

Tolerancing with Random Distributions

Abstract



For systems with many parameters, investigating tolerance can be done by randomly varying the parameters within given boundaries. VirtualLab Fusion offers various random distributions to assist optical engineers in this task. Within the Parameter Run document, users can specify uniform, normal and asymmetrical normal distributions for the parameters.

Where to find the Components?

: Tolerancing with Different Random Distributions					
meter Specification					
up the parameter(s) to be varied.					
can select one or more parameters which shall be varied as well as the resul	ting numbe	r of iterations.	Several modes	are availat	ole specifying how
d per iteration.	2				
ge Mode Random V					
ter by					× Show On
Decementar	Voru	From	Та	Stand	Original Value
n Parameter	Valy	From	10	steps	Original value
Environment					
System Temperature		-273.15 °C	1e+100 °C	1	20 °C
Air Pressure		0 Pa	1 GPa	1	101 325 kPa
			1 Ol u		101.525 KFd
"Ideal Plane Wave" (# 0)			1010		101.525 KPa
"Ideal Plane Wave" (# 0) Define the second of the second o			Toru		101.525 KPa
"Ideal Plane Wave" (# 0) Medium at "-" Output (Air in Homogeneous Medium) Material (Air) Constant Absorption Coefficient		0	1e+300	1	01.525 KPa
"Ideal Plane Wave" (# 0) Medium at "-" Output (Air in Homogeneous Medium) Material (Air) Constant Absorption Coefficient Material (Air) Partial Pressure of Water Vapor		0 0 Pa	1e+300 1e+291 GPa	1	0 Pa
Ideal Plane Wave" (# 0) Medium at "-" Output (Air in Homogeneous Medium) Material (Air) Constant Absorption Coefficient Material (Air) Partial Pressure of Water Vapor (empty)		0 0 Pa	1e+300 1e+291 GPa	1	0 0 0 Pa
Ideal Plane Wave" (# 0) Medium at "-" Output (Air in Homogeneous Medium) Material (Air) Constant Absorption Coefficient Material (Air) Partial Pressure of Water Vapor (empty) Wavelength		0 0 Pa 527 nm	1e+300 1e+291 GPa 537 nm	1 1 5000	0 0 0 Pa 532 nm
Ideal Plane Wave" (# 0) Medium at "-" Output (Air in Homogeneous Medium) Material (Air) Constant Absorption Coefficient Material (Air) Partial Pressure of Water Vapor (empty) Wavelength Weight		0 0 Pa 527 nm 0	1e+300 1e+291 GPa 537 nm 1e+300	1 1 5000 1	0 0 Pa 532 nm 1
Ideal Plane Wave" (# 0) Medium at "-" Output (Air in Homogeneous Medium) Material (Air) Constant Absorption Coefficient Material (Air) Partial Pressure of Water Vapor (empty) Wavelength Weight Polarization Angle		0 0 Pa 527 nm 0 0°	1e+300 1e+291 GPa 537 nm 1e+300 360°	1 1 5000 1 1	001.323 kPa 0 0 Pa 532 nm 1 0°

The *Property Browser* can be found at the right side of the main window. It shares the same panel with the *VirtualLab Explorer*, the *Assistant* and *Distributed Computing*.

The displayed options and properties are dependent on the type of active* document (e.g., data array, optical setup etc.).

*The active document is the last document the user have clicked on.

Preview of the Distribution

10 * 52: Tolerancing Parameter Run			1 2 *	Parameter	Vary Fro	m To	Steps	Original Value
Settings for Random Mode			Basal Po	sitioning (# 1)				
			Rotat	ion #1 (about X-Axis)		-2° 2°	5000	0.11118°
			Rotat	ion #2 (about Y'-Axis)		-2° 2°	5000	0.02253°
Seed						_ *		,
Set Seed Manually								
			1					
Distribution Type Normal Distribution via Standard Deviation 💛 🔽 Cutoff Distribution		1	🛃 57: Histogi	am				
Variance				Nume	erical Data Array (Eq	uidistant)		
The Parameter Range Corresponds to2 σ2 σ.		· · · ·		ble Value at x-Coordinate				
Preview of Distribution		1			,,	л		
Preview Number of Intervals 71			50		յլս	4		
		i			л	5		
		!				In		
			ts 150					
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The <i>Preview</i> button displays the	Â.		f Data		1			
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overall shape of the fandom	1	1	Un N	لے		1	.	
distribution based on the given	1						L .	
parameters. The Number of Intervale		i i	8 -				-L	
parameters. The Number of Intervals	Ва						5	
parameter is for visualization only and	In this examp	ole, only 1					الحر	
door not affect the number of	intervals are	displayed			0.4	0.6	0.0	
				0 0.2 Relativ	ve Position in Par	ameter Interv	als	
iterations, which is defined in the	meter Run							
Stand column on the provious page	will iterate 50	000 times						
Steps column on the previous page.								

Preview of the Distribution

		ſ	1 2 *	Parameter	Vary	From	То	Steps	Original Value
32 * 52: Iolerancing Parameter Run			"Sawtooth	Grating" (# 1)					
Settings for Random Mode			🖃 🗏 Basal Po	ositioning (Relative)					
			Rotat	tion #1 (about X-Axis)		-2°	2°	5000	0.11118°
Seed			•• Rotat	tion #2 (about Y'-Axis)	×.	-2°	2°	5000	0.02253°
Set Seed Manually									
Distribution Type 🛛 Normal Distribution via Standard Deviation 🗸 🥑 🛛	utoff Distribution		💌 57. 1 Katao						
Variance			E Dr. Histog	Nume	erical Data A	rray (Equidist	ant)		
The Parameter Range Corresponds to -2 σ	2 σ.		Diagram Ta	ble Valuet x-Coordinate					V
Preview of Distribution						Гл			
Preview Number of Intervals 71			- 30			ղԱ կ			
					ار		1		
Parameter Range Color Decity 50.196	b						Π		
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	<i>Type</i> and <i>Variance</i> , the paramete	er 🤇	of Dat		_ لے		L		
	range may exceed the borders define	ned	- 10 100	1	لی		ι		
	in the Devergetor Due The evicine			L L			ե	1	
	in the Parameter Run. The origina			4				5	
	specified range is shown in a		2					L	
	austamizable color block while th			لي				1_	
				كسر				- ⁶ 1	
	actual range is indicated by two yell	low	7	0 0.2	0.4	0.6	5	0.8	1
	lines The Cutoff Distribution parame	otor		Relati	/e Position	in Paramet	ter Interv	als	
	can prevent this overflow.								

Uniform Distribution

12 * 52: Tolerancing Parameter Run
Settings for Random Mode
Seed
Set Seed Manually
Distribution Type Uniform Distribution
Preview of Distribution
Preview Number of Intervals 71 🖨
Parameter Range Color Opacity 50.196 %
< Back Next > Show *

For a *Uniform Distribution*, all values in the parameter range have the same probability of being chosen by the random function.



Normal Distribution via Standard Deviation

😥 * 52: Tolerancing Pa	arameter Run	×
Settings for Random I	Mode	
Sand		
Seed		
Set Seed Manua	ally	
Distribution Type	Normal Distribution via Standard Deviation 🗸 🔽 Cutoff Distribution	
Variance The Parameter Ran	ge Corresponds to $-2 \sigma_{m} = 2 \sigma_{m}$	
Preview of Distribu	ition	
Preview Nur	nber of Intervals 71 🖨	
Para	ameter Range Color 📃 Opacity 50.196 %	

Normal distribution via Standard Deviation follows the formula of a Gaussian normal distribution:

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\nu)^2}{2\sigma^2}}$$

with μ being determined as the center of the parameter range.



Normal Distribution – Parameter Range

10 * 52: Tolerancing Parameter Run		
Settings for Random Mode		
Seed		
Set Seed Manually		
Distribution Type Normal Distribution via Standard Deviation 🧹 🥑 Cutoff Distribution	- Variance	Variance
Variance		
The Parameter Range Corresponds to $-2 \sigma_{m} = 2 \sigma_{m}$		
Preview of Distribution	57: Histogram	59: Histogram
Preview Number of Intervals 71	Numerical Data Array (Equidistant)	Numerical Data Array (Equidistant)
Parameter Range Color Dpacity 50.196 %	Diagram Table Value at x-Coordinate	Diagram Table Value at x-Coordinate
For this random distribution the user	er of Data Points	Der of Data Points 100 150 200
specifies the factor between parameter range and the standard deviation.	E	E

Normal Distribution – Cutoff Distribution

* 52: Tolerancing Parameter Run ettings for Random Mode		
Seed Seed Manually		
Distribution Type Normal Distribution via Standard Deviation Variance The Parameter Range Corresponds to2 σ.	Cutoff Distribution]
Preview of Distribution	🔀 62: Histogram	
Preview Number of Intervals 71	Numerical Data Array (Equidistant) Numerical Data Array (Equidistant)	
Parameter Range Color Dpacity 50.196 %	Diagram Table Value at x-Coordinate Diagram Table Value at x-Coordinate	
< Back	suide area () suide	1.2 1.4

Normal Distribution via Process Capability

52: Tolerancing Parameter Run	
ttings for Random Mode	
Seed	
Set Seed Manually	
Distribution Type Normal Distribution via Process Capability 💛 🕑 Cutoff Distribution	
Mean	
Relative Position in Interval 50 %	
Variance	
Calculated from Parameter Range and Process Capability Index C _s \checkmark 2	
$C_p = rac{\xi_{ ext{max}} - \xi_{ ext{min}}}{6\sigma}$	
Preview of Distribution	
Preview Number of Intervals 71	
Parameter Range Color Opacity 50.196 %	
< Back	Next > Show •

An asymmetrical normal distribution can be defined by *Process Capability*. Here the user can specify the mean μ and the *Process Capability* Indices to calculate the standard deviation.



Normal Distribution – Relative Position in Interval

The P D Talana in December Date		
Settings for Random Mode		
Seed Seed Set Seed Manually Distribution Type Normal Distribution via Process Capability V Cutoff Distribution Mean Relative Position in Interval 50%	Mean Relative Position in Interval 30 %	Mean Relative Position in Interval 70 %
Variance Calculated from Parameter Range and Process Capability Index C. 2	5: Histogram	A: Histogram
	Diagram Table Value at x-Coordinate	Diagram Table Value at x-Coordinate
Contrary to the symmetric case, in the asymmetric case the mean can be determined by the user.	Numper ot par otherwise par	Number of Data Points 0 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
	Relative Position in Parameter Intervals	Relative Position in Parameter Intervals
	Relative Position in Parameter intervals	Relative Position in Parameter Intervals

Normal Distribution – Process Capability index

10 * 52: Tolerancing Parameter Run				
Settings for Random Mode				
Seed				
Distribution Type Normal Distribution via Process Capability 🧹 🥑 Cutoff Distribution				
Mean Relative Position in Interval 50 %	🔀 5: Histogram		🔀 6: Histogram	
Variance	Numerical Data Array (Equidistant) Diagram Table Value at x-Coordinate		Numerical Data Arr Diagram Table Value at x-Coordinate	ray (Equidistant)
$C_p = rac{\xi_{ m max} - \xi_{ m min}}{6\sigma}$	8		8	
Preview of Distribution Preview Number of Intervals Parameter Range Color Opacity 50.196 % < Back	150 2 150 2 150 2 150 2		150 2	
Process Capability knows to different ndices C_n and C_{nx} to define the			Z - Z	
tandard deviation. In case of the ormer the standard deviation is		1 1.2	-0.2 0 0.2 0.4 Relative Decition	0.6 0.8 1 1.2
hile in the latter it is depended.	C_p			

Analysis of the Result

To e.g. find the minimum efficiency of a specific grating which has been tilted between $-2^{\circ}/2^{\circ}$:



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software version	2024.1 (Build 1.132)
category	Feature Use Case
further reading	