PARAMETRIC ANALYSIS

Parametric analysis is a design-optimization feature that allows you to use variables, rather than static values for specifying design parameters. You define parametric variables by type and by a series of values. You define all parametric variables in the same fashion as the non-parametric variables. Parametric analysis reduces the tedious, repetitive tasks associated with fine-tuning design parameters. For each parametric analysis, you can assign up to 16 variables.

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INTEGRATED ENGINEERING SOFTWARE 2D Parametric Analysis

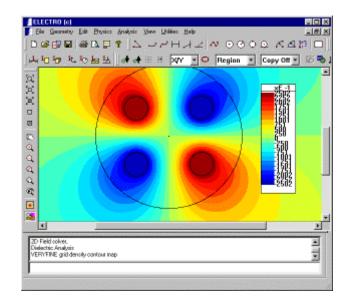




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PARAMETRIC ANALYSIS

Parametric analysis is a design-optimization feature that allows you to use variables, rather than static values for specifying design parameters. You define parametric variables by type and by a series of values. You define all parametric variables in the same fashion as the non-parametric variables. Parametric analysis reduces the tedious, repetitive tasks associated with fine-tuning design parameters. For each parametric analysis, you can assign up to 16 variables.

Parametric Variable Types

There are four types of parametric variables:

- Geometry Use a geometry variable when you want to optimize the size or position of different parts of the device.
- Boundary Use a boundary conditions variable to see the effect of different boundary conditions, including potential on a boundary and normal derivative of potential crossing a boundary.
- Media Use media to optimize materials properties, including permeability and different nonlinear curves, in regions of the model.
- Sources Use sources to see the effects of different sources on the model.

The Parametric Window Bar

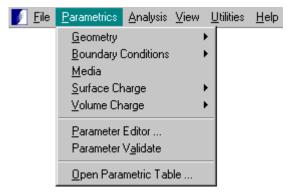
The parametric window contains five menus with commands that help create and analyze parametric design.

File menu

The Parametric File menu contains all of the Print and Save commands found in the main File menu. It does not contain the Open, Merge, Delete and Reset commands.

Parametrics menu

The Parametric menu contains the parametric variable sub-menus and commands as well as several commands editing for the parametric setup.

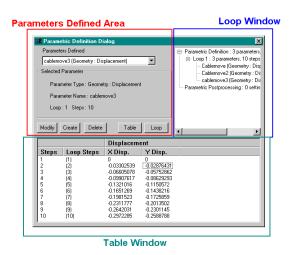


Parametric variable functions

Geometry	Contains the geometry modification commands - Displace, Rotate, Scale and Pull commands. These commands allow you to simulate geometric variations on a basic geometry.
Boundary Conditions	Contains the same commands as the main Boundary Conditions menu (Potential, dA/dn, Display and Delete).
Media	Select Media to create a material parametric variable. You can define this variable using the same Material Table that exists in the main Physics menu.
Sources	Contains the commands found in the main Physics menu.
Parameter Editor	Allows you to setup and edit parametric tables
Parameter Validate	Steps through the parametric variables
Open Parametric Table	Opens the current parametric table for editing.

The Parametric Definition Dialog is divided into three parts:

- The parameter defined section
- The Loop Window
- The Table Window



The Parameters Defined Area

- Modify Opens the Modify dialog to allow you to modify existing data.
- **Create** Opens the Create dialog to allow you to create a new parameter.
- **Delete** Opens the Modify dialog allowing you to delete existing parameters.
- **Table**Opens the Table window to display the step variables.
- **Loop** Opens the Loop window to display the Parametric Definition, Loop Structure, and Parametric Post Processing functions.

Performing a Parametric Analysis

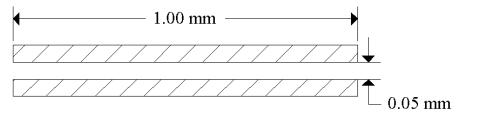
There are two methods of setting up a parametric analysis:

- One method utilizes the Parametric Editor command and the Parametric Definition dialog box.
- The other method utilizes the Parametrics menu commands and program prompts in the message area to guide you through the process.

Parametric analysis using the Parametric Editor

To set up a parametric analysis using the Parametric Editor command:

1) Create a basic model. Normally, this is the base design where you want to see the effect of different variables. As an example, we will vary the gap between the plates of a capacitor. The top plate is assigned 1 Volt and the bottom is grounded.



- From the Utilities menu, select Parametric On/Off. This changes the menu bar to the parametric menu bar.
- 3) Select Loop Initialization from the Parametric menu to open the Loop Initialization dialog box.

Loop Initialization	×
Parameters Defined	
	▼ Display
Selected Parameter	
Unknown	
Unknown	
Unknown	
Modify Create C	Velete Update Table 🔽 🕨
Create a	new parameter

4) Click the Create button on the Loop Initialization dialog box to open the Loop Editor dialog.

Loop Editor						
Parameter Type	Geometry : Displace	ement 💌] _{Loop} [1		
Parameter Name	Stroke		Steps	21		
Creating Parameter Linear Steps	Table By					
Reference Point(x	.y) 0.5	0	mm	Pick		
Target Point(x,y)	0.5	0.05	mm			
Ap	iply Create	C	ancel			
						Point X:0.5 fmm
					K	X : 0.5 [mm] Y : 0.05 [mn
					<u> </u>	-
					Ð.	Point X : 0.5 [mm Y : 0 [mm]

5) In this box, first select the Parameter Type; in this case a Geometry Displacement.

- 6) Every parameter must have a name (if you require more than one parametric variable, each name must have a unique first letter) in this case use "Stroke".
- 7) Specify a Loop number (the program can support up to 4 nested Loops). In this case, there will only be one loop, so leave the default setting to 1.
- 8) Enter the number of steps (the number of different values assigned to the variable under examination) as 21.
- 9) Make sure that the geometry selection type is set to regions. Then, using the mouse, select the top plate of the capacitor as the region that is to be displaced. (The Apply Create button will then become active but the parametric definition is not yet complete.)
- 10) You can have parameters vary linearly (equally spaced intervals) or non-linearly, or by a Function, or from a File. In this case, use the default Linear Steps.
- 11) The Reference (start) and Target (end) points for the displacement can be entered directly into the dialog, or can be selected using the mouse. To use the mouse, press the "Pick" button and select the points shown above.
- 12) Click the Apply Create button. The Loop Editor will close.
- 13) The Loop Initialization dialog will be updated with the information on the Stroke parameter and appear as shown:



- 14) Before continuing, click the two arrow buttons to open the Loop View and Parameter Value Table.
- 15) From the Analysis menu, select Force>Region and select the bottom plate of the capacitor when prompted. Right click to end the selection.
- 16) From the Analysis menu, select Charge and then select the top plate when prompted. Right Click to end the selection.
- 17) The Loop View section of the dialog box will show the post processing you have defined. It should appear as shown below:

8 Loop I	nitialization				E
Paramet	ters Defined			Parametric Definition : 1 parameters, 1 loops, 21 total steps	
Stroke (G	eometry : Displaceme	ent)	 Display 	E-Loop 1 : 1 parameters, 21 steps	
Selected	d Parameter			Stroke (Geometry : Displacement) Parametric Postprocessing : 2 settings	
				- Force on region	
	ameter Type : Geome		ierii	Charge	
Para	ameter Name : Stroke				
Loop	p:1 Steps:21				
Modify	Create Delete	Lindate T	able 🔺 ┥		
modaly		0,000			
		Displace	ment		-
Steps	Loop Steps	X Disp.	Y Disp.		
1 2	(1) (2)	0.5 0.5	0 0.0025		_
3	(3)	0.5	0.005		
4 5	(4)	0.5 0.5	0.0075		
0	(5)	0.5	0.01		-



Selecting Parameters or Post Processing items in the Loop View causes the corresponding geometry to become high lighted in the main program window.

- 18) At this point the parametric and post processing can be modified if desired. The final definition of the parametric does not occur until you press the "Update Table" button.
- 19) To verify that the top plate will be displaced during the parametric run, select Parameter Validate from the Parametrics menu. This should cause the top plate to become high lighted and then move vertically up to the maximum displacement and back again to the start position.
- 20)Once the parametric has been validated, press the "Update Table" button on the Loop Initialization dialog box. This will update and open the Final Parametric Table which should appear as shown below:

		Stroke (1)*		
		Displace	ment		
steps	Loop Steps	X Disp.	Y Disp.		
	(1)	0.5	0		
	(2)	0.5	0.0025		
	(3)	0.5	0.005		
	(4)	0.5	0.0075		
	(5)	0.5	0.01		
	(6)	0.5	0.0125		
	(7)	0.5	0.015		
	(8)	0.5	0.0175		
	(9)	0.5	0.02		
0	(10)	0.5	0.0225		
1	(11)	0.5	0.025		
2	(12)	0.5	0.0275		
3	(13)	0.5	0.03		
4	(14)	0.5	0.0325		
5	(15)	0.5	0.035		
6	(16)	0.5	0.0375		
7	(17)	0.5	0.04		
8	(18)	0.5	0.0425		
9	(19)	0.5	0.045		
0	(20)	0.5	0.0475		
1	(21)	0.5	0.05		
				Rese	ОК 🛛

21) This table can be edited if desired. If it is correct, press the OK button to close it.

Now the parametric setup is complete. From the Utilities menu, select Parametric On/Off. This closes the parametric window and returns to the main menu bar.

To run the parametric analysis:

 From the Utilities menu, select Run Parametric. A save dialog box will open to allow you to specify the name of a Record File that will record each parametric step. Enter any name you wish (such as "rec.rec") and press the Save button.

Record File					? ×
Save jn:	🔁 UpdatePara	•	E	ď	
Fields×51F	ireeSpaceMetricNarrow.dbs				
File <u>n</u> ame:	rec.rec				<u>S</u> ave
Save as type:	Record File(*.*)		•		Cancel

2) A second save dialog box will open to allow you to specify a database that will contain a table of the post processing results. You can specify a new name (in this case "Results") if you do not wish to overwrite your base model.

Select Para	metric Result Database File				? ×
Save in:	🔄 UpdatePara	-	È.	ď	
Fields:X5	1FreeSpaceMetricNarrow.dbs				
File <u>n</u> ame:	Results				<u>S</u> ave
Save as typ	: Database (*.DBS)		•		Cancel

3) Once you click the Save button, the parametric run will start. During the run, the current step number will be displayed.

Current Parametric Step : 2 Total Parametric Steps : 21	rametric Step
Fotal Parametric Steps : 21	Current Parametric Step : 2
	tal Parametric Steps : 21
	li Quit i

4) When the parametric run is completed, you will be informed by the dialog box.

After the solution is complete, you can find the results for each parametric step in the same directory as the original model. The results filename (8 characters in length) starts with P followed by the step number, e.g. P00000001.dbs for the first step.

Viewing the Parametric Results

The results of the parametric run can be viewed in table or graph format by performing the following steps.

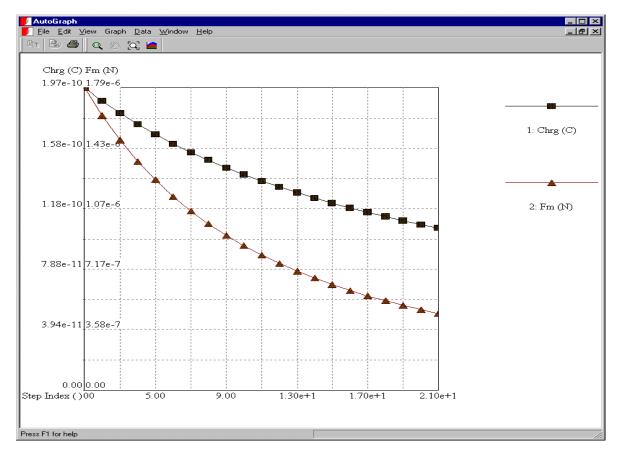
1) Select Parametric Results from the Utilities menu. This will open the Final Parametric table.

Steps						
Steps		Displace	ment			
	Loop Steps	X Disp.	Y Disp.	Fx	Fy	Fm
1	(1)	0.5	0	-6.853928e-012	1.791554e-006	1.791554e
2 3	(2)	0.5	0.0025	-4.818378e-012	1.625813e-006	1.625813e
3	(3)	0.5	0.005	-3.458984e-012	1.482123e-006	1.482123e
4	(4)	0.5	0.0075	-3.601498e-012	1.35672e-006	1.35672e-0
5 6	(5)	0.5	0.01	-5.458853e-012	1.246629e-006	1.246629e
6	(6)	0.5	0.0125	-5.063404e-012	1.149463e-006	1.149463e
7	(7)	0.5	0.015	-4.956931e-012	1.063246e-006	1.063246e
8	(8)	0.5	0.0175	-1.155658e-012	9.864336e-007	9.864336e
9	(9)	0.5	0.02	-5.011705e-012	9.17663e-007	9.17663e-
10	(10)	0.5	0.0225	-3.35219e-012	8.558701e-007	8.558701e
11	(11)	0.5	0.025	-4.464375e-012	8.001305e-007	8.001305e
12	(12)	0.5	0.0275	-2.075663e-012	7.496857e-007	7.496857e
13	(13)	0.5	0.03	-2.76043e-012	7.038862e-007	7.038862e
14	(14)	0.5	0.0325	-1.861287e-012	6.621701e-007	6.621701e
15	(15)	0.5	0.035	-3.288894e-013	6.240739e-007	6.240739e
16	(16)	0.5	0.0375	-3.217272e-012	5.891811e-007	5.891811e
17	(17)	0.5	0.04	-2.850579e-012	5.571537e-007	5.571537e
18	(18)	0.5	0.0425	-2.318002e-012	5.276813e-007	5.276813e
19	(19)	0.5	0.045	-2.047045e-012	5.004872e-007	5.004872e
20	(20)	0.5	0.0475	-3.183861e-012	4.753569e-007	4.753569e
21	(21)	0.5	0.05	-3.842517e-014	4.520784e-007	4.520784e
•						

- 2) There is a button at the bottom of the table that allows you to copy the data to the Windows Clipboard for use by other applications.
- 3) Clicking the Graph Plot button will open the Plot Graph dialog box.

Graph Plot	×
Independent Variable 1 (X Axis)	Independent Variable 2
Stroke-Displacement(1)	None 💌
Dependent Variable (YAxis) Loop Step Fixing Loop 1	E Fx Fy
	Fm Fa Area Chrg
Results 1 Curve(s)	Plot Graph Close

- Using the drop down list, select a dependent variable to plot and click the Plot Graph button to produce a graph using the Autograph utility. Do this for each variable you wish to plot.
- 5) The following graph shows that the charge on the top plate decreases (approximately) inversely with the gap while the force on the bottom plate decreases (approximately) according to the inverse square of the gap. This is in close agreement with simple analytic formulas (discrepancies are due to the fact that the analytic formulas do not consider fringing effects).



This completes the example.

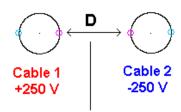
Parametric analysis using the Parametrics menu

To set up a parametric analysis using the Parametrics menu commands:

- 1) Create a basic model.
- 2) From the Utilities menu, select Parametric On/Off.
- 3) Select the parameter that you want to vary from the Parametrics drop down list.
- 4) Follow the prompts in the program message area.

We will use the displace geometry variable as an example.

In this example we have two cables, with equal voltages, but with opposite polarities. We will observe the interaction of the Voltage fields as the distance between the two decreases.



Two Cables Example

"D" distance between cables

- 5) From the Utilities menu, select Parametric On/Off.
- 6) Select the Parametrics, then Geometry then Displace.
- 7) Enter "move" for the name for the parameter.
- 8) Enter 10 for the Number of displacement steps at the prompt.
- 9) Enter N at the prompt "will the values be imported from a file?".
- 10) Enter N at the prompt "Will the values be expressed as a Function?"
- 11) Enter Y at the prompt " Will the values be linearly spaced?"
- 12) Select Cable 1 at the prompt "Select Regions (or segments, or objects)".
- 13) Select the center point of the cable as the reference point and press the right mouse button.
- 14) Move the outline of the cable from its original placement, to a point where the two conductors are touching, and press the right mouse button.



15) From the Parametrics menu, select Parametrics validate, and watch Cable 1 move towards cable 2.

The physical movement of cable 1 to cable 2 is now defined.

To assign the post processing functions to the parametric:

- 1) Select Analysis from the Analysis menu.
- 2) The model will solve.
- 3) Select Field Results from the Analysis menu.
- 4) Set the Field Analysis Results to:

Voltage Contours Medium density 31 Bands Select the solid option

- 5) Press Apply Settings.
- 6) Close the Field Analysis Dialog box.

This adds the post processing option for the example

To View the Parametric table and definitions:

- 1) Select Loop Initialization from the Parametrics menu.
- 2) Press the down arrow and right arrow buttons.

nove (Searchy Duplacement)	
alested Patameter	
Paveneter Type: Electreity Displace	ener d'
Parameter Name more	
Log 1 Sept 10	

3) The Dialog opens up to allow you to view the steps and parameters involved in the parametric analysis.

Cook II	nitialization			E Contraction of the second
Paramete	ers Defined			E-Parametric Definition : 1 parameters, 1 loops, 10 total steps
move G	ieometry : Displace	ment]	*	E-Loop 1 : 1 parameters, 10 steps move (Geometry : Displacement)
Selected	Parameter			Parametric Postprocessing: 1 settings
Para	neter Type : Geom	atau : Divelacamen		V color contour plot in window (-1.2900 -0.69109) - (1.2900 0.49073)
1.010	neter (ype : Georg	ery - proprietienen	•	
Para	neter Name : move	•		
Loop	:1 Steps:10			
		1		
Modify	Create Delete	Update Tabl		
Modify	Create Delete	,		
Modify	Create Dalets	Update Tabl		
Steps	Loop Steps	Displacem X Disp. -0.3368715	ent Y Disp. 0.1468272	
Steps	Loop Steps	Displacem X Disp. -0.3368715 -0.3567474	ent Y Disp. 0.1468272 0.1473251	
Steps	Loop Steps	Displacem X Disp. -0.3968715 -0.3567474 -0.3166232	ent Y Disp. 0.1463272 0.1473251 0.147723	
Steps 1 2 3 4	Loop Steps	Displacem X Disp. -0.3968715 -0.3567474 -0.3166232 -0.2764991	ent V Disp. 0.1463272 0.1473251 0.147723 0.1481209	
Steps 1 2 3 4 5	Loop Steps	Displacem × Disp. -0.3968715 -0.3968715 -0.3968715 -0.39687474 -0.3166232 -0.2764991 -0.2363749	ent V Disp. 0.1463272 0.1473251 0.147723 0.1491209 0.1495188	
Steps 1 2 3 4 5 6	Loop Steps 11 12 13 14 15 15 15	Displacem X Disp. -0.3968715 -0.3968715 -0.3967474 -0.3166232 -0.2764991 -0.2764991 -0.2764991 -0.1962508	ent Y Disp. 0.1468272 0.1473251 0.147723 0.1491209 0.1485188 0.1485188	
Steps 1 2 3 4 5 6 7	Loop Steps 11 12 13 14 15 15 15	Displacem X Disp. -0.3960715 -0.3967474 -0.3166232 -0.2764991 -0.2363749 -0.1962908 -0.1962908 -0.1961266	ent Y Disp. 0.1463272 0.1473251 0.147723 0.1491209 0.1495188 0.1495188 0.1493168 0.1493147	
Steps 1 2 3 4 5 6	Loop Steps	Displacem X Disp. -0.3968715 -0.3968715 -0.3967474 -0.3166232 -0.2764991 -0.2764991 -0.2764991 -0.1962508	ent Y Disp. 0.1468272 0.1473251 0.147723 0.1491209 0.1485188 0.1485188	

4) At this point if required, you could edit the parametric analysis.

- 5) Close the Dialog box.
- 6) Select Parametrics On/Off from the Utilities menu.
- 7) Select Run Parametric from the Utilities menu.
- 8) The record file dialog box opens

Record File	2 ×
Severa 20	
2 di eve 2 di evp 7 2 di 8 2 di 80 2 di 80 4 Autogr ⁻¹ , gid 4 A	AUTOGRAPHIN E debugin fLECTR0000000005154 E ELECTR000000000000050 FL ELECTR00000000000000000 ELECTR000000001020 ELECTR000000001020 ELECTR000000001020 ELECTR0000000001020 ELECTR0000000001020 ELECTR0000000001020 ELECTR0000000001020 ELECTR000000001020 ELECTR000000001020 ELECTR000000001020 ELECTR000000001020 ELECTR000000001020 ELECTR0000000001020 ELECTR0000000001020 ELECTR000000001020 ELECTR0000000001020 ELECTR000000001020 ELECTR0000000001020 ELECTR000000000000000000000000000000000000
Fiegune: Provosor	
Save as jost Record Fi	41-71 I Cancel

- 9) Enter movement.rec as the record file and press save.
- 10) The result database file dialog opens

Select Parametric Result Database File	. ? ×
Savejit 🔄 Electro	- 🗈 🗃 📼
persosample a.dbs coble.dbs coble2.dbs coble2.dbs coble2b.dbs co	electro analytic-problem ¹ decurve.dl electro-analytic-problem ¹ jecurve.db electro-analytic-problem ² -bothourve. ELECTROSAMPLESESSIONT043- Ex example.dbs Fininsulator.dbs Milikan.dbs
	브
File game: C '\$cablemovement dbs Save as gps: Delabere (".DBS)	Save Cancel

11) Enter cablemovement.dbs as the file name and press save.

The program runs the parametric analysis, and displays the dialog box, when complete.

Run Par	ametric: 💌
ৃ	Parametrics analysis is completed. Do you want to save the results ?
	Yes No

12) Press Yes and enter a file name for the completed parametric results.

Viewing the Parametric Results

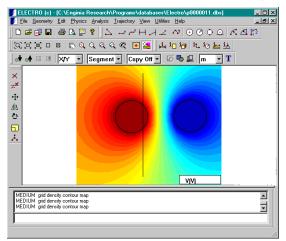
In the Cable sample, we had generated the results for the voltage contour plots at 10 positions of Cable 1 vs. Cable 2. The Parametrics function created 10 databases for us, each containing the results for that particular step.

- 1) To view the results for a particular step:
- 2) Select Parametric Results from the Utilities menu.

- This opens the Parameter Table dialog.
- In this case the Parameter Table dialog shows you the cross reference between each step and the database for it's results.

		move (1)		
		Displaceme		
Steps	Loop Steps	X Disp.	Y Disp.	
1	(1)	-0.2899362	0.1516528	p0000001.dbs
2	(2)	-0.2481232	0.1518842	p0000002.dbs
3	(3)	-0.2063102	0.1521155	p0000003.dbs
4	(4)	-0.1644972	0.1523469	p0000004.dbs
5	(5)	-0.1226843	0.1525782	p0000005.dbs
6	(6)	-0.08087127	0.1528096	p0000006.dbs
7	(7)	-0.03905828	0.1530409	p0000007.dbs
8	(8)	0.002754707	0.1532723	p0000008.dbs
9	(9)	0.04456769	0.1535036	p0000009.dbs
10	(10)	0.08638068	0.153735	p0000010.dbs
		y To Clipboard	Graph P	lot Close

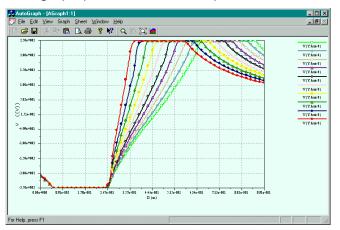
- 5) To view the results at a particular step, select File, Open from the main menu of the 2D program.
- 6) Select any one of the listed Databases.
- 7) When the database opens, the plot for that step is displayed.



- 8) This method of displaying the results is used for Contours, Arrows, Loci, and Streamline Plots. For Graphs along a segment or line, the results are produced a little differently.
- 9) If we added an arbitrary segment running through the centers of each of the cables, we could graph the voltage on that line at the various points of Cable 1's movement.



When you select Run Parametrics from the Utilities menu, the Parametric analysis opens the Autograph utility and sends the data to it.



You can see that there is a graph plotted for each step of the cable's movement.

Single value Results are items that produce one number for each step of the analysis. They are:

- Force
- Torque
- Flux Linkage
- Induced Voltage

They will depend on the type of program that you have, (electrostatic, magnetostatic, etc.) The results for a Torque analysis on the cable are displayed below.

Parameter Table Dialog				
		move (1)		
	Displacemen			
Steps	Loop Steps	X Disp.	Y Disp.	Tq
1	(1)	-0.2899362	0.1516528	-1.343889e-009
2	(2)	-0.2589723	0.1519739	-1.86905e-009
3	(3)	-0.2280085	0.1522949	-2.59308e-009
4	(4)	-0.1970446	0.152616	-3.613934e-009
5	(5)	-0.1660807	0.1529371	-5.093241e-009
6	(6)	-0.1351169	0.1532581	-7.312046e-009
7	(7)	-0.104153	0.1535792	-1.079071e-008
8	(8)	-0.07318913	0.1539003	-1.657633e-008
9	(9)	-0.04222526	0.1542213	-2.702762e-008
10	(10)	-0.01126139	0.1545424	-4.839935e-008
	Copy To	o Clipboard	Graph Plot	. Close

1) To plot a graph of the torque values vs. cable displacement, press Graph Plot. This brings up the Graph Plot dialog.

Graph Plot Dialog		×
Independent Variable 1 (X Axis)	Independent Variable 2	
move-Displacement(1)	None	•
Dependent Variable (Y Axis)	Τα	•
Loop Step Fixing		
Loop 1		
All		
Results 1 Curve(s)	Plot Graph Clo	ise

2) Select the Plot Graph button and the plot of the Torque is displayed in the AutoGraph utility.

Please Note: You may have to format the graph view ranges in order to display the graph as shown.

