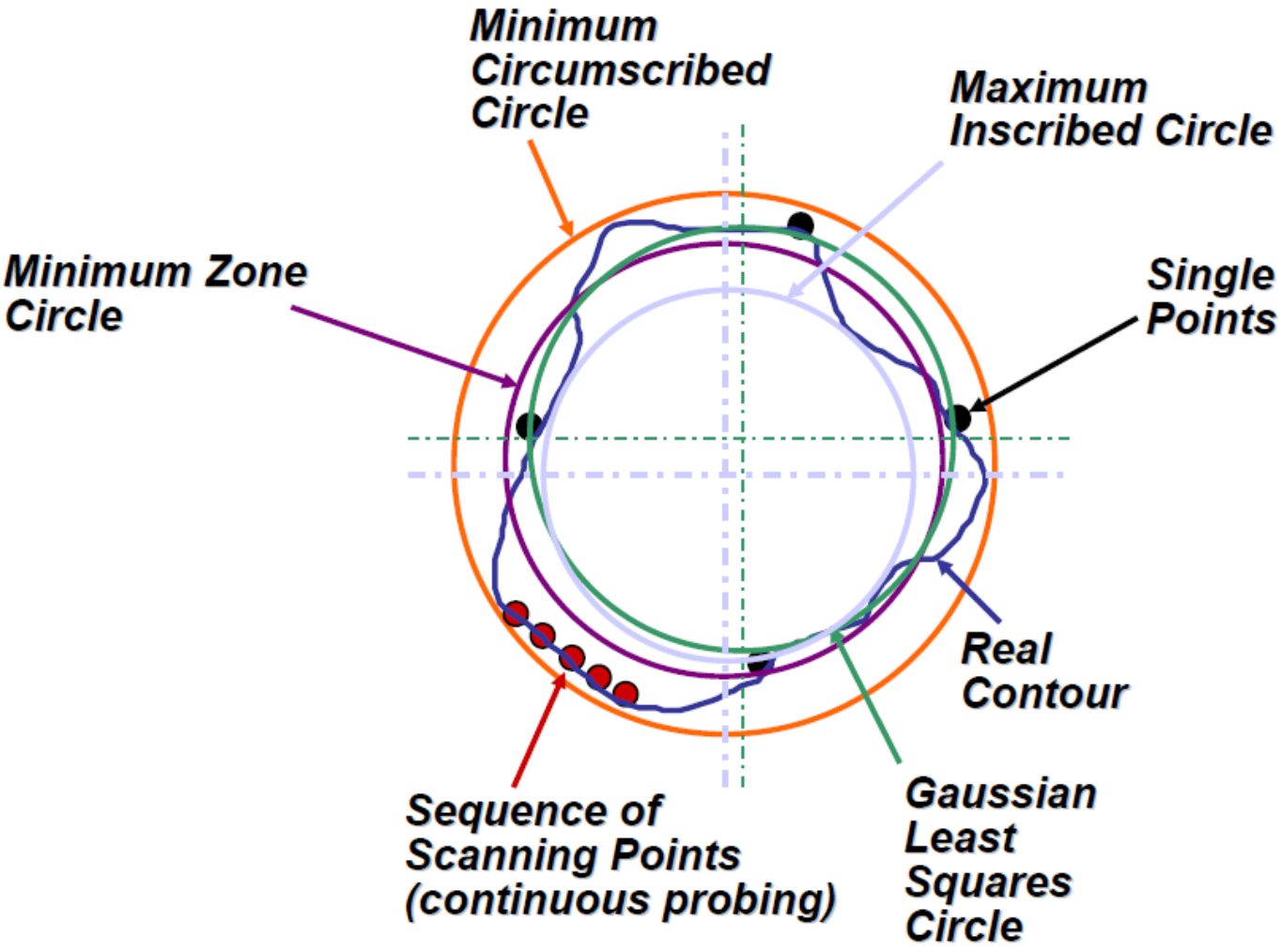
Zeiss Calypso Advanced – Filters and Outliers

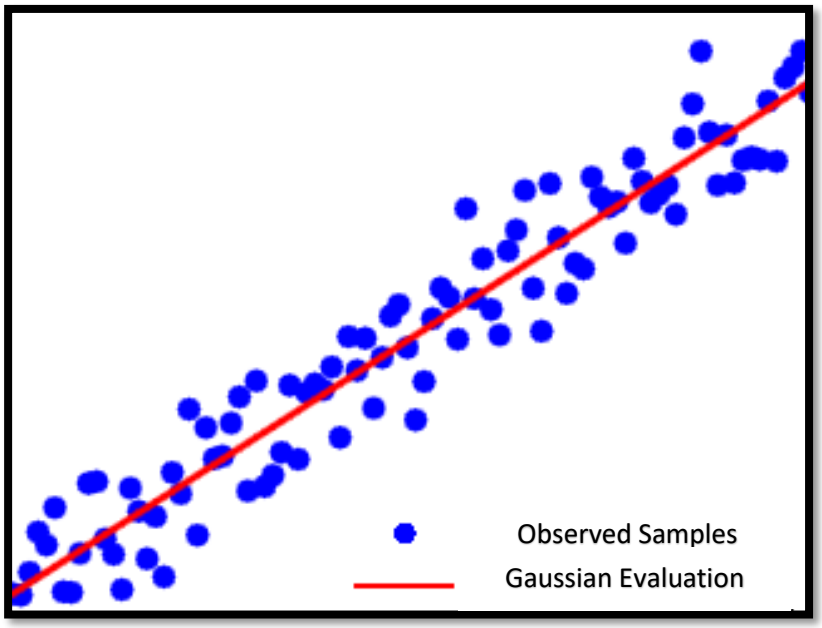


By: Joseph Giacona

Basic Evaluation Types:

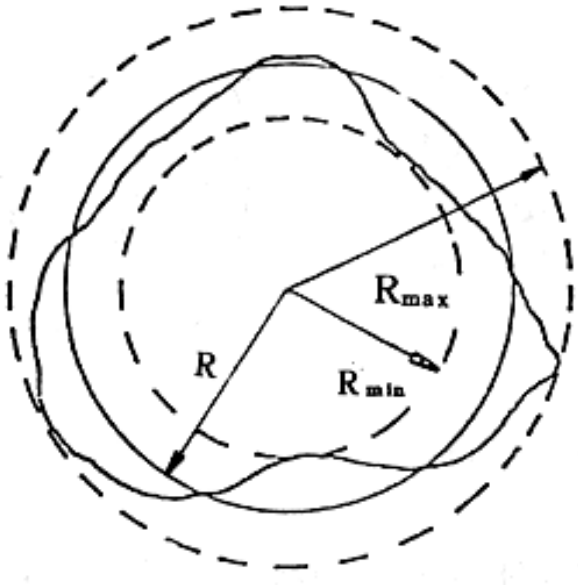
Gaussian (Least Squares): This is Calypso's default evaluation method for all features.

- This uses an average of the data to establish a stable feature.
  - All data points have the same weight.
- Result is very stable, meant for the process control environment.
- This is **not** a **functional** way for checking parts.

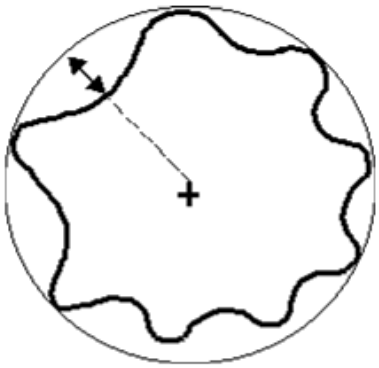


Chebyshev (Minimum Zone): This is Calypso's default evaluation method for common GD&T callouts such as roundness, profile, flatness, and form.

- This finds the maximum and minimum radius while keeping the circles on the same centers and constructs a circle between the zone.
- Typically used for form callouts.
- Not as repeatable as LSQ due to how it fits around the extreme points of the actual feature.

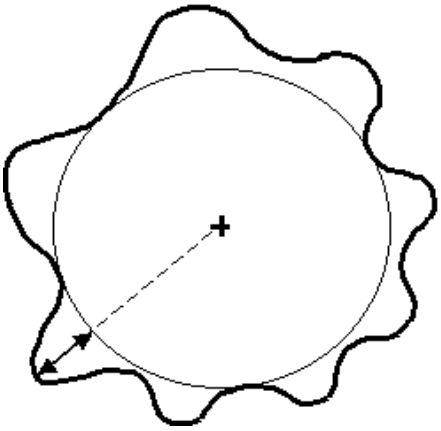


Minimum Circumscribed Feature: This evaluation provides the smallest ring gage diameter.



- This evaluation is gives the correct functional size and location for external diameters.
- It is not as stable as Least Squares due to the circle fitting on external extreme points.
- This is absolutely a **functional** check.

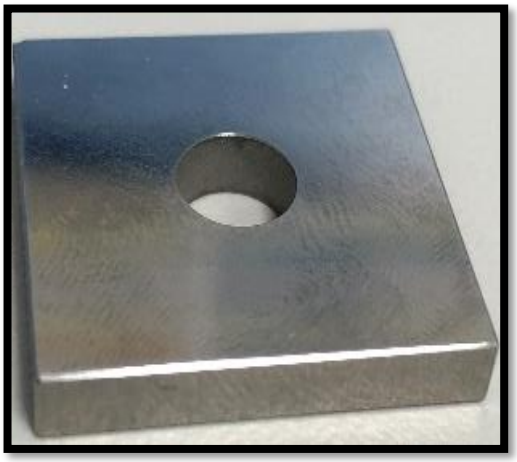
Maximum Inscribed Feature: This evaluation provides the largest gage pin diameter.



- This evaluation is gives the correct functional size and location for internal diameters.
- It is not as stable as Least Squares due to the circle fitting on internal extreme points.
- This is absolutely a **functional** check.

Using these evaluation tools together can help decipher whether the part will functionally work or not.

Let's measure each of these mating parts to check which one will fit.



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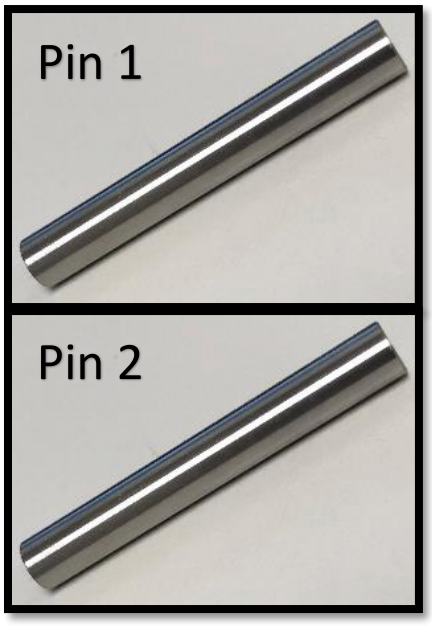
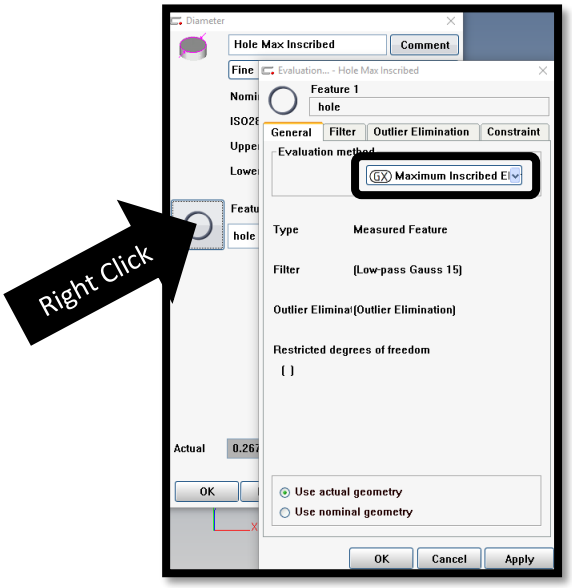
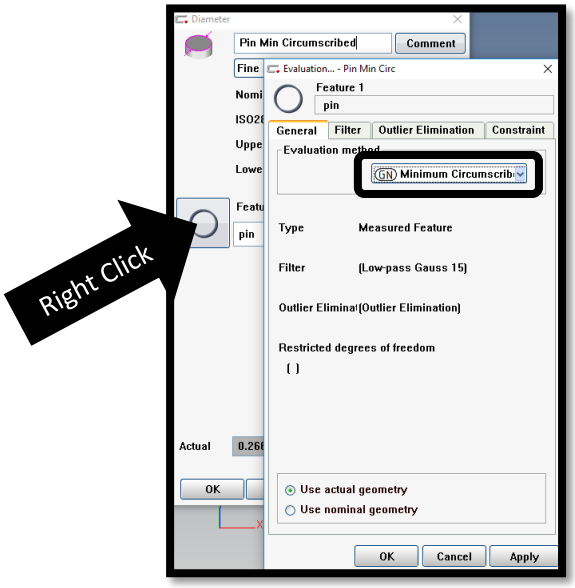


In Calypso we will go through the beginning necessary steps to begin each of our programs. Following the Zeiss cookbook as a strategy guide (Z100D-F, Z200D-F), we will measure each ID and OD to find the functional diameter.

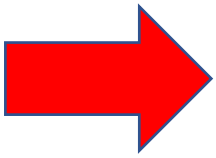
Then most importantly we will modify each **Evaluation Method** from LSQ (Default) to Minimum Circumscribed (Pin) and Maximum Inscribed (Hole).

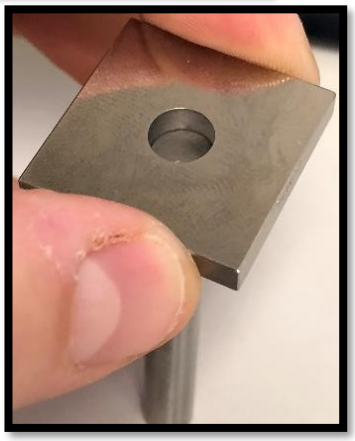




Hole Max Inscribed
0.2679

Pin 1 Min Circumscribed
0.2679

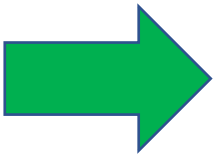


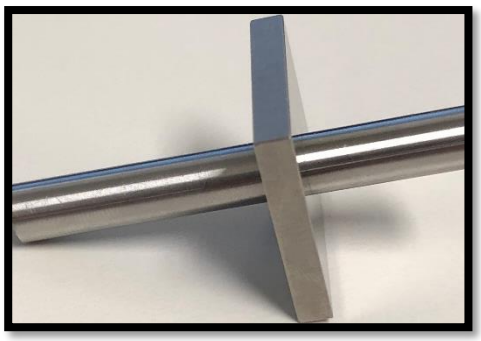


Close, but No Cigar!

Hole Max Inscribed
0.2679

Pin 2 Min Circumscribed
0.2669



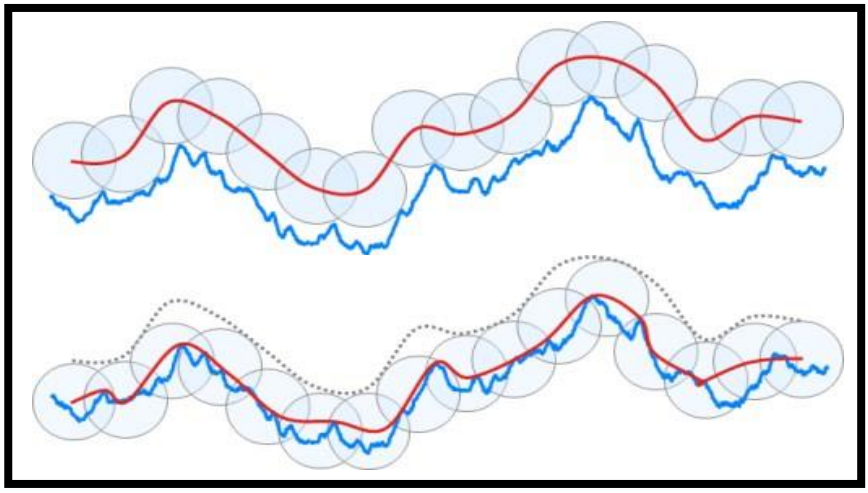


That's The Ticket!

Filtering:

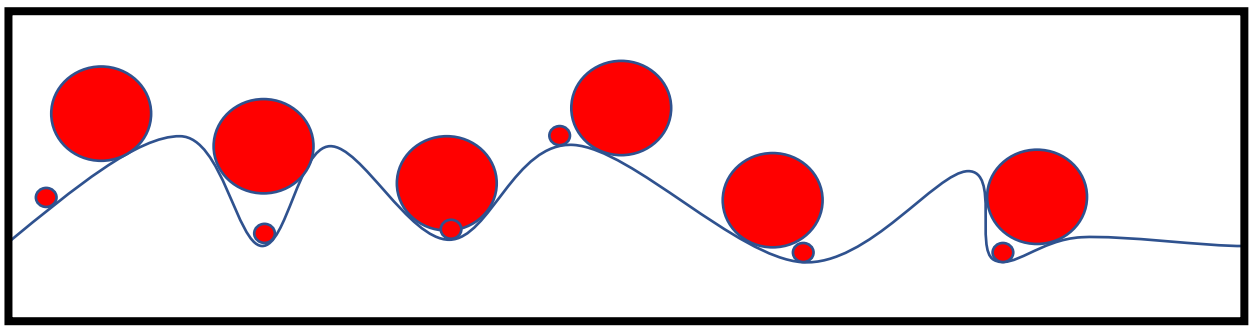
Morphological filters, this is also known as mechanical or natural filtering. This comes into play when you are choosing your stylus more specifically the stylus ball diameter.

In the pictures below, you see first hand how the stylus will not be able to acquire all the data in the nooks of the blue surface. This results in a "smoother" measurement scan.

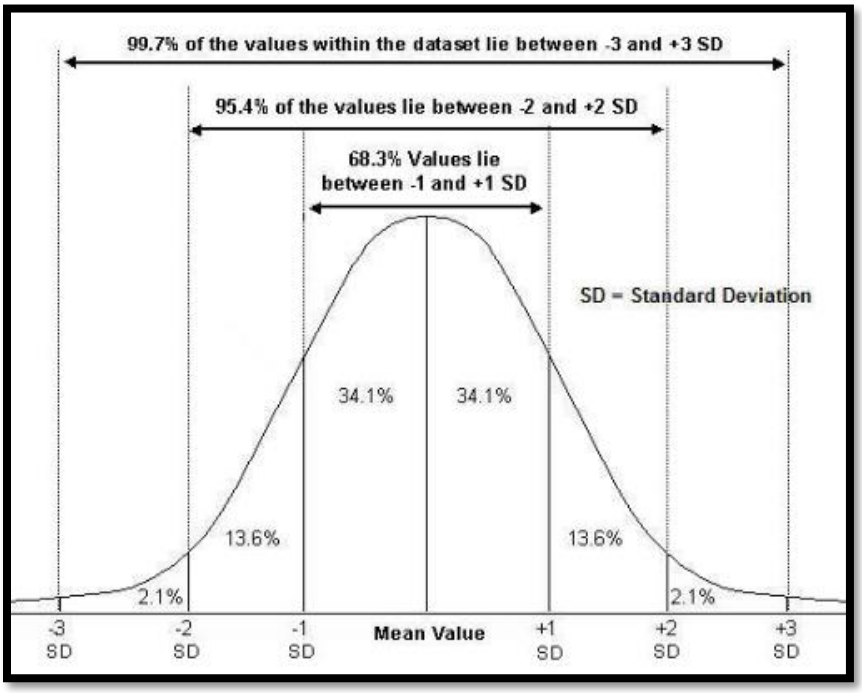


It just goes to show you how important it is to choose the right tool for the job. You will notice that in the Zeiss cookbook, each strategy has a recommended stylus tip diameter that depends on the measured feature size. The recommendation is usually a maximum stylus tip diameter you should not exceed.

A stylus tip diameter must be selected, which enables the capture of the expected wave height of the expected waviness. The stylus tip naturally filters some surface finish out.



Normal distribution: When talking about filtering it is important to keep in mind the idea of normal distribution. Normal distribution is how many measured points are located within dispersion width areas.



The normal distribution is a bell curve created around the average of the set of data, sectioned off by the sigma value or standard deviation. Standard deviation is a quantity calculated to indicate the extent of deviation for a data set as a whole. (Percentage)

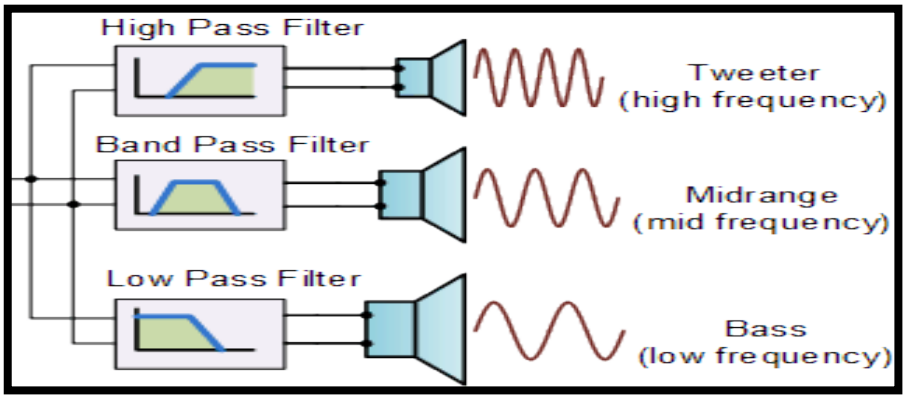
- **±1S** is equal to **68.27%** of the entire data set.
- **±2S** is equal to **95.45%** of the entire data set.
- **±3S** is equal to **99.73%** of the entire data set.
- Anything past 3 Sigma is considered the last 0.27% of the data set.
    - This is the data we tend to try to remove.

Let's take a closer look at what filtering is, and what it does.

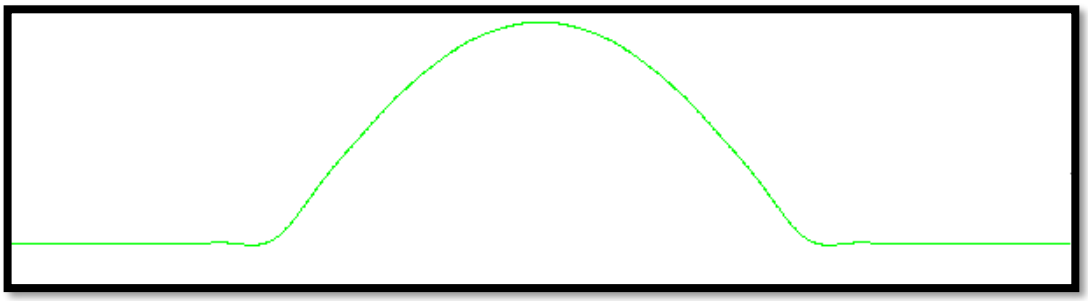
Filtering generally will separate the form errors from the surface roughness. The form error is the only information we need for typical measuring tasks. Roughness is typically measured with a profilometer and not a CMM (Zeiss ROTOS excluded). Keeping this data can falsify the results from the extraneous noise from the measurement.

Three Filter Types:

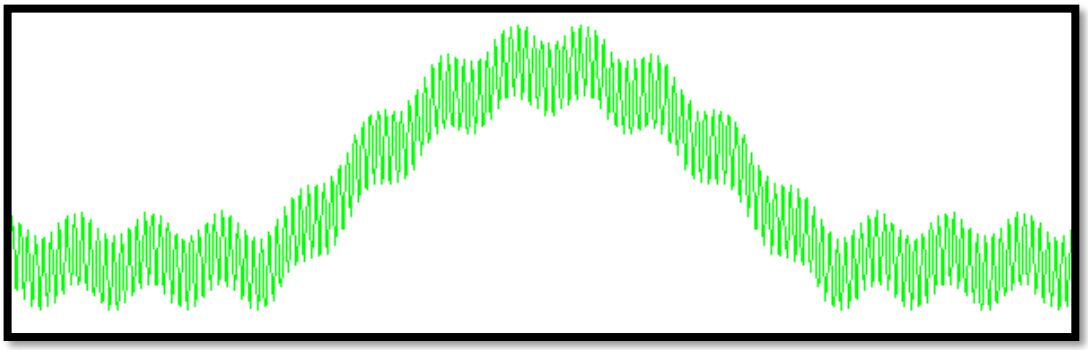
These filters can be compared to an acoustic speaker.



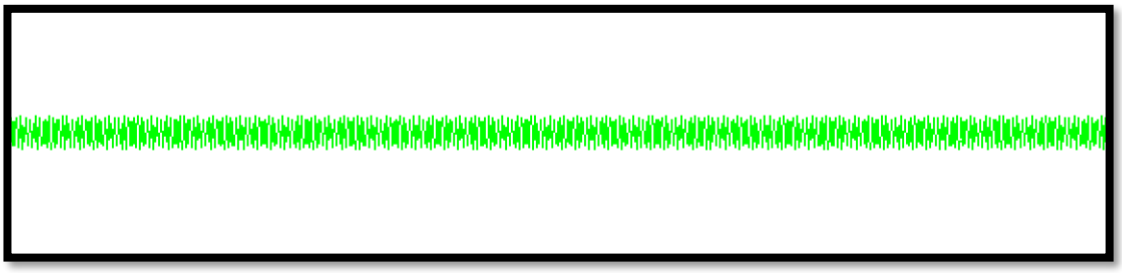
- **Low Pass:** This filter allows low frequency data to pass through and ignores the roughness and waviness data found in higher frequencies. This shows the true form of the workpiece.



- **Band Pass:** This filter allows a certain band of high or low frequency parts to pass. This filter is used to determine or examine waviness on a workpiece with some form.



- **High Pass:** This filter allows only the high frequency parts of the surface to pass. This is used to determine roughness of the workpiece with no form.



When measuring with a CMM it is important to use the **Low Pass filter**. This rule is especially important when you are using other evaluation methods other than Gaussian, such as minimum circumscribed or max inscribed. Remember that these evaluations ride on the extreme points of the data set.

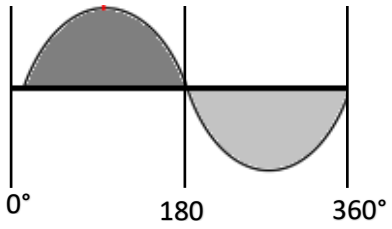
Three Filter Methods:

- **2 RC-Filter:** This filter is no longer used. This was used primarily for roughness and roundness measurements but has been replaced with modern filter calculations.
- **Spline:** This filter method is based on enhanced filter equations (Polynomial Calculations). This filter is standardized, and has benefits over the Gaussian filter, but has not been accepted into the standard as of May 2018.
- **Gauss:** This is the standard filter method in coordinate measuring. This filter is based with the Gaussian bell curve to weight the measured points.
    - **This method is used for all filter methods in calypso, per the Zeiss Calypso Cookbook.**
    - The main drawback of this filter happens in open ended data sets.

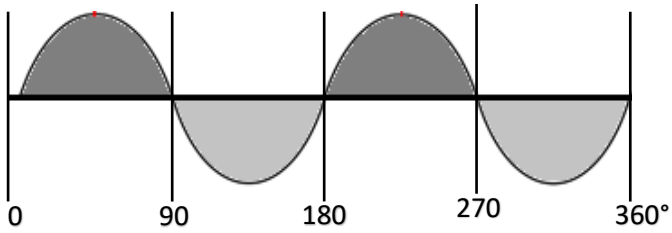
Depending on the feature type you will either be using Undulation Per Revolutions(UPR) for circular features, or Wavelength Lc for linear features.

- These can be described as harmonic vibration.
- The cutoffs of these harmonic frequencies can be calculated by size of feature in question.
- The vibrations can tell us certain things about our feature in question.

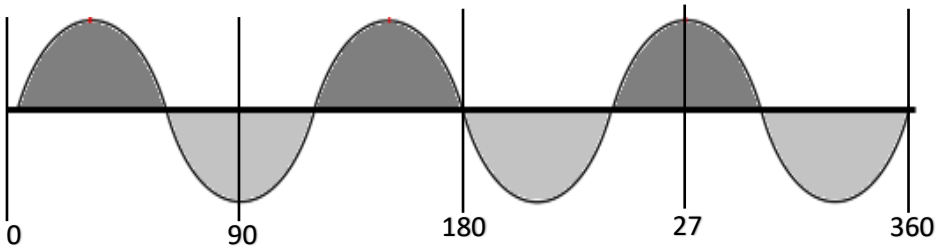
- A single harmonic vibration can show us that the circle is eccentric or off center.



- Two harmonic vibration shows us the circle has an elliptical or oval form.

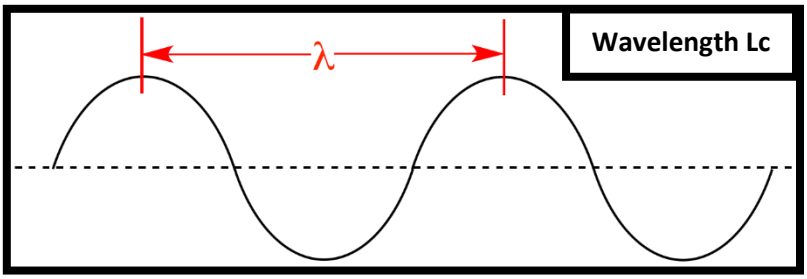


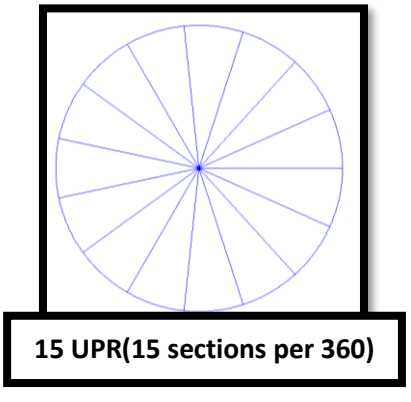
- Three harmonic vibration shows us the circle has a tri-lobed shape, that is caused by a three-jaw chuck.



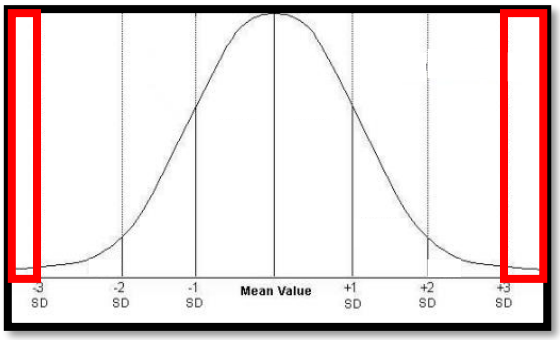
For the filter to work properly there must be a minimum of 7 points per wavelength or undulation.

- **linear features:** Minimum Number of points = (length x 7 points per wave)/ Cutoff Wavelength.
  - Length of 100mm and a cutoff of 2.5 Lc needs a minimum of 250 points. (100 x 7 /2.5)
- **Circular features:** Minimum Number of points = Number of Undulations Per Revolution x 7.
  - Ø8mm with 15UPR needs a minimum of 105 points. (15 x 7)





Outlier Elimination: Outlier elimination when enabled is used to remove data points that are based on the normal distribution (Bell Curve). The Calypso Cookbook uses the standard ±3 standard deviation. So, anything outside of the ±3 is in considered an outlier. Remember that 0.27% was past the 3 standard deviations. That is the data that usually gets kicked out. Not a lot when you think that we are keeping 99.73% of our data.



We also like to eliminate the **5 adjacent points** around the 0.27%. The reason for this is to eliminate any possibility for bad points to go through to our measurement. This is also a Calypso Cookbook Standard.

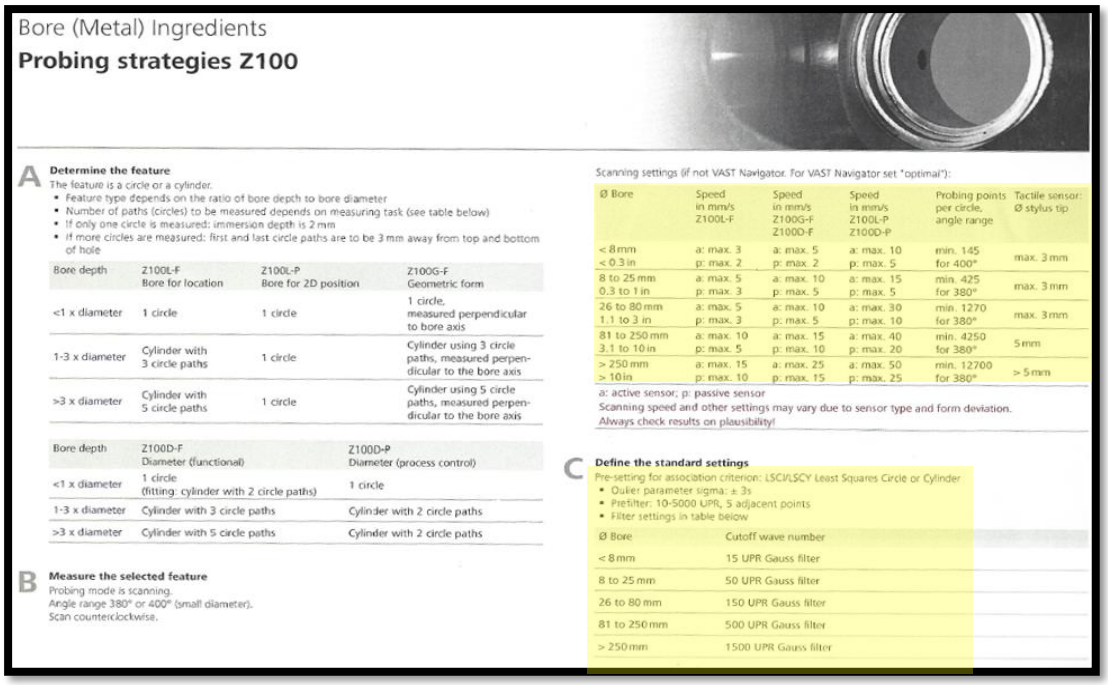
For example, if we have a 100-point scan, and 1 point was out of the ±3 standard deviations; Calypso would eliminate that point and the 5 points on either side of it. 11 points total will be eliminated.

Pre-Filter: Outlier elimination works ideally for straight or round measurements. When there are extreme form deviations such as oval shaped holes or when tri-lobing is occurring, this becomes more challenging. We use pre-filter, so the outlier elimination doesn't remove too much data from our out of round part.

The Calypso Cookbook defaults all circular features to 10 to 5000 UPR. The defaults for all linear features are 0 to 10mm Wavelength LC.

Thankfully we don't have to remember everything, all these outlier and filter settings are in our handy Zeiss Calypso Cookbook.

For each probing strategy in our cookbook all the settings we need are in the two charts highlighted below.



Bore (Metal) Ingredients

Probing strategies Z100

A Determine the feature

The feature is a circle or a cylinder.

- Feature type depends on the ratio of bore depth to bore diameter
- Number of paths (circles) to be measured depends on measuring task (see table below)
- If only one circle is measured: immersion depth is 2 mm
- If more circles are measured: first and last circle paths are to be 3 mm away from top and bottom of hole

Bore depth	Z100L-F Bore for location	Z100L-P Bore for 2D position	Z100G-F Geometric form
<1 x diameter	1 circle	1 circle	1 circle, measured perpendicular to bore axis
1-3 x diameter	Cylinder with 3 circle paths	1 circle	Cylinder using 3 circle paths, measured perpendicular to the bore axis
>3 x diameter	Cylinder with 5 circle paths	1 circle	Cylinder using 5 circle paths, measured perpendicular to the bore axis

Bore depth	Z100D-F Diameter (functional)	Z100D-P Diameter (process control)
<1 x diameter	1 circle (fitting: cylinder with 2 circle paths)	1 circle
1-3 x diameter	Cylinder with 3 circle paths	Cylinder with 2 circle paths
>3 x diameter	Cylinder with 5 circle paths	Cylinder with 2 circle paths

B Measure the selected feature

Probing mode is scanning.
Angle range 380° or 400° (small diameter).
Scan counterclockwise.

Scanning settings (if not VAST Navigator. For VAST Navigator set "optimal"):

Ø Bore	Speed in mm/s Z100L-F	Speed in mm/s Z100G-F Z100D-F	Speed in mm/s Z100L-P Z100D-P	Probing points per circle, angle range	Tactile sensor: Ø stylus tip
< 8 mm < 0.3 in	a: max. 3 p: max. 2	a: max. 5 p: max. 2	a: max. 10 p: max. 5	min. 145 for 400°	max. 3 mm
8 to 25 mm 0.3 to 1 in	a: max. 5 p: max. 3	a: max. 10 p: max. 5	a: max. 15 p: max. 5	min. 425 for 380°	max. 3 mm
26 to 80 mm 1.1 to 3 in	a: max. 5 p: max. 3	a: max. 10 p: max. 5	a: max. 30 p: max. 10	min. 1270 for 380°	max. 3 mm
81 to 250 mm 3.1 to 10 in	a: max. 10 p: max. 5	a: max. 15 p: max. 10	a: max. 40 p: max. 20	min. 4250 for 380°	5 mm
> 250 mm > 10 in	a: max. 15 p: max. 10	a: max. 25 p: max. 15	a: max. 50 p: max. 25	min. 12700 for 380°	> 5 mm

a: active sensor; p: passive sensor
Scanning speed and other settings may vary due to sensor type and form deviation.
Always check results on plausibility!

C Define the standard settings

Pre-setting for association criterion: LSCI/LSCY Least Squares Circle or Cylinder

- Outer parameter sigma: ± 3s
- Prefilter: 10-5000 UPR, 5 adjacent points
- Filter settings in table below

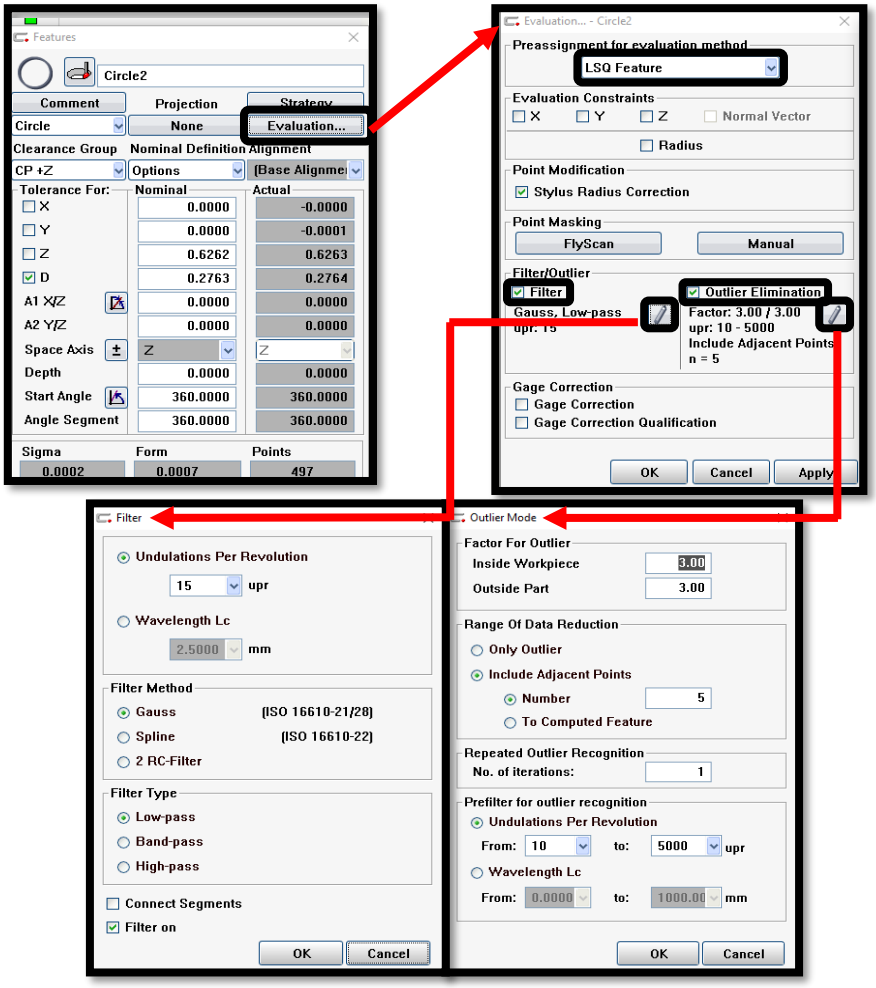
Ø Bore	Cutoff wave number
< 8 mm	15 UPR Gauss filter
8 to 25 mm	50 UPR Gauss filter
26 to 80 mm	150 UPR Gauss filter
81 to 250 mm	500 UPR Gauss filter
> 250 mm	1500 UPR Gauss filter

In addition, all these setting can also be turned on with the **Save / Load Defaults / Filter Outlier Tab** that I mentioned yesterday. The only downside to this is that it only applies to the characteristic side only. So, all our features may not be filtered.

I personally do not apply filtering and outlier elimination on the characteristic side, but instead apply it to the feature side.

- I find it easier to apply filters and outliers through the feature side as I am programming, the transfer format tool makes light work of that.
- The only evaluation methods I change on the characteristic side are maximum inscribed and minimum circumscribed ect.
- **All constructions are on the feature side and are constructed using features.**
    - **If all my features do not have filters or outlier enabled, this means that my constructions are not filtered.**

Modifying Filters & Outlier Elimination through the Feature Tab.



Modifying Filters & Outlier Elimination through the Characteristic Tab.