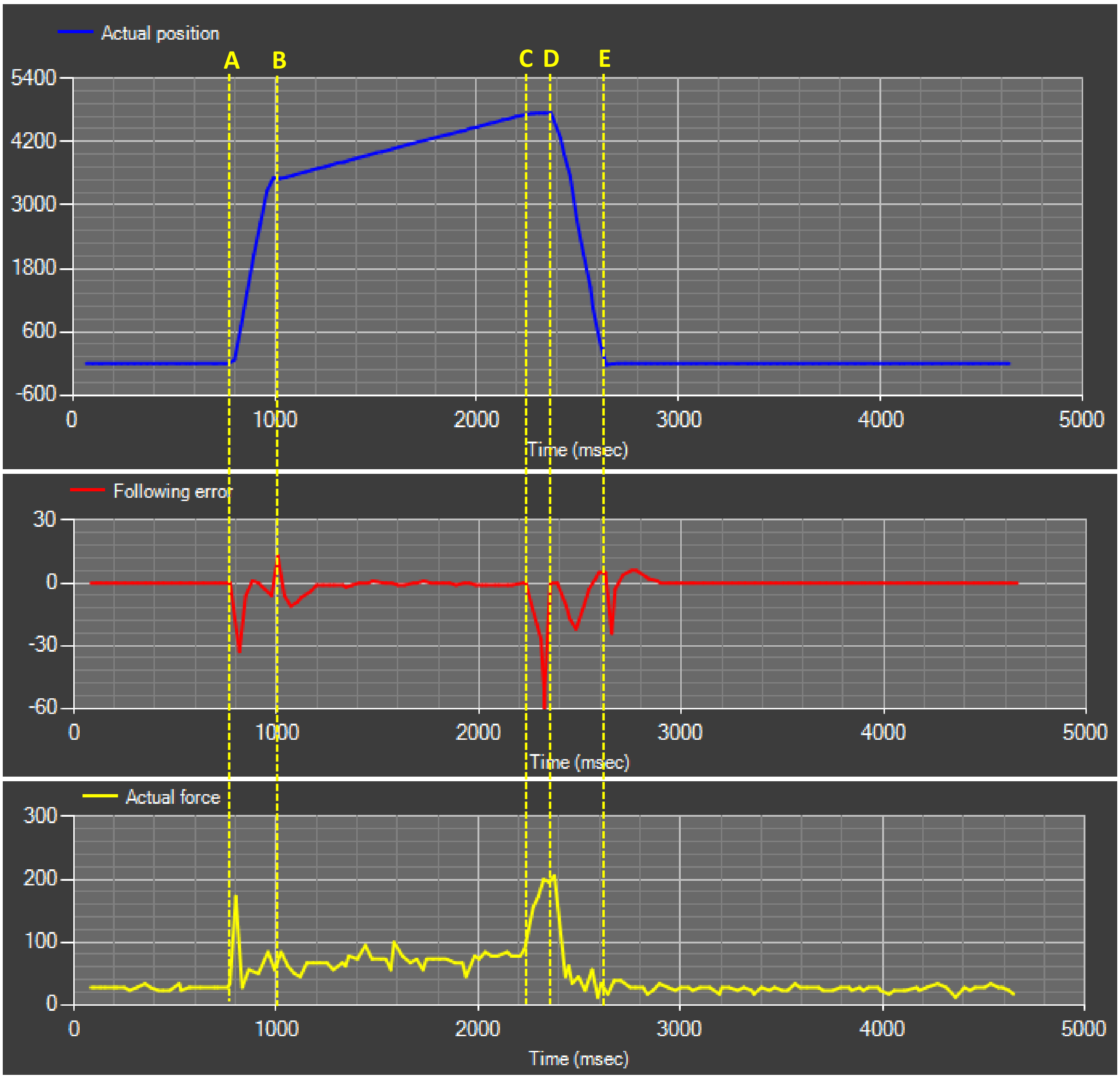
Softland

The goal of a softland is to touch an object with defined low (impact) force but within a short time. A softland cycle contains a fast position move from A to B and a velocity move from B to C. During the velocity move the controller checks if the position error is beyond a predefined threshold value. If so the condition "Landed" is reached (between C and D in the example below). After being landed, the actuator moves back to its home position (between D and E).



The softland function in the LCC control center creates only the motion between B and D .

A complete sequence that performs the total cycle as shown in the graphs can look like this:

#	Line	Command	Parameter
0		MacroNumber	2
4	2-1	PositionMove	Absolute,Target=3500,Vel=20000,Acc=,Change_immediate
3	2-2	Wait	Trajectory_generator_ready
1	2-3	Wait	Time,Timeout=40
1	2-4	SetVariable	Var=Max_current(0x006073),Constant,Const=200
12	2-5	Softland	Positive,Vel=1000,Acc=,Force=200,Error=80,Apply_force
1	2-6	Wait	Time,Timeout=50
2	2-7	SetVariable	Var=General_purpouse_registers-W10(0x0A2C00),Variable,Var1=Position_actual_value(0x006064)
2	2-8	SetVariable	Var=Max_current(0x006073),Variable,Var1=Max_torque(0x006072)
4	2-9	PositionMove	Absolute,Target=0,Vel=20000,Acc=,Change_immediate
1	2-10	GetVariable	Var=General_purpouse_registers-W10(0x0A2C00)
3	2-11	Wait	Trajectory_generator_ready

At A : Line 2-1 to 2-3

Make a fast move to position 3500 [counts] with a velocity of 20000 [counts /sec] with the default acceleration and deceleration (Line 2-1). Then wait until the traject generator has reached that position (Line 2-2), wait another 40 msec to give some time for settling of the motion (Line 2-3).

From B to D : Line 2-4 to 2-7

Set the maximum current (= landing force) to 200 [‰ of Motor Rated Current] (Line 2-4). Creating a softland with a landing velocity of 1000 [counts/sec] and setting the position error trigger level to 80 [counts]. As soon as the landing is detected it will apply a force of 200 [‰ of Motor Rated Current] (Line 2-5). It will wait for 50 [msec] to enable settling into this situation (Line 2-6). And it will copy the actual position into register W10 to enable to export the landed position at a later stage (Line 2-7).

At D : Line 2-8 to 2-11

Set the maximum current level back to its original value by copying the maximum torque value to the maximum current value in order to have enough force for fast moves (Line 2-8). Make a position move to home with high velocity (Line 2-9). Export the measured landed position over the serial port using the W10 register (Line 2-10). Then wait until the traject generator has reached that position (Line 2-11).

At E the cycle is completed.

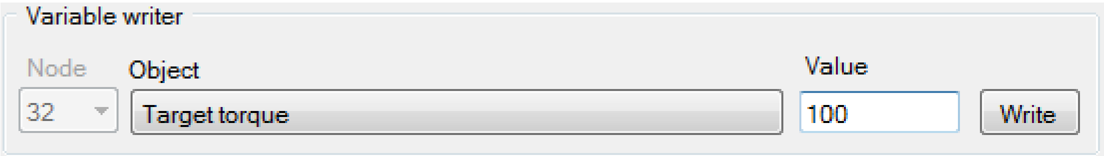
Note, if a variable is not entered in a function (empty), the value that is previously set will be used. If you haven't set a value previously, the value that is loaded by the config file is used.

Determine Maximum Landing Force

The maximum landing force is a force that needs to be determined in the application. It is the force at which you can comfortably say that you didn't damage the product or haven't moved (part of) the product. You can determine the force by using a force gauge or by using a force mode program:

#	Line	Command	Parameter
0		MacroNumber	3
2	3-1	Motor	On
4	3-2	ForceMove	Target=,Slope=

Leaving the target force variable open gives you the opportunity to change it during the test in the Run Programs tab:



This way you can run macro 3 and change the target force value. If the current loop is tuned correctly (which should be the case with a standard config file) and the force value is within the limits, the target torque value equals the Current Actual Value (CAV)

The force of the actuator is calculated by:

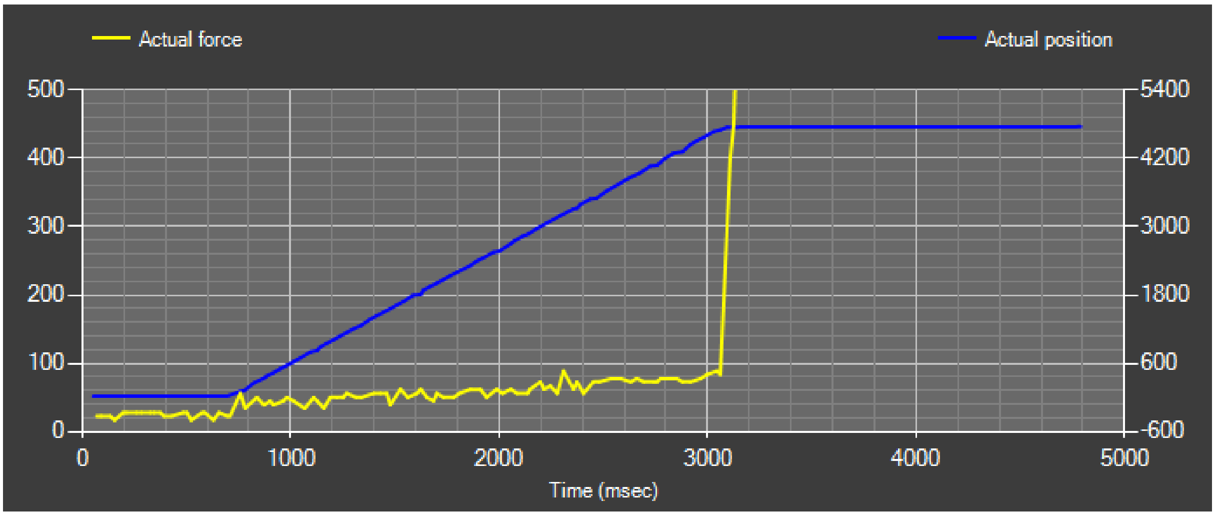
$$F = \frac{\mathrm{CAV} * \mathrm{MRC} * \mathrm{K}}{1000000}$$

With

F = Force in [N]
CAV = Current Actual Value (0x6078) in [‰ of MRC]
MRC = Motor Rated Current (0x6075) in [mA]
K = Motor constant in [N/A]

Note that the gravity forces (if in vertical orientation) and friction forces are not included in this formula.

The force required for moving in velocity mode needs to be considered (= friction force). The plot below shows this force (= Current Actual Value).



In this plot you see that the actual force (=CAV) is just below 100 ‰ of MRC during the velocity move. Logically it goes up when the actuator reaches end of stroke of the actuator. Normally you set the force not lower than the force you require for moving in velocity mode.
The friction of most actuators lies between 0.1 and 1N.

You need to determine both forces from this section:

- Maximum landing force (CAV) using force mode method
- Friction force (CAV) using velocity mode

The Maximum Landing force must be higher than the friction force. If that is not the case, this actuator is not suitable for this application.

The force you use for the softland needs to be chosen between the maximum landing force and the friction force. In general twice or 3 times the friction force is both robust and sensitive enough.

Calculate Landing Velocity

The landing velocity determines the impact force of the landing. To make an estimate of the impact force you can calculate the landing velocity with the following formula:

$$v = \sqrt{0.08 * \frac{F}{m}}$$

With:

v = landing velocity in [m/sec]
F = peak landing force [N]
m = total moving mass [gram]

The factor of 0.08 represents the elasticity of the contact. The value 0.08 is for a contact area of a few mm^2 between metal and plastic (most common situation). If the contact surface is bigger or the materials are harder, a lower value than 0.08 would give more accurate results.

Example:

Moving mass of actuator and payload on the shaft of the actuator = 500 gram
Allowed force (which doesn’t damage the product) = 2 N

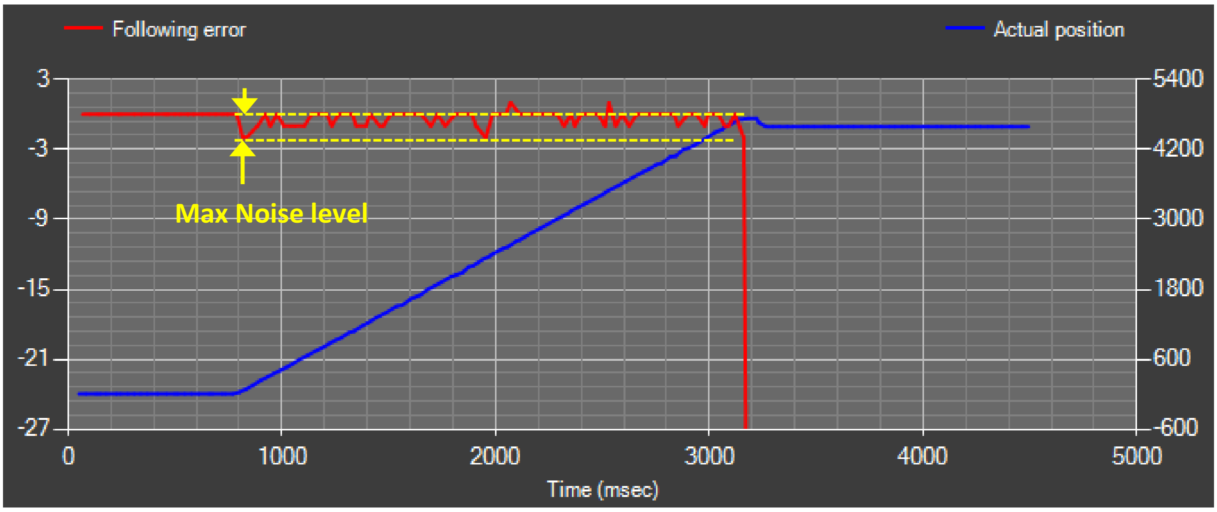
This means that the landing velocity must be lower or equal to:

$$v = \sqrt{0.08 * \frac{2}{500}} = \sqrt{0.00032} = 0.01788 \text{ [m/sec]} = 17.88 \text{ mm/sec}$$

If your actuator has a 5 micron encoder the value entered in the program is 3576 [counts/sec]

Determine Position Error Trigger Level

The position error trigger level is determined by the amount position error level during velocity mode and the variation during that constant velocity. In order to determine these values you need to run the actuator at the landing velocity and log the position error (= following error, 0x60F4) during constant velocity at the location where you expect the softland. The graph below shows the position error for a velocity move.



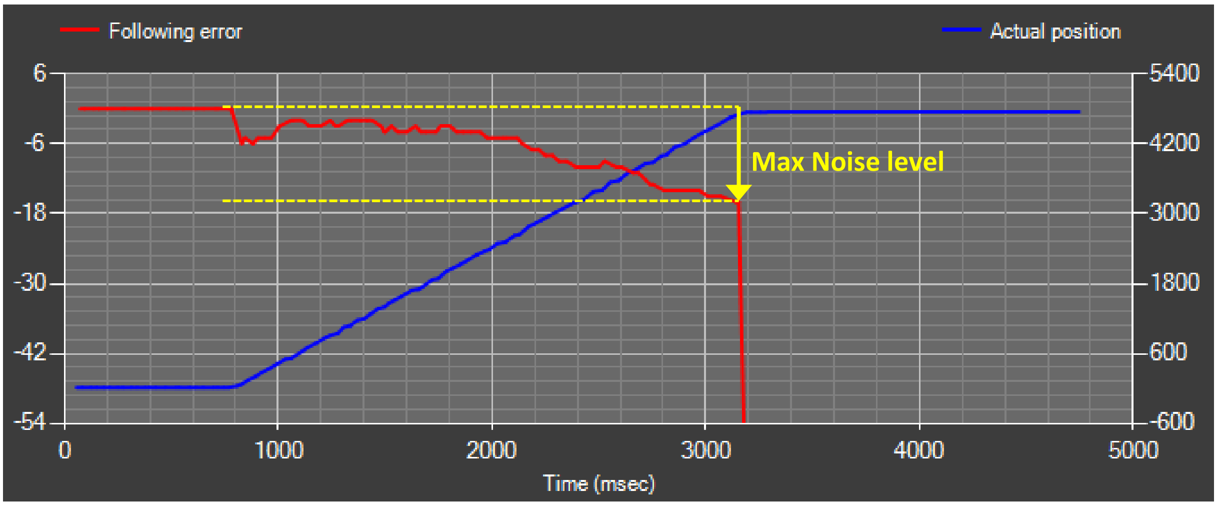
During velocity move the noise level of the following error (= position error) is only a few counts. In the cases that the noise level is small, the Position Error Trigger Level can be determined from the table below.

Encoder resolution	Max Noise level	Position Error Trigger Level
5 micron	< 10 counts	50 counts
1 micron	< 20 counts	120 counts
0.1 micron	< 80 counts	600 counts

In this example we have a 5 micron encoder having a following error noise level below 3 counts. This means that we can apply the 50 counts to the Position Error Trigger Level.
If the noise would be above 10 counts, we need to apply the rule like the table below.

Encoder resolution	Position Error Trigger Level
5 micron	Noise Level * 5
1 micron	Noise Level * 6
0.1 micron	Noise Level * 8

As an example the image below shows a noise level of about 16 counts (just before landing to the endstop). The situation is the same as the previous example but the position PID tuning is less strong and a return-spring has been added.



Since the encoder is a 5 micron, and the noise is bigger than 10 counts, the Position Error Trigger Level is best set to 80 counts (noise level of 16 * 5 = 80 counts)

Ending the Softland

The softland needs to be ended with an action after it has landed. In the softland function there are a few selections available:

- **Apply force**
  A set force, expressed in ‰ of Motor Rated Current, is applied after the position error threshold level is reached. The motion mode changes to force mode.
- **Hold Force**
  Holding the actual force when the position error threshold level is reached. The motion mode changes to force mode.
- **Hold position**
  The actual position at the time the position error threshold level was reached, becomes the new target position. The motion mode changes to position mode.
- **Hold motion status**
  The motion is unchanged, the actuator will try to continue its motion. When the position error threshold level is reached the program will continue.
- **Motor off**
  The motor will be switched off when the position error threshold level is reached.

Special cases

There are a few special cases that affect the softland significantly. This is the case of a spring and in case there is no spring but the actuator is mounted vertically.

Spring:

In case of a spring the force and following error will in general not be constant over full stroke. This is best compensated using the spring compensation. Spring compensation is available on firmware versions of 2.0 and higher. Even if you have spring compensation, you need to check the forces in the softland area. Please see the technical note on spring compensation for more information.

Vertical orientation:

In case of vertical orientation (shaft pointing down) the gravity force of the moving mass is added to the force of the actuator. So if you have to limit the force, the lowest value would be 0 (which means no control anymore). At this value the gravity force would still provide a force downward. So the limit should be set asymmetrical in order to make a softland with a force lower than the moving mass. Adding a force offset can help in the controlloop to optimise the following error.

The positive limit must be set close to 0 or even negative in order to reach the optimal softland force. The asymmetrical limit can be set in a program as shown below.

1	2-4	SetVariable	Var=Positive_torque_limit_value(0x0060E0),Constant,Const=-40

Resetting this limit can be done like:

2	2-8	SetVariable	Var=Positive_torque_limit_value(0x0060E0),Variable,Var1=Max_torque(0x006072)

If you want to check the limits, you can find them in the program tab in the group limit settings:

Positive force limit	4833	‰ of rated
Negative force limit	-4833	‰ of rated