHASE CONTROL WITH FIXED RATIO OTHER THAN 1:1

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…

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 to1800 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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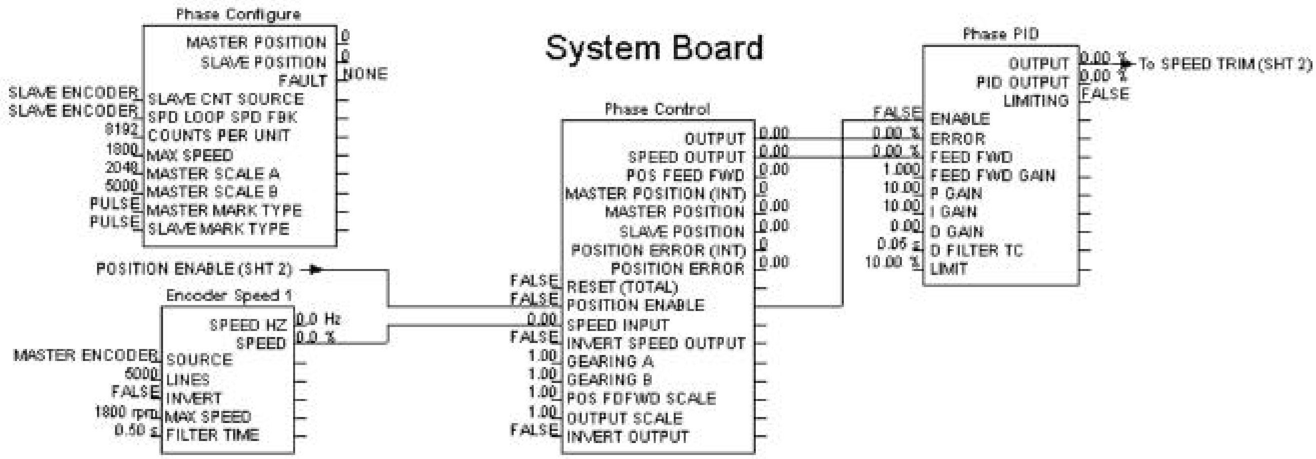
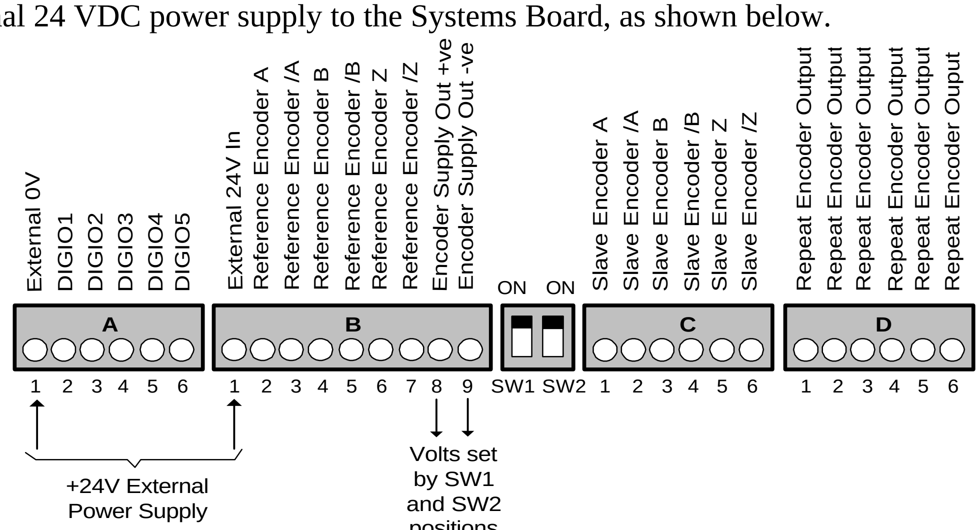
Procedure

1. Using ConfigEd Lite, configure a "default*.690" template as shown:



2. In the CELite template, the OUTPUT of the PHASE PID goes to the REFERENCE:: SPEED TRIM block. This input will bypass all of the Accel & Decel ramps of the drive and will allow for a 100% speed control of the drive. The PHASE CONTROL::POSITION ENABLE can come from a Digital Input or the SEQUENCE LOGIC::RUNNING block.
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.
4. Enter the required data for the PHASE CONFIGURE block and the ENCODER SPEED 1 block, per the "Phase Configure Applications" described earlier. In the ENCODER SPEED block set SOURCE to MASTER ENCODER. For a Phase Control with fixed 1:1 Ratio, the GEARING A & B should be set to 1&1 respectively.
5. Connect the (Feedback) Slave Encoder to terminal block "C" on the Systems Board, as shown on below. This is the encoder that is mounted to the slave drive motor.
6. Connect the Reference Encoder to terminal block "B" of the Systems Board. Also connect the External 24 VDC power supply to the Systems Board, as shown below.



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7. Set up the drive (motor data, encoder data & etc) using the QUICK SETUP menu. Set the CONTROL MODE for VOLTS / HZ.
8. Run the drive in the Local Mode via the MMI Keypad. Verify that the motor is operating in the correct direction as required for the application. Run the motor up to100% speed to make sure that max speed can be obtained.
9. 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 left 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 to make it positive. Do NOT change the parameter ENCODER INVERT. This parameter must be FALSE for the Phase Control to operate properly.**
10. Set the CONTROL MODE to CLOSED LOOP VEC and perform an Autotune.
11. Run the drive in the remote mode, enable the POSITION CONTROL::POSITION ENABLE. Verify that the Slave drive is operating in the correct direction and at the correct speed as required.
12. The Phase Tuning function block can now be used to optimize the drive speed loop and phase loop. To set up the Speed Loop:

a) Disable the phase loop by setting the PHASE CONTROL :: RESET to True.
b) In the PHASE TUNING block, set PERIOD to1.0s, SPEED OFFSET to 10% and ENABLE to True.
c) Monitor speed feedback with an oscilloscope via an Analog Output.
d) Start the drive in the remote mode. The speed will step between 0 and 10%. Adjust the SPEED LOOP :: SPEED PROP GAIN & SPEED INT. TIME for optimum response.
e) Stop the drive, set the PHASE CONTROL to False and save the drive parameters.

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

a) 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).
b) Set the PHASE TUNING block set, PERIOD to 4s, PHASE OFFSET to 0.3, and ENABLE PHASE to True.
c) Start the drive in the remote mode. 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.
d) Stop the drive, set the ENABLE PHASE to False and save the drive parameters.

14. The drive is now optimized for Phase Control.

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