# Electromechanical Automation Applications Note



Product:Trilogy coils & Positioners with ACR9000, AriesEPL with ACR9040, or AriesControllerRev:1.0Subject:Tuning Trilogy with ACR Controller

This applications note gives step-by-step instructions for tuning with the Trilogy motors and positioners with the ACR9000 controller, the Aries-EPL with ACR9040, or AriesCE drive/controller.

ACR-View's ServoTuner is a powerful 4-channel software oscilloscope allowing performance evaluation of servo systems and adjusting of the PID and feed-forward gains. This procedure shows how to setup and tune a step-response.



Example of a well-tuned T2D-4P (unloaded), settling within 30ms

#### 1. To display the tracking error on Channel 1:

Select Parameter for Channel 1:

- a. Press "..." to open "Parameter Picker"
- b. Select "Axis Parameters" from top drop-down
- c. Select "Position Parameters" from middle dropdown
- d. Select "Following Error" from bottom drop-down
- e. Select the desired axis from list.



#### 2. To display the encoder position on Channel 2:

For an ACR90x0 with AriesEPL:

- a. Press "..." to open "Parameter Picker"
- b. Select "EPL Parameters" from top drop-down
- c. Select "EPLD Position Parameters" from middle dropdown
- d. Select "EPLD Position" from bottom drop-down
- e. Select the desired axis from list.

Parameter	Picker	
EPL Paramet	ters 💌	OK
EPLD Positio	on Parameters 📃 💌	Cancel
EPLD 0	•	
Item	Description	Parameter
EPLD0	EPLD Position	P38144
EPLD0	EPLD Velocity	P38145
EPLD0	Reserved	P38146
EPLDO	Reserved	P38147
EPLDO	Reserved	P38148
EPLDO	Reserved	P38149
EPLD0	Reserved	P38150
EPLDO	Reserved	P38151

Parameter	Picker	
Object Para	meters 💌	OK
Encoder Pa	rameters 💽	Cancel
Encoder Po	sition 👤	
Item	Description	Parameter
Enc 0	Encoder Position	P6144
Enc 1	Encoder Position	P6160
Enc 2	Encoder Position	P6176
Enc 3	Encoder Position	P6192
Enc 4	Encoder Position	P6208
Enc 5	Encoder Position	P6224
Enc 6	Encoder Position	P6240 💉
<		>

#### For an ACR9000 or AriesCE:

Select Parameter for Channel 2:

- a. Press "..." to open "Parameter Picker"
- b. Select "Object Parameters" from top drop-down
- c. Select "Encoder Parameters" from middle dropdown
- d. Select "Encoder Position" from bottom drop-down
- e. Select the desired axis from list.

#### 3. To display the commanded position on Channel 3:

- a. Press "..." to open "Parameter Picker"
- b. Select "Axis Parameters" from top drop-down
- c. Select "Position Parameters" from middle dropdown
- d. Select "Target Position" from bottom drop-down
- e. Select the desired axis from list.

Axis Parame	iters 🗾	ОК
Position Par	ameters 💽	Cancel
Target Posit	ion 🗾	
Item	Description	Parameter
Axis 0	Target Position	P12289
	Target Position	P12545
Axis 1		
Axis 1 Axis 2	Target Position	P12801
Axis 1 Axis 2 Axis 3	Target Position Target Position	P12801 P13057
Axis 1 Axis 2 Axis 3 Axis 4	Target Position Target Position Target Position	P12801 P13057 P13313
Axis 1 Axis 2 Axis 3 Axis 4 Axis 5	Target Position Target Position Target Position Target Position	P12801 P13057 P13313 P13569
Axis 1 Axis 2 Axis 3 Axis 4 Axis 5 Axis 5	Target Position Target Position Target Position Target Position Target Position	P12801 P13057 P13313 P13569 P13825



## 5. Select "SAMPLING..." and configure the scope for Controller-based sampling:

- a. Select "Onboard Sampling"
- b. Select "Servo Period"

Display

c. Click on "..." under "Trigger Source"

Trigger Source-		
Inp00		
Trigger Edge		
Rising Edge	C Falling Edge	

-

PC-based Sampling 20 ms

OK

Cancel

d. In 'Select A Bit' Window:
Select "Master Flags"
... then "Primary Master Flags"
... followed by "Primary Master0 Flags"
... finally "Bit 516 – In Motion"

Note: Select the In Motion bit for the Master that the axis is attached to. i.e., if Axis2 is attached to Master0, use bit516 If Axis3 is attached to Master3, use bit612 To confirm which Master the Axis is attached to see the Configuration Wizard > Masters



## 6. SET TORQUE LIMIT

Set TORQUE LIMIT to a level that ensures that the amplifier current stays within the "continuous current" region of the motor and amplifier. This will prevent overheating of motor and amplifier in case of tuning instability. The Torque Limit setting is based upon the amplifier's command voltage input range and the percentage of that range as it applies to the continuous regions of both motor and amplifier. For our example, we will assume that our drive is matched to our motor with respect to peak current limit. If our motor's continuous current range is 33% of its peak current range we would want to set our Torque Limit to approximately 3.3. Using the tuning gain window, set the Torque Limit to "3.3", or we could issue the "TLM X3.3" or "AXISO TLM 3.3" command in the terminal emulator. If for example the 210-4P motor is being used with an AR-08, this motor is rated at 3.5Arms continuous / 16Arms peak, the drive at 4.5Arms continuous / 13.5Arms peak. Since 3.5 Arms / 13.5Arms = .259, the torque limit should then be set to 2.5. These current ratings can be found in the Aries and Trilogy catalog pages.

## 7A. Initial Servo Tuner setup - Millimeters

ARxxCE: Tools:	:Servo T 🔳 🗖 🗙	ceTri:ARxxCE:S	copes:Oscillos	ope		🔳 🗆 🔀
Axis 0 💌	Auto Inertia Detection	Oscillocope				Channel 1
Proportional Gain	0.004185	.8 2.0			2.0 4	Axis 0: Following Error
Integral Gain	0 00000	.6 1.5			1.5 3	0.00 ms, 0.00 kU
Integral Limit	Motion				0.5 1	
Integral Delay	DRIVE UN X DWL .2 EXC X 25		Cancel		kU U	Enc 0: Encoder Position
Derivative Gain	RES X ACC 0				-0.6 -1	0.00 ms, 0.00 kU
Derivative Width	STP 0 VEL 10000				-1.0 -2	0.5 kUnit / Div
FF Velocity	JRK 0 X5			0 70 80	-2.0 -4	Channel 3 Axis 0: Target Position
FF Acceleration						0.00 ms, 0.00 kU
Torque Limit				splay Channel 1	Channel 3	0.5 kUnit / Div 📑 🚽
Feedback Vel				Channel 2	Channel 4	Channel 4
Upload from Contro	Download Commands To	PROGO Vher	Run Button Is Hit	Erase	Spare	0.00 ms, 0.00 kU
Get from Config	Save to Config	Bun	Single	Zero	Spare	1 Unit / Div 🕂 🚽
5	//					

Select Motion... button and set the below commands for motion. Ensure that "Download Commands to PROG0 When Run Button Is Hit" is checked. This will send the code to the controller when the Oscilloscope is set to RUN or SINGLE.

DRIVE ON X DWL .2 EXC X 25 RES X ACC 0 DEC 10000 STP 0 VEL 10000 JRK 0 X5

## 7B. Initial Servo Tuner setup - Inches

ARxxCE: Tools:	Servo T 💶 🗖 🔀	🖁 ceTri:ARxxCE	:Scopes:Oscillos	cope		
Axis 0 💌	Auto Inertia Detection	Oscillocope				Channel 1
Proportional Gain	0.004185	8 20			2.0 4	Axis 0: Following Error
Integral Gain	Motion	.6 1.6			1.5 3	0.2 kUnit / Div +
Integral Limit	DRIVE ON X		—		0.5 1	Channel 2
Integral Delay	DWL.2 EXCX1 BESX		Cancel		kU U	Enc 0: Encoder Position
Derivative Gain	ACC 0 DEC 400				-1.0 -2	0.5 kUnit / Div
Derivative Width	VEL 400 JRK 0				-1.5 -3	Channel 3
FF Velocity	X.2			0 70 80	90 100	Axis 0: Target Position
FF Acceleration				splay		0.5 kUnit / Div
Feedback Vel				Channel 1 Channel 2	Channel 3	Channel 4
Upload from Contro	✓ Download Commands To	PROGO Vł	nen Run Button Is Hit			Enc 3: Encoder Position
Get from Config	Save to Config	Pue	Cingle	Erase	Spare	1 Unit / Div +
				2.00		

Or for inches, select Motion... button and set the below commands for motion. Ensure that "Download Commands to PROG0 When Run Button Is Hit" is checked. This will send the code to the controller when the Oscilloscope is set to RUN or SINGLE.

DRIVE ON X

DWL .2 EXC X 1 RES X ACC 0 DEC 400 STP 0 VEL 400 JRK 0 X.2

### 8A. ACR9000: Set Starting Gains

For the ACR9000, start with basic tuning gains for of proportional gain .0024, derivative gain of .00001 for an unloaded positioner at 5um resolution. For other resolutions, scale proportionally. i.e., if using a 1um resolution encoder, this is 5 times more resolution than the 5um, start with proportional gain of .00048, derivative gain of .000002

### 8B. ACR9040/9030 or AriesController: Enable EPL Network and Click Auto Inertia Detection

In the terminal window at the system prompt type EPLC ON or in the Configuration Wizard under EPL Network, click Start EPL Network. The ACR9040/9030's EPL led will turn green, showing the EthernetPowerlink network has initiated. Next, start by clicking Auto Inertia Detection. This will move the motor <sup>1</sup>/<sub>4</sub> pitch, i.e. <sup>1</sup>/<sub>4</sub> of 60.96mm for a 110/210/310 motor. Base tuning gains will be set.

## 9. Use Single shot tuning and graphical display, iterate for best dynamic response.

Now press "SINGLE". This will result in the motor moving 5mm (or .2 inches) in the forward direction and stop.

Note, when the Run or Single buttons the motion commands are downloaded and while this is running, the Run and Single buttons will change to Stop. With Single, this will run once and display the tuning. Run will loop continuously. However, if no waveforms are shown and you only see Stop, the system is still waiting to trigger. Double-check which master the axis is attached to and trigger based on that master's In Motion bit. If you see Run or Single after they're selected and no waveforms are shown, open the terminal emulator and look for error messages such as "Out of memory", "Unknown command", and "Out of range". "Out of memory" and "Out of range" indicate that not enough memory was set aside for PROG0 in the Configuration Wizard. Update the Configuration Wizard, Finish and download configuration again. "Unknown command" indicates the axes were not attached to Master0.

The following steps are based upon the graphical response. An AriesCE was used but the concepts of tuning are consistent with ACR9000 and Aries, ACR9040 and Aries EPL, or Aries Controller.

🖉 ARxxCE:Tools:Servo T 🔳	🛛 🔀 🖼 ce Tri: ARxxCE: Scopes: Oscilloscope
Axis 0 🗸 Auto Inertia Dete	tion Oscillocope Channel 1
Proportional Gain 0.001241	2.0 4 Axis 0: Following Error
Integral Gain 0.000012	1.6 1.5 1.6 3 0.00 ms, 0.00 k0
Integral Limit 0.000000	2 0.5 0.5 1 Channel 2
Integral Delay 0.000000	ku ku 🖅 📶 📶 📩 📩
Derivative Gain 0.000012	.2 -0.5 -1 0.00 ms, 0.00 kU
Derivative Width 0.000000	.6 -1.5 -1.5 -3
FF Velocity 0.000000	.8 -2.0 40 60 80 ms 120 140 160 180 4.2.0 -4 Axis 0: Target Position
FF Acceleration 0.000000	Stopped 0.00 ms, 0.00 kU
Torque Limit 10.000000	1 Imebase Uisplay 0.5 kUnit / Div ÷ ↓ 20 ms / Div ÷ ↓ ↓ ↓ ↓ Channel 1 ♥ Channel 3
Feedback Vel 0.000000	Channel 2 Channel 4     Channel 4     Channel 4     Enc 3: Encoder Position
Upload from Controller Save in Contro	er Motion Sampling Erase Spare 0.00 ms, 0.00 kU
Get from Config Save to Conf	Run Single Zero Spare 1 Unit / Div

For an ACR9040/9030 system or AriesCE, scale the proportional gain by 10, in this example from .001241 to .01241



To dampen the overshoot, increase the derivative gain.



Further increasing the derivative gain...



ARxxCE:Tools:Servo T 🔳 🗖 🗙	CeTri:ARxxCE:Scopes:Oscilloscope	
Axis 0  Auto Inertia Detection	Oscillocope	
Proportional Gain 0.022	.8 2.0 2.0 4 6 1.5 3 0.00 ms, 0.00 kU	
Integral Gain 0.00001	.4 10 1.0 2 0.2 kUnit / Div	1 -
Integral Limit 0.0001	0.6 1 Channel 2	
Integral Delay 0.000000	ки ки Enc 0: Encoder Position	] []
Derivative Gain 0.0002 📩	.2 -0.5 -1 0.00 ms, 0.00 kU .4 -1.0 -2 0.5 kUnit / Div	
Derivative Width 0.000000	16 -15	
FF Velocity 0.0000	.8 -2.0 -4. 20 40 60 80 ms 120 140 160 180 Stopped	
FF Acceleration 0.0000	0.00 ms, 0.00 kU	
Torque Limit 10.000000	20 ms / Div ÷ ✓ Channel 1 ☞ Channel 3	1 -
Feedback Vel	Channel 2 Channel 4	
Upload from Controller Save in Controller	Motion Sampling Erase Spare 0.00 ms, 0.00 kU	
Get from Config Save to Config	Run Single Zero Spare 1 Unit / Div	1 -

Increasing the integral limit, allowing the integrator to correct for steady-state errors:

This shows a well-tuned system, with a step response settling within 30ms.

After the tuning has been completed, click Save in Controller and also Save to Config, which saves the tuning gains to both the controller and project file.

If you have any questions, please contact:

• Technical Assistance, Applications Engineering Department (e-mail: emn\_support@parker.com or call 800-358-9070 North America, 707-584-7558 International)