Electronic Gearing

Associated QuickControl® programs included:
- SlaveSD EGM.qcp
- SlaveSD EGM 32bit.qcp
- SlaveSD EGM Multi Trap Moves.qcp
- SlaveSD EGM Phase Adj.qcp
- SlaveSD EGM Trap Move.qcp
- SlaveSD.qcp
- SlaveSN.qcp

This application note describes how to implement electronic gearing between two SilverLode servos or a master encoder and a SilverLode servo. See Encoder Signal Types in SilverLode User Manual for more details.

In these examples, the “Master” servo is setup to output encoder signals to the “Slave” servo. The Slave moves as the Master moves as if the two servos were mechanically linked or "geared".

See Application Note “QCI-AN029 Camming” for advanced electronic gearing applications.

Hardware

In general, the encoder output of the Master must be wired to the External (or secondary) Encoder input of the slave. The details of which pins to use depends on the controller being used. The following sections describes Master encoder output and Slave External encoder input for all QuickSilver’s servo controllers.

Note: The SMI Port is QCI’s standard DB15HD (pin) connector which comes on all our controllers. See specific controller datasheets for more details. All the controllers are able to be slaves using the SMI port.

Slave Using SMI Port

Signal	Slave	
	I/O	SMI Port
Encoder "A"	I/O 4	Pin 14
Encoder "B"	I/O 5	Pin 10
Logic Ground		Pin 8

SilverNugget Master

Use the Modulo Set (MDS) command to output the internal encoder to:

Signal	Master	
	I/O	SMI Port
Encoder "A"	I/O 6*	Pin 5

Encoder "B"	I/O 7*	Pin 15
Logic Ground		Pin 8

*4.7K pull-up resistors (I/O pin to +5 volt) should be added to increase signal integrity.

SilverDust MG/IGF/IGC Master

The SilverDust MG, IGC, and IGF do not have an encoder output option and can therefore not be Masters.

SilverDust IG Master

The SilverDust IG always outputs it encoder on Aux connector pins 13,15 and 16. See QCI-DS019 for details.

Signal	**Master** Aux Conn
Encoder “A”	Pin 15
Encoder “B”	Pin 13
Logic Ground	Pin 16

SilverDust IGB

The SilverDust IGB always outputs its encoder on the breakouts terminals ENC OUT A,B,Z. See QCI-DS003 for details. External encoder input is available from either the breakout terminals ENC IN A,B,Z or from the SMI port.

Master

Signal	**Master** Breakout
Encoder “A”	ENC OUT A
Encoder “B”	ENC OUT B
Logic Ground	Gnd*

Slave:

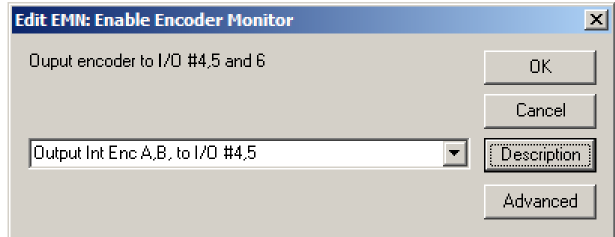
Standard SMI Port

or

Signal	**Slave** I/O	Breakout
Encoder "A"	I/O 4	ENC IN A
Encoder "B"	I/O 5	ENC IN B
Logic Ground		Gnd

SilverDust IG8

The user can configure the IG8 to output its encoder to the SMI port (I/O 4,5) using the Encoder Monitor (EMN) command. See Command Reference and QCI-DS018 for more details.



Signal	Master w/ EMN cmd	
	I/O	SMI Port
Encoder "A"	I/O 4	Pin 14
Encoder "B"	I/O 5	Pin 10
Logic Ground		Pin 8

Gear Ratio (GR)

The GR of the Slave to Master is expressed as follows:

< Change in Slave Encoder (CS) >:< Change in Master Encoder (CM)>
<CS|CM>

For example a 1 to 2 GR would be expressed as 1:2 and would mean for every 2 encoder counts of the Master, the Slave would move 1 encoder count.

Therefore a Gear Ratio of CS:CM would be

Gear Ratio (GR) = CS/CM = CS:CM
Slave Position (S)
Master Position (P)

S = GR * M
S = (CS/CM) * M

For 1:2 Gear Ratio example

CS = 1
CM = 2
GR = CS/CM = ½
S = GR * M = ½ * M

There are several ways of programming GR depending on what controller is being used. See below for details.

Software

In order for a Slave to follow the Master's encoder, it must first be configured to read the encoder and then to slave off it using a specific GR.

Select External Encoder (SEE)

On all the controllers, the SEE command is used to read the Master servo's encoder signals through I/Os 4 and 5 in A/B Quadrature format or Step and Direction formats. Once SEE is executed, the master encoder is automatically read in the background. The master encoder value is also stored in register 200. See example programs below for usage information.

Gear Ratio Commands

Registered Step and Direction (RSD) and Electronic Gearing Mode (EGM) can both be used to specify a GR and start electronic gearing.

RSD	**EGM**
Simple	Advanced
Available on both SilverDust and SilverNugget	Available on SilverDust Only
Specify GR as interger ratios i.e. 1:3	Specify GR as decimal i.e. 1:1.234567
	Optional: Acceleration Factor An acceleration ramp can be specifed to change between GR.
	Optional: Trapezoid Move A trapezoid move can be triggered to advance/retard a specified distance in addition to base GR.

Registered Step And Direction (RSD)- SilverDust Rev 32

CM and CS are stored in the upper and lower words of the SF register specified by the RSD command. This allows for easy entry when both CM and CS are integers (i.e. GR=CS/CM=1:3).

RSD SF Register

Upper Word	Lower Word
Change in Master Encoder (CM)	Change in Slave Encoder (CS)

CM may range from 1 to 32767 and CS may range from -32768 through 32767. A negative CS causes the slave to move in the opposite direction as the master.

Note, a GR of 1000:2000 is the same as 1:2, therefore setting CS and CM to 1 and 2 will have the same affect as setting them to 1000 and 2000.

The example to the right (SlaveSD.qcp), GR=1:2 (CS=1, CM=2). RSD's SF registers is register 11.

<table>
<tr><th>Line#
Oper</th><th>Label</th><th>Command</th></tr>
<tr><td>1:REM</td><td></td><td>SlaveSD.qcp
This file is used in Application Note
QCI-AN019 Electronic Gearing

Requires:
QuickControl Rev 4.51
SilverDust Firmware Rev 32</td></tr>
<tr><td>2:REM</td><td></td><td>Configure the I/O lines for an External Encoder input source. The Index will not be used and this I/O line can be re-configured for other operation.</td></tr>
<tr><td>3:SEE</td><td></td><td>Select External Encoder:
Index Source I/O #6
Encoder Style: A/B Quad on I/O #4 & 5</td></tr>
<tr><td>4:REM</td><td></td><td>Set Gear Ratio (GR) to 1:2

For every 2 counts of the Master encoder, move 1 count.</td></tr>
<tr><td>5:REM</td><td></td><td>Change in Master Encoder (CM)
Change in Slave Encoder (CS)

Gear Ratio (GR) = CS/CM

Slave Position = GR * Master Position

Therefore a GR of 1/2 is also written as "1:2" which is read a "1 to 2" gear ratio.

For our example CS=1 and CM=2
GR = 1/2</td></tr>
<tr><td>6:WRP</td><td></td><td>Write 2 to
"CM[30]" Register</td></tr>
<tr><td>7:WRP</td><td></td><td>Write 1 to
"CS[31]" Register</td></tr>
<tr><td>8:REM</td><td></td><td>Set GR register to <CM | CS></td></tr>
<tr><td>9:CLX</td><td></td><td>GR[32] = LO(CM[30])<<16 + LO(CS[31])</td></tr>
<tr><td>10:REM</td><td></td><td>Start Electronic Gearing</td></tr>
<tr><td>11:RSD</td><td></td><td>Registered Step and Direction:
Scale Factor = "GR[32]" Register</td></tr>
</table>

Registered Step And Direction (RSD)- SilverNugget and SilverDust Pre Rev 32

An older implementation of RSD defines the SF register as follows. Note this implementation is the only option for the older SilverNugget controllers.

SF = GR * SF1

SF1 is the Scale Factor for a 1:1 gear ratio. SF1 depends on encoder resolution as follows:

4000 CPR; SF1 = 1024
8000 CPR; SF1 = 512
16000 CPR; SF1 = 256

Example:
If the Slave has an 8000 counts per revolution (CPR) encoder and the desired GR is 1:2, what should be stored in the SF register.

Step 1. Determine the SF1.

The Slave's encoder is 8000 CPR so SF1=512.

Step 2. Calculate SF Value.

SF = GR * SF1
SF = 1/2 * 512
SF = 256

Line# Oper	Label	Command
1:REM		SlaveSN.qcp This file is used in Application Note QCI-AN019 Electronic Gearing Use this program to electronically gear a slave SilverNugget or an older SilverDust (pre rev 32).
2:REM		Configure the I/O lines for an External Encoder input source. The Index will not be used and this I/O line can be re-configured for other operation.
3:SEE		Select External Encoder: Index Source I/O #6 Encoder Style: A/B Quad on I/O #4 & 5
4:REM		Set Scale Factor (SF) for a 1:2 Gear Ratio (GR) assuming an 8000 CPR encoder. Scale Factors for 1:1 Ratio (SF1) CPR SF1 4000 1024 8000 512 16000 256 SF = GR * SF1 For our example: SF1=512 GR =1/2 SF = GR * SF1 = 256
5:WRP		Write 256 to "SF[11]" Register
6:RSD		Registered Step and Direction: Scale Factor = "SF[11]" Register

Electronic Gearing Mode (EGM) - SilverDust Rev 34

EGM provides high-resolution electronic gearing capability including the ability to smoothly transition between different gear ratios.

The basic EGM command requires two registers. See below for advanced Trapezoid Move.

Scale Factor (SF) Register

The Scale Factor (SF) register is Gear Ratio multiplied by 10,000,000 to provide a range of +/- 200 with 7 places behind the decimal point. The upper limit will depend upon the motor encoder resolution and the allowable output shaft motion for each Master count.

SF = GR * 10,000,000

Acceleration Factor (AF) Register

The Acceleration Factor (AF) register is used to limit the rate of change of the Internal Scale Factor (ISF). ISF is the internal or actual scale factor used by EGM while SF is the desired or target scale factor. Normal usage has a positive value for AF.

When first initialized, the ISF starts at 0. For each count change in the "Master" position, ISF is moved in the direction of SF by AF counts. Once running, when the SF register is changed, the ISF smoothly ramps from its previous value to the new requested value over a number of Master counts.

In the example “SlaveSD EGM.qcp”
SF=10,000,000 (1:1)
AF=10,000

Then ISF will ramp from 0 (stopped) up to SF=10,000,000 (1:1) over 1000 Master counts.

Note: if the input is oscillating back and forth, these movements count as excursions and the ISF will grow without regard to the direction of the motion.

Setting AF to a negative value will act as if a Stop Condition was met, causing the EGM to ramp to a stop using the absolute value of AF. This will also cause the EGM command to end regardless of the “End Command When Stopped” option setting. If the continuous operation is desired, then set the SF register to zero, which will cause ISF to ramp to zero, but will not cause the motion to end.

A value of zero for the Acceleration Factor is flagged as an error, and will cause the EGM to ramp down fairly quickly and to end.

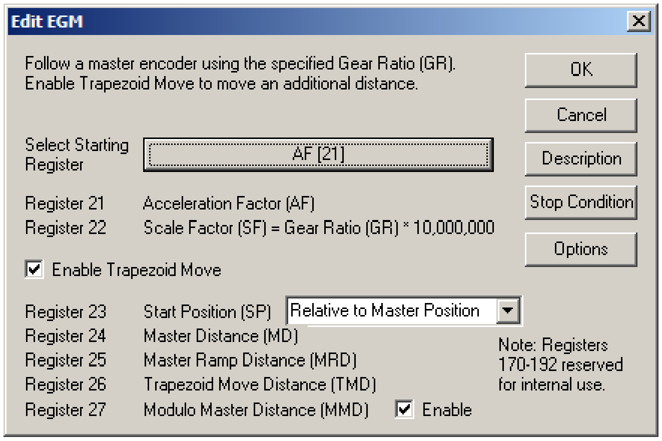
Line# Oper	Label	Command
1:REM		SlaveSD EGM.qcp This file is used in Application Note QCI-AN019 Electronic Gearing Requirers: QuickControl Rev 4.62 SilverDust Firmware Rev 34
2:SEE		Select External Encoder: Index Source I/O #6 Encoder Style: A/B Quad on I/O #4 & 5
3:REM		Scale Factor (SF) SF= GR * 10,000,000 GR = SF/10,000,000 Where GR is Gear Ratio i.e. SF=10,000,000, GR=1 (1:1)
4:WRP		Write 10000000 to "SF[31]" Register
5:REM		AF= 10,000 Ramp Internal Scale Factor (ISF) from its current value to SF (desired Scale Factor) AF counts for every Master count. Note ISF starts at zero when EGM is first executed. Example AF=10,000 SF=10,000,000 (1:1) ISF will ramp from 0 to 10,000,000 in 1000 Master counts. Or in other words, GR will ramp from 1 to 1:1 in 1000 Master counts.
6:WRP		Write 10000 to "AF[30]" Register
7:EGM		Electronic Gearing Mode: Acc Factor in "AF[30]" Scale Factor in "SF[31]"

If the user does not want the command to smoothly ramp between values, but to rather operate as just a fixed scale factor, set the Acceleration Factor to larger than the largest expected Scale Factor (i.e. 100,000,000) and the ramping will all occur with a single count of motion.

See below for description of Options.

EGM-Trapezoid Move - SilverDust Rev 37

When “Enable Trapezoid Move” is checked, the EGM advanced Trapezoid Move option is enabled.



Requirements:

QuickControl Rev 4.64
SilverDust Rev 37

The Trapezoid Move option provides the high-resolution electronic gearing capability of the EGM command plus the ability to add an electronically geared Trapezoid Move while the background gearing is under way.

A set of seven registers is required to configure EGM and the Trap Move. With the Starting Register=N, the seven registers are as follows:

Background EGM Registers:

- Register N = Acceleration Factor (AF)
- Register N + 1 = Scale Factor (SF)

For a given Gear Ratio (GR), SF = Gear Ratio (GR) * 10,000,000.

Trapezoid Move Registers:

- Register N + 2 = Start Position (SP)
- Register N + 3 = Master Distance (MD)
- Register N + 4 = Master Ramp Distance (MRD)
- Register N + 5 = Trapezoid Move Distance (TMD)
- Register N + 6 = Master Modulo Distance (MMD)

These registers are described in detail below.

Note: During the move, only the background EGM registers (AF, SF) can be updated. The Trap Move registers are only sampled when the command is started.

The Trap Move works in both directions. If the modulo option is enabled, continuous forward motion will allow repeated trapezoids to be commanded, otherwise the trapezoid will only be executed as the Master transitions through Master Distance (MD).

Note: The EGM command utilizes registers 170 through 192 for its internal operations. The user should not alter these registers while the EGM command is operating.

Register Definitions

Acceleration Factor (AF) (Starting Register N)
Scale Factor (SF) (Register N+1)
These are described above.

Start Position (SP) (Register N+2)
SP is used to locate the Trap Move with respect to the Master position count in register 200. This trapezoid may be located at ether an absolute position or relative to the current value in register 200. The Trap Move is located either positive from the starting point or negative from the starting point according to the sign of MD (see below).

Master Distance (MD) (Register N+3)
MD may be positive or negative, according to the intended direction of motion of the master. A positive value will locate the Trap Move motion positive of Start Position (SP), while a negative value will locate the Trap Move motion negative from SP.

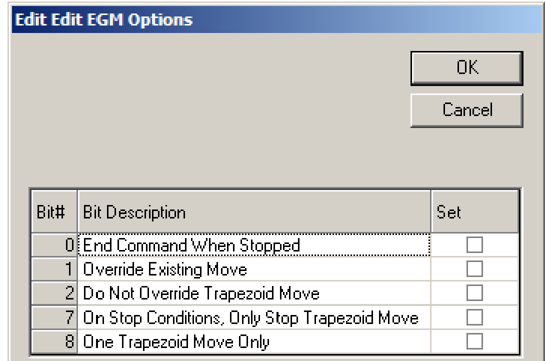
Master Ramp Distance (MRD) (Register N+4)
MRD defines the number of Master counts the Trap Move will accelerate/decelerate over. MRD must be positive, and must be less than half of the absolute value of Master Distance (MD) - that is, the acceleration and deceleration ramps must fit within MD.

Trapezoid Move Distance (TMD) (Register N+5)
TMD is the total extra counts the Slave will move the Master position count (register 200) has transitioned across the selected MD in the specified direction.

Master Modulo Distance (MMD) (Register N+6)
MMD allows register 200 to be modulo'ed. Note: this modulo is only realized outside the region of the Trap Move motion, thus the MMD must be greater than MD and the Trap Move starting position, SP, must also be consistent with MD. A single add or subtract is calculated each cycle (when not inside the trapezoid), so it may take a considerable amount of time to initially reach the valid modulo range if register 200 contains a large value when the modulo is first engaged.

Options - QuickControl

The Trapezoid Move has the following options.



End Command When Stopped

Set this option to end the command when the Trap Move has completed and servo is commanded to zero velocity (SF=0) and stops (actual velocity=0). Note, if Trap Move enabled, option "One Trapezoid Move Only" must be set for this option to work.

Override Existing Move

Set this option to have EGM override any existing move commands (requires multi-tasking enabled).

Do Not Override Trapezoid Move

Do not override if Trap Move is still active. When used in conjunction with "Override Existing Move", the option allows the prior Trap Move to complete while keeping the background EGM operation active.

On Stop Conditions, Only Stop Trapezoid Move

If unchecked, all motion is stopped and EGM exits if a Stop Condition is met.

If checked, only Trap Move is stopped when Stop Condition is met. EGM continues.

One Trapezoid Move Only

If checked, once the Trap Move completes, it will not repeat even if the Master count reverses or Master Modulo Distance is enabled.

EGM Mode Word (non-QuickControl)

The Mode parameter is edited by QuickControl. The following bit definitions are provided for those users who are not using QuickControl.

Bit #	Description
0	End Command When Stopped see Options above
1	Override Existing Move see Options above
2	Do Not Override Trapezoid Move see Options above NOTE: Only valid if bit 4 set
3	Must be set to 1. NOTE: EGM has the same command number as PVC (cmd=93). The command is EGM if this bit=1 and PVC if this bit=0.
4	1 enables the Trapezoid Move
5	0 causes the Trapezoid start position to be Relative; 1 causes the Trapezoid start position to be absolute. Input value is Register N+2 NOTE: Only valid if bit 4 set
6	1 enables the Modulo operation, allowing the Trap Move to repeat multiple times. Register 200 is automatically modulo'ed by Register N + 6. This may take some time to initially adjust if register 200 has a large value. This Modulo is only adjusted between trapezoid moves. NOTE: Only valid if bit 4 set
7	On Stop Conditions, Only Stop Trapezoid Move see Options above NOTE: Only valid if bit 4 set
8	One Trapezoid Move Only see Options above NOTE: Only valid if bit 4 set

SlaveSD EGM Trap Move.qcp

This example will help clarify the Trap Move parameters and how they affect a motion.

In this example, the Slave will move an additional 6000 counts every 10000 Master counts.

Lines 9-21: Initialize Trapezoid Move Parameters

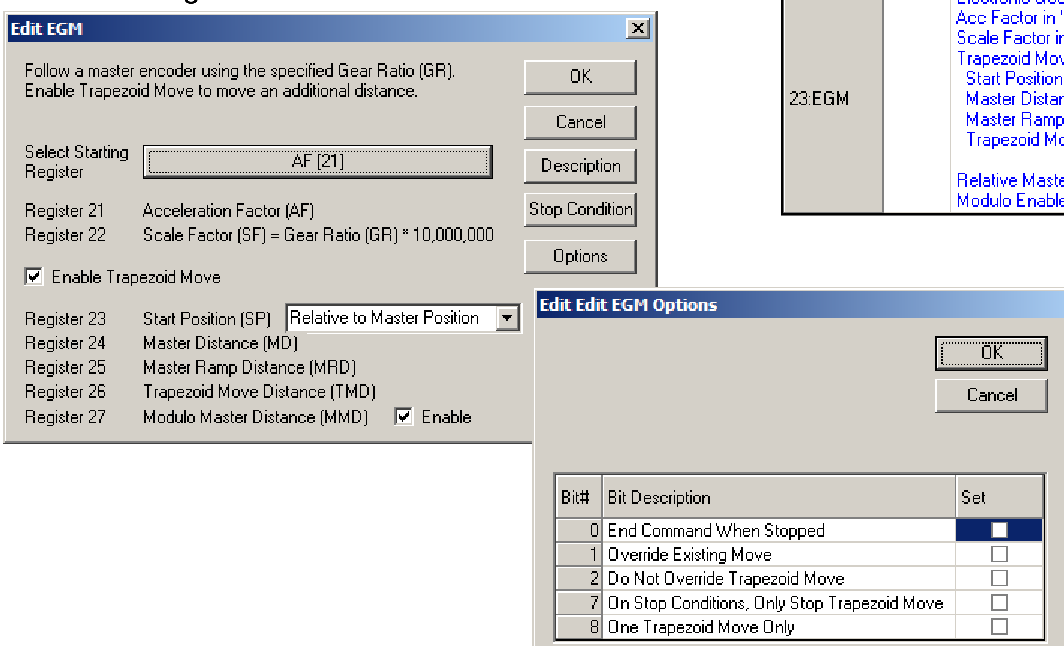
The seven EGM registers are initialized prior to executing EGM.

Line 23 Execute Trapezoid Move

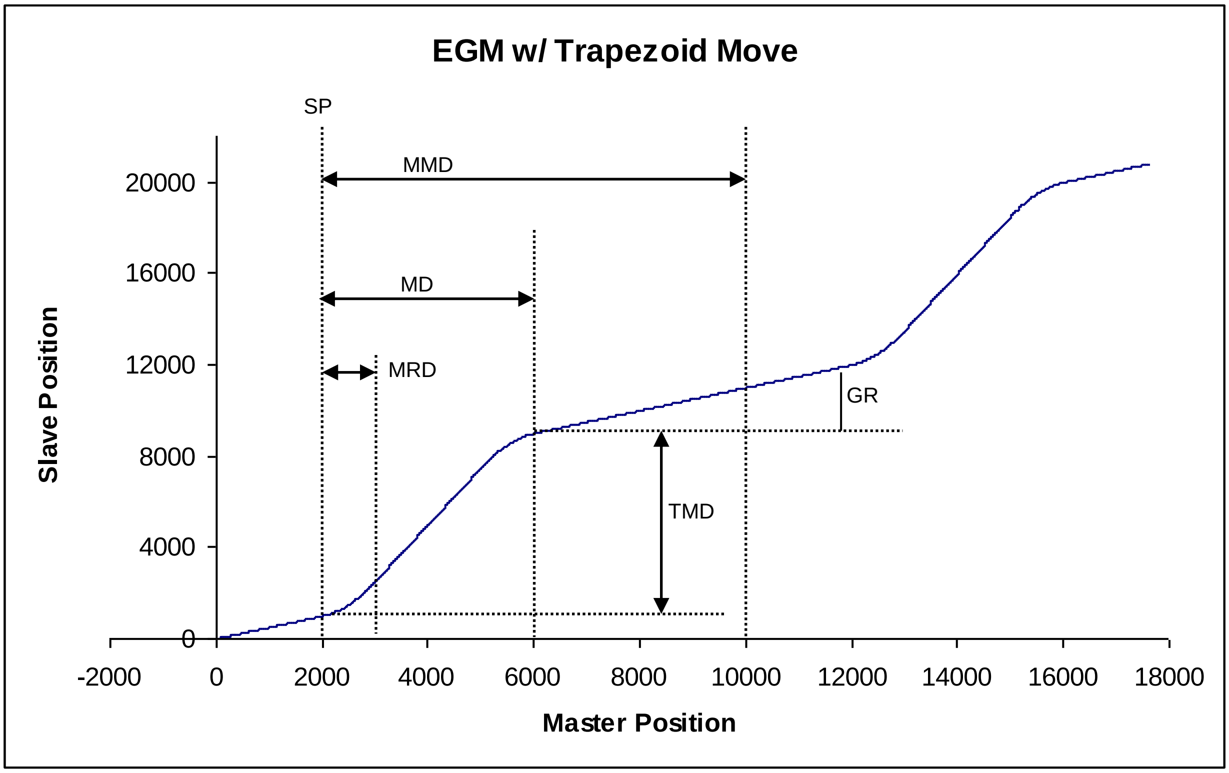
The move is executed in the background because of the Enable Multi-Task Command (EMT) command at the top of the program.

9:WRP		Write 500000 to "AF[21]" Register
10:REM		Scale Factor (SF) SF = Gear Ratio (GR) * 10,000,000
11:WRP		Write 5000000 to "SF[22]" Register
12:REM		Start Position (SP)
13:WRP		Write 2000 to "SP[23]" Register
14:REM		Master Distance (MD)
15:WRP		Write 4000 to "MD[24]" Register
16:REM		Master Ramp Distance (MRD)
17:WRP		Write 1000 to "MRD[25]" Register
18:REM		Trapezoid Move Distance (TMD)
19:WRP		Write 6000 to "TMD[26]" Register
20:REM		Master Modulo Distance (MMD)
21:WRP		Write 10000 to "MMD[27]" Register
22:REM		======================== EGM with Trapezoid Move ========================
23:EGM		Electronic Gearing Mode: Acc Factor in "AF[21]" Scale Factor in "SF[22]" Trapezoid Move Enabled Start Position (SP) in Register 23 Master Distance (MD) in Register 24 Master Ramp Distance (MRD) in Register 25 Trapezoid Move Distance (TMD) in Register 26 Relative Master Position Modulo Enabled

EGM is configured as follows:



The following chart of Slave Position with respect to Master Position shows how the Slave moves as the Master changes from 0 to 18000.



The following table details each transition point.

Master Position	Internal Gear Ratio (IGR)[1]	Description
0-2000	IGR = GR = 0.5	Base Gear Ratio (GR)
2000	IGR = GR = 0.5	Start of Trap Move
2000-3000	IGR = 0.5 to Trap Move GR [2]	Ramp up to Trap Move GR [2]
3000-5000	IGR = Trap Move GR [2]	
5000-6000	IGR = Trap Move GR [2] to 0.5	Ramp down to GR
6000	IGR = GR = 0.5	Trap Move Complete
6000-10000	IGR = GR = 0.5	Base Gear Ratio (GR)
10000	IGR = GR = 0.5	End of Modulo

[1] Internal Gear Ratio (IGR) is the actual GR being used. The controller calculates this based on the Base Gear Ratio (GR) and what part of the Trap Move is currently being executed.
[2] Trap Move GR is calculated internally by the controller to achieve the TMD in the given MD.

SlaveSD EGM Phase Adj.qcp

This example shows how to follow a master encoder with the additional ability to adjust the phase. In particular, the Slave will advanced an additional 1000 counts every time I/O #1 goes LOW.

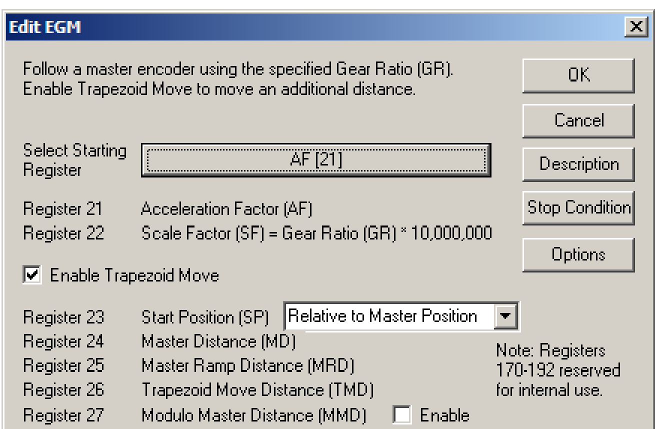
Lines 9-19: Initialize Trapezoid Move Parameters
In this example, only 6 of 7 EGM registers are required because EGM modulo feature is not being used.

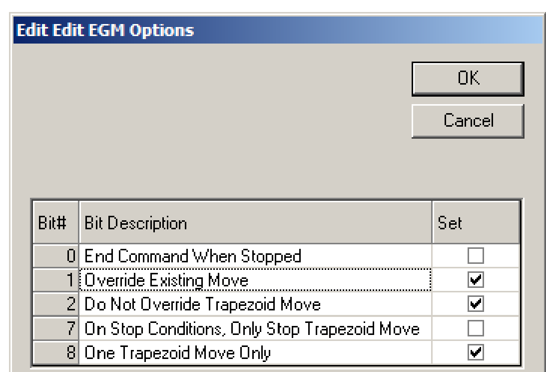
Line 21 EGM
EGM is executed in the background. Note, the Trap Move is not enabled, so this EGM simply sets GR to 0.5 and starts moving.

Line 24 WBE
Wait for I/O #1 to transition from HIGH to LOW.

Line 25 EGM – Advance 1000 Counts
This second EGM is configured as follows to override the previous EGM at the same base GR but with a 1000 count Trap Move.

8:REM		Acceleration Factor (AF)
9:WRP		Write 500000 to "AF[21]" Register
10:REM		Scale Factor (SF) SF = Gear Ratio (GR) * 10,000,000
11:WRP		Write 5000000 to "SF[22]" Register
12:REM		Start Position (SP)
13:WRP		Write 0 to "SP[23]" Register
14:REM		Master Distance (MD)
15:WRP		Write 4000 to "MD[24]" Register
16:REM		Master Ramp Distance (MRD)
17:WRP		Write 1000 to "MRD[25]" Register
18:REM		Trapezoid Move Distance (TMD)
19:WRP		Write 1000 to "TMD[26]" Register
20:REM		========================== EGM ========================== NOTE: No trapezoid move yet
21:EGM		Electronic Gearing Mode: Acc Factor in "AF[21]" Scale Factor in "SF[22]" Override Existing Move
22:REM	LOOP	======================== Main Loop ========================
23:REM		Advance 1000 counts when I/O # goes LOW
24:WBE		Wait On Bit Edge Until "I/O #1" is LOW/FALSE
25:EGM		Electronic Gearing Mode: Acc Factor in "AF[21]" Scale Factor in "SF[22]" Trapezoid Move Enabled Start Position (SP) in Register 23 Master Distance (MD) in Register 24 Master Ramp Distance (MRD) in Register 25 Trapezoid Move Distance (TMD) in Register 26 Override Existing Move Do Not Override Trapezoid Move Relative Master Position One Trapezoid Move Only
26:JMP		Jump to "LOOP"





Note, both "Override Existing Move" and "Do Not Override Trapezoid Move" are checked. This will cause this EGM to override the previous EGM, but it will not interrupt any unfinished Trap Moves.

Note, "One Trapezoid Move Only" is checked to ensure that the Slave will not "retard" 1000 counts if, after completing the Trap Move, the Master reverses.

SlaveSD EGM Multi Trap Moves.qcp

This example shows how to follow a master encoder with the additional ability to adjust the phase. In particular, the Slave will advanced an additional 1000 counts every time I/O #1 goes LOW.

7:WRP		Write 0 to "AF[21]" Register
8:WRP		Write 0 to "SF[22]" Register
9:REM		Trapezoid Move Params
10:WRP		Write 0 to "SP[23]" Register
11:WRP		Write 16000 to "MD[24]" Register
12:WRP		Write 2000 to "MRD[25]" Register
13:WRP		Write 1000 to "TMD[26]" Register
14:REM	LOOP	Main Loop
15:WRP		Write 2000 to "TMD[26]" Register
16:EGM		Electronic Gearing Mode: Acc Factor in "AF[21]" Scale Factor in "SF[22]" Trapezoid Move Enabled Start Position (SP) in Register 23 Master Distance (MD) in Register 24 Master Ramp Distance (MRD) in Register 25 Trapezoid Move Distance (TMD) in Register 26 Override Existing Move Do Not Override Trapezoid Move Relative Master Position
17:WRP		Write -2000 to "TMD[26]" Register
18:EGM		Electronic Gearing Mode: Acc Factor in "AF[21]" Scale Factor in "SF[22]" Trapezoid Move Enabled Start Position (SP) in Register 23 Master Distance (MD) in Register 24 Master Ramp Distance (MRD) in Register 25 Trapezoid Move Distance (TMD) in Register 26 Override Existing Move Do Not Override Trapezoid Move Relative Master Position
19:JMP		Jump to "LOOP"

Lines 7-13: Initialize Trapezoid Move Parameters
In this example, only 6 of 7 EGM registers are required because EGM modulo feature is not being used.

Note, AF and SF=0. This means that the Base Gear Ratio (GR) = 0. In other words, the Slave will only move the Trapezoid Move Distance (TMD) when triggered.

Line 15-16 1st EGM
Move 2000 counts over a Master Distance (MD) of 16000 counts.

Line 17-18 2nd EGM
Move -2000 counts over a Master Distance (MD) of 16000 counts.

Since "Do Not Override Trapezoid Move " is checked, each EGM will wait for the previous EGM's Trap Move to complete before executing a new Trap Move.

SlaveSD EGM 32bit.qcp

This example shows how to dynamically calculate very accurate gear ratios.

The SilverLode servos deal only in integers, so calculating a gear ratio like:

GR = 123.456 to 789.123 (123.456/789.123)

requires some extra manipulation.

1) Multiply GR's numerator and denominator by 1000 to get rid of the fractions.
   GR = 123456/789123

2) Since SF = GR*10,000,000, multiply numerator by 10,000,000 first then divide by denominator. This has to be done in this order or resolution will be lost do to truncation.
   *SF = 123456 * 10000000/789123*

The only problem with the above method is that the resultant of
123456 * 10000000
is greater than 32 bits which means it cannot be held in a normal 32 bit register.

The CLX command solves this by providing a 32x32 multiply that puts the resultant into a pair of 32 bit registers. For division, CLX has a 64/32 operation.

Line 5: Numerator (reg 25)
Line 6: Denominator (reg 26)
Line 7: 32x32
Store
reg 25 * 10,000,000
into reg 27/28.

Line 8: SF
Divide 64 bit value stored in reg 27/28 by reg 26 and store as SF in reg 31.

3:REM		Scale Factor (SF) SF= GR * 10,000,000 GR = SF/10,000,000 For high resolution gear ratios, use CLX 32x32 multiply i.e. Let GR=123.456 to 789.123
4:REM		GR = 123.456 /789.123 GR = 123456/789123 SF = GR * 10000000 SF = 123456 * 10000000/789123
5:WRP		Write 123456 to "User[25]" Register
6:WRP		Write 789123 to "User[26]" Register
7:CLD		User[27] (U64) = User[25] * 10000000
8:CLX		SF[31] = (User[27] (U64))/User[26]
9:WRP		Write 10000 to "AF[30]" Register
10:EGM		Electronic Gearing Mode: Acc Factor in "AF[30]" Scale Factor in "SF[31]"