QCSPCChart SPC Control Chart Mobile App (Free Version)

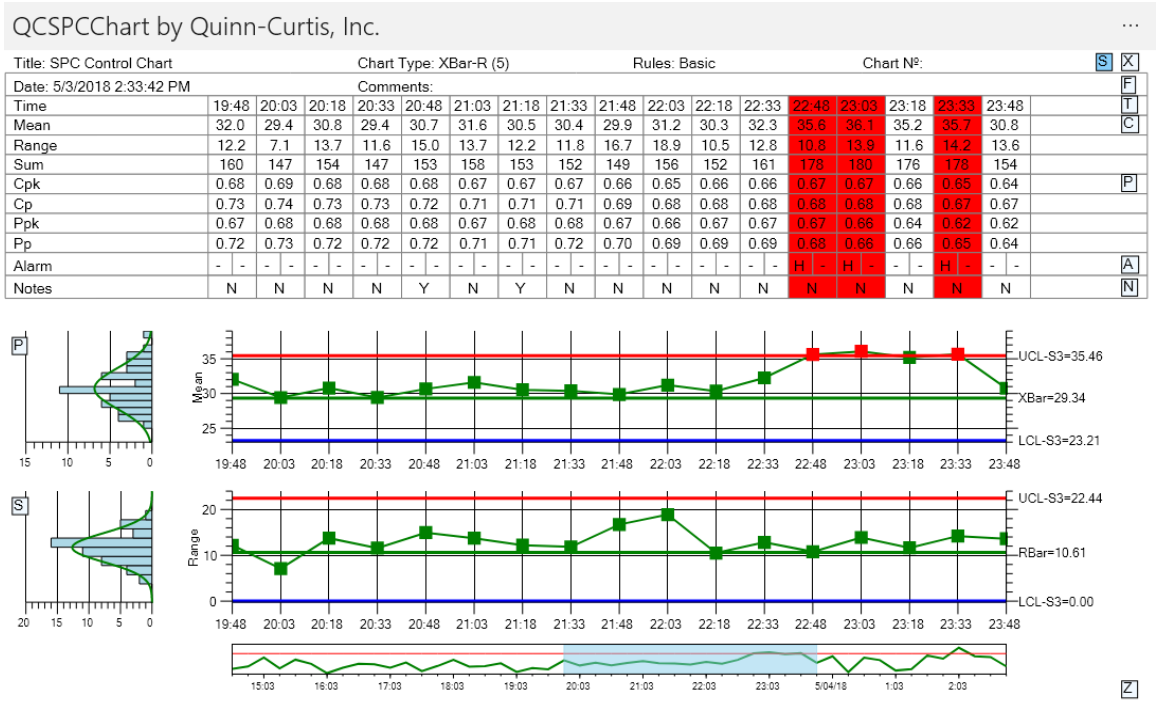

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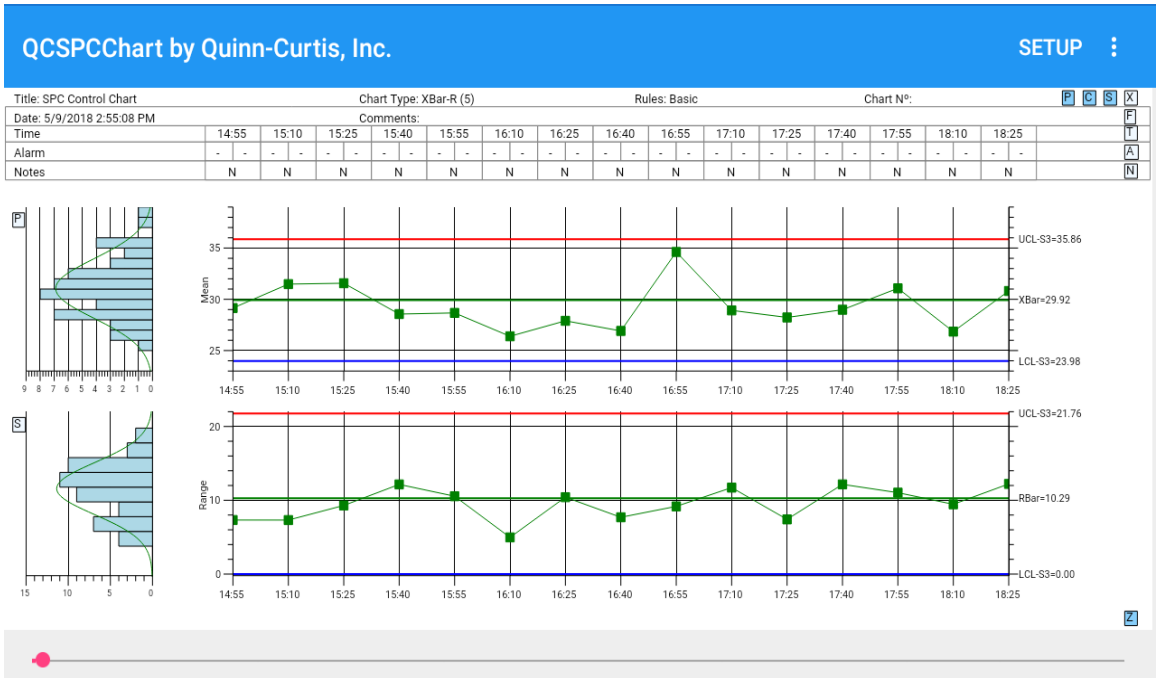
Table of Contents

1. Introduction

Getting Started

Thank you for installing the free version of our Statistical Quality Control software package, QCSPCChart. When you first start the software, you will see a chart which looks like this.



The Xbar-R chart (also known as a Mean-Range chart) is the most common of the SPC Chart types.

The image, captured from an Android mobile device, represents the most popular of all SPC control charts. It is known as an Xbar-R chart, along with other names including a Mean-Range chart, Shewhart chart, and 6-sigma chart. The chart is pre-populated with simulated data, making it look like an Xbar-R chart which is in progress, monitoring a manufacturing operation and comparing critical process values to control limits. Should the process exceed the control limits, an alarm is flagged so that the operator can see that something may be wrong in the process, and investigate and/or correct if needed. If you want to learn more about different types of control charts and where they might apply, read the later chapters of this manual. Other, more advanced features supported in the

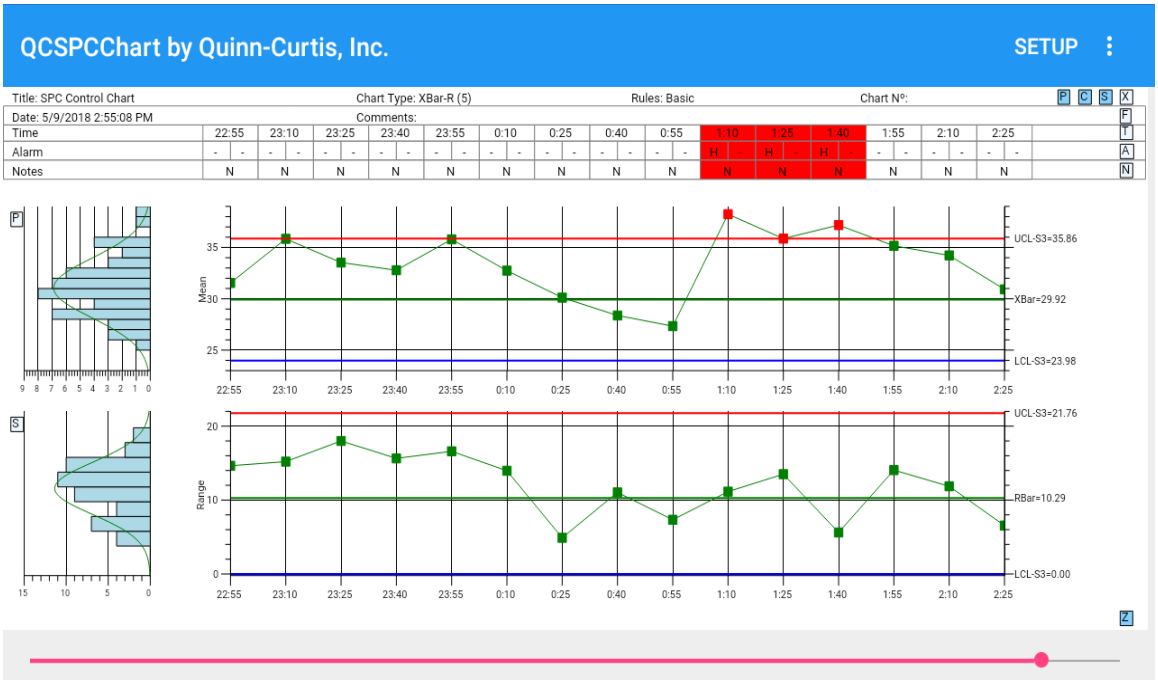
software, such as performance indices (Ppk, Cpk), and named control rule sets are also covered.

Since you have downloaded this app, it is assumed you already know something about Quality Control, and charts like the Xbar-R chart. You may be working for a company, or you may be in school or a seminar, studying Quality Control methods and techniques. SPC control charts represent an important aspect of Quality Control. But, the specifics of an SPC Chart are going to be as varied as there are industries which use it. And the raw data used in the chart is going to vary from 10-16 to 10 10^16. This opening section of the manual is to familiarize you with the UI aspects of this software, so that you can customize the look of the charts to match SPC charts you are studying in school, or using at your company.

The default screen (which you will learn how to change in order to load in your own data automatically) monitors a fictional manufacturing process which monitors the thickness of a widget. When the process is in control, the widget has a thickness of 30.5, and the standard deviation of the thickness is 2. The actual units of measurement (mm, inches, microns) are unimportant for purposes of this example. When Xbar-R control limit calculations are run on the current data, it shows that a +3-sigma high limit should be placed on 36, and a -3-sigma low limit should be placed at 24.5. In a basic Xbar-R chart, this means that as long as the measured thickness of the widget falls between 24.5 and 36, the process is considered in control and no corrective action needs to be taken.

Several of the SPC control charts (Xbar-R, Xbar-Sigma, Median-Range, Individual-Range to name the most common), use two synchronized charts, one above the other, to display different attributes of the sampled measurement data. The top (Primary) chart will display something akin to a mean (or median) value for the measured data within a sample interval, and the bottom (Secondary) chart will plot a measurement of the variance (a range or sigma value) of the data within the sample interval. Either one can trigger an alarm condition.

Scrolling the chart view



Scroll the charts, and the table above, using the scroll bar at the bottom of the display.

The initial chart shows the first 15 sample intervals of the data. As you can see, for these first samples, the chart is in control because the measured variable does not exceed the control limits. But charts will usually contain may more sample intervals, typically hundreds, and in some cases, millions. So you need to be able to view scroll the data forward and backward in time. There are two ways to do this. First you can use the default Slider found at the bottom of the chart. It can be slid to the right, all the way to the end, causing the chart to update with new data. That way you can see if at any point the measured variable exceeds the control limit.

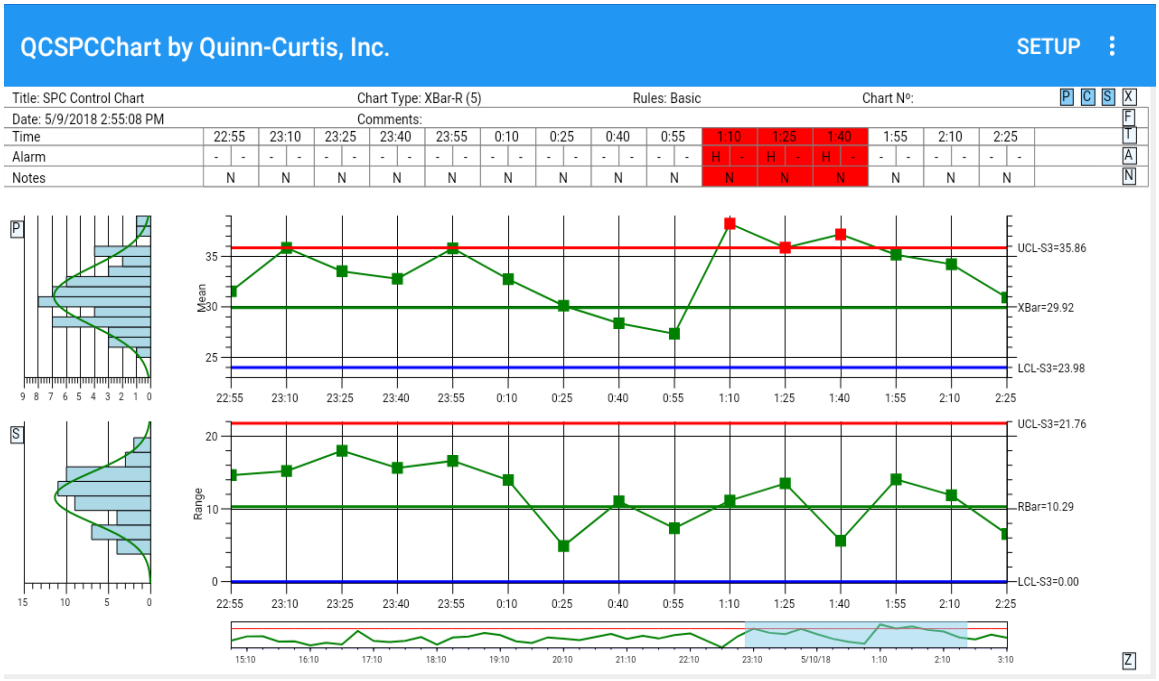
Zoom controlled

The chart is initially limited to showing 15 sample intervals at a time. This limitation is mostly to keep the columns of the table data above the chart from overlapping. If you have a display which is significantly narrower, or wider than what we use for the default, you can change this value using the Setup | Chart Type option.

If you have hundreds, or even thousands of sample intervals, you may not want to look at only 15 at a time. It is possible to squeeze many more data points on the screen so that you have a much wider view of the data. You do this using the Zoom control. The Zoom control is enabled using the [Z] button in the lower right hand corner of the display, just above the right-top of the slider. If you select that button, the slider will displaced by a

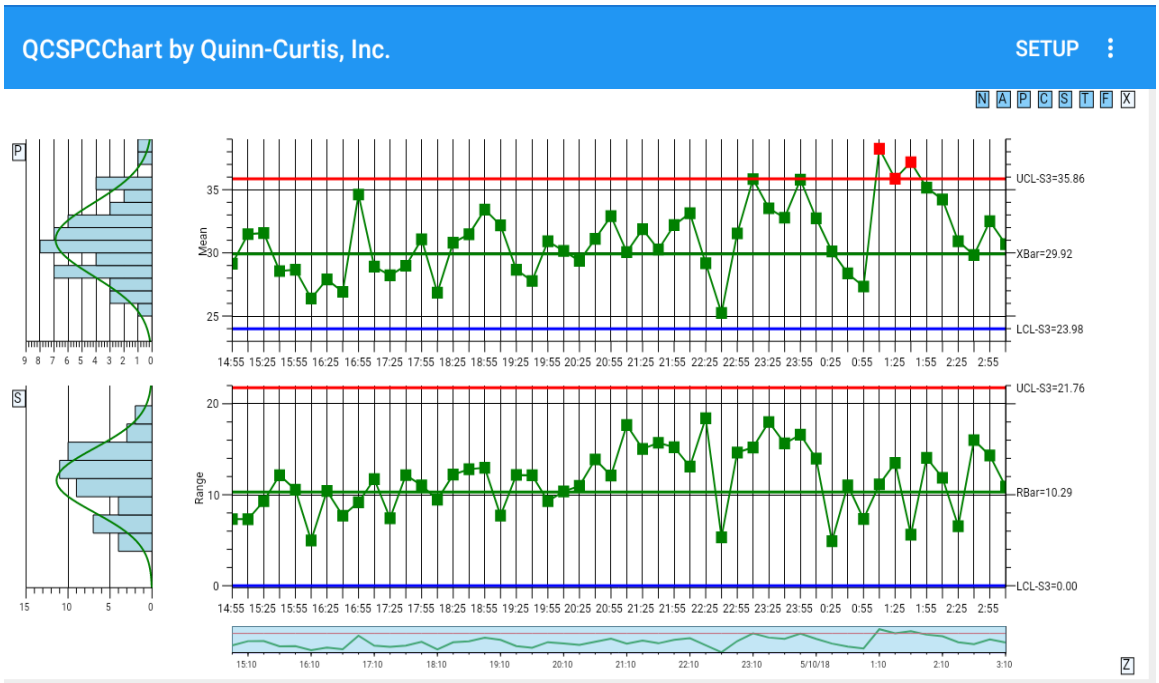
zoom control. The Zoom control is a short chart which shows an miniaturized version of the entire dataset loaded into the app. The transparent blue section (zoom box) represents the current view of the data represented by the large Primary an Secondary charts above.

[Zoom Control]



The user can change the time scale (the number of data points) of the x-axis using the zoom control, using either the mouse, or by touch.

You can use the Zoom control much like the slider. If you press on the center of the zoom box, you can slide it left and right, moving the current view of the data forward and backward in time. But, you can also use it to expand the view area, You can select the left or right edge of the zoom box and drag the edge left or right, expanding or contracting the size of the zoom box. You can expand the zoom box so that all of the data is plotted in the Primary and Secondary charts above. When the zoom box is expanded to where it contains more sample intervals than the initial default value for the width of the zoom box, the table above the charts is turned off, so that the columns to do not overlap.

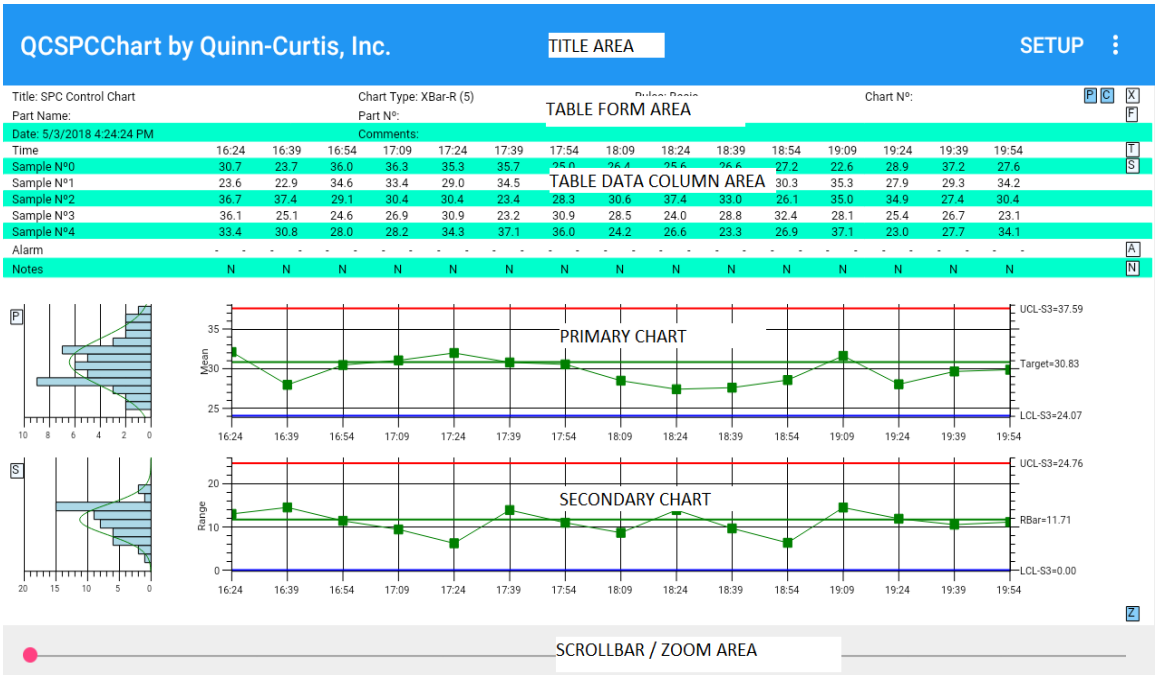


A wide view of the data makes it easier to spot trends.

Alternative UI method for defining the zoom box - Sometimes the combination of small devices and large fingers make selecting the edge of the zoom box difficult, resulting in erratic results when trying to adjust the zoom box width. In that case, just press in the zoom graph area near the top, at the x-position you want to start at, and drag your finger (or mouse) down and to the right, ending at the x-position you want to end at. The zoom box will jump to those starting and ending x-coordinates and update the Primary and Secondary charts accordingly. Don't start the press and drag operation inside or near the edge of the current zoom box, because then you will select and drag the box instead of defining a completely new zoom box.

Press the Zoom button [Z] while in the zoom mode and you will return to slider control, with the data table, displaying the same number of points you had when you entered the Zoom mode.

SPC Chart Areas



The display area is broken down into six different areas: Title, Table form, Table data, Primary chart, Secondary chart and the Scrollbar/zoom area.

There are several different areas of an SPC Chart. There is the Title and Menu area at the top, which is small but unchanging. Then there is the Table Form area, which displays descriptive information and notes you can enter concerning the current SPC chart as a whole. Followed by the Table data column area, which displays data specific to each sample interval of the current chart. Each sample interval is represented as a column in the table. Each row in the data column area represents a specific piece of information about the sample interval you might want to know. The individual samples values can be found there, and also calculated summary information used in the chart, such as the sample interval mean, range, sigma and sum. Following that are other rows for Cpk and Ppk values, alarm status, and notes for individual sample intervals.

Under that is the chart area, that normally contains one or two charts (and associated histogram plots to the left), where the measured variable is plotted as a line-marker plot, and control limit lines are plotted as horizontal lines across the width of the chart. Some SPC chart types use two charts (Primary and Secondary) and others use just one. If two charts displayed, then the top most one is the Primary chart, and the one underneath is the Secondary chart. If one chart is displayed, then it is the Primary chart.

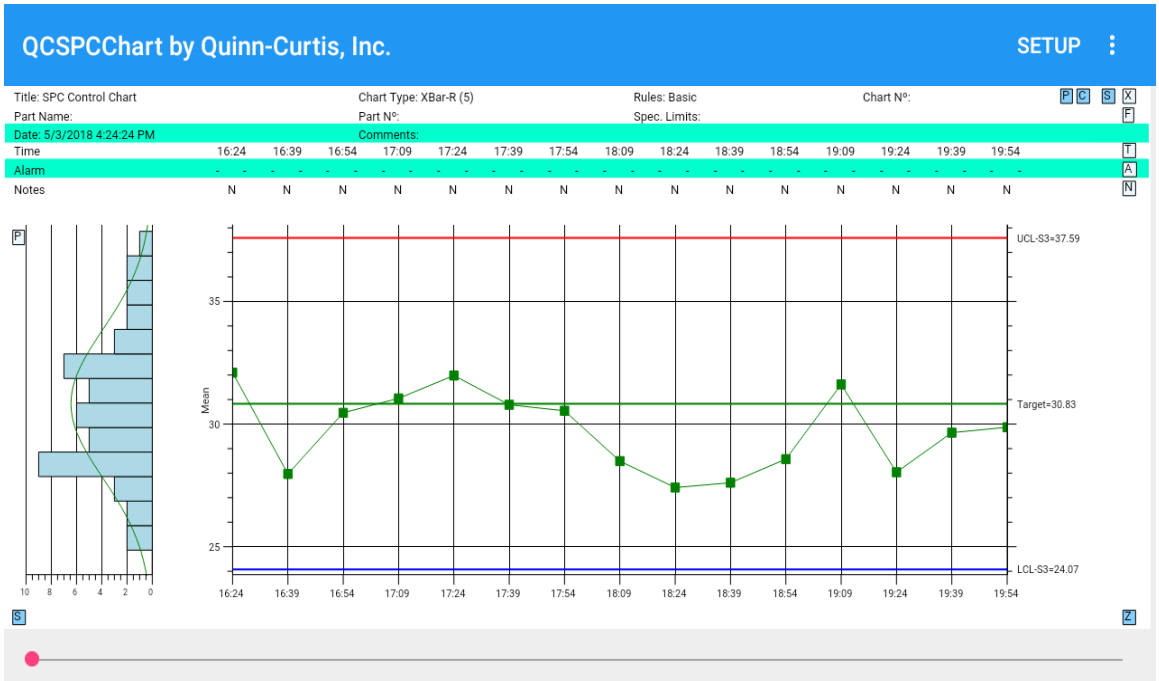
At the very bottom you have either the scrollbar, or zoom control.

There is much information to show in an SPC chart, in the limited are of a mobile device display. How much room is devoted to each SPC chart area (Table Form data, Table Row

data, Primary chart, Secondary chart, is a trade off on what data you need to see at any particular time. In order to maximize the utility, the different SPC chart areas can be collapsed using small buttons on the left and right sides of the display, to so that the other SPC chart areas can use the saved space.

Collapsible Charts and Table Rows

The small, single letter, buttons on the left and right side of the display toggle on and off the SPC chart display areas. The button letters are meant to be simple mnemonics for the SPC chart area they are meant to control. The English version of these buttons are seen in the picture below. If any of the buttons are pressed, they toggle on and off the SPC chart area they are associated with. For example, if you press the [S] button on the left of the Secondary chart, you will turn off the secondary chart area. The primary chart will then grow in height to fill in the space where the secondary chart was. You can do the same with the primary chart. If you press the [P] button to the left of the Primary chart, you wlll remove it from the display, and the secondary chart will fill the space where the primary chart was. If a chart area is turned off, the [P] and [S] chart buttons relocate to the bottom left of the display, above the slider or zoom control. If you press them again, the charts will reappear in their original location.



The buttons on the left and right edges of the chart make it easy to collapse parts of the display, making it easy to customize the display.

The buttons to the right of the Table area rows will collapse the associated Table row area, freeing up the space to be used by other table rows, or by the charts below. There

are several row areas which can be toggle on or off, and the letter assigned to them is a meant as a rough mnemonic for the category the row belongs to.

Button	Table Areas
[F]	Table Form Areas
	Table Row Data Areas
[T]	Time row
[S]	Samples row
[C]	Calculated value row (mean, range, sigma, sum)
[P]	Process Measurement Indices (Cpk, Ppk, Cp, Pp)
[A]	Alarms
[N]	Notes
	Chart Area
[P]	Primary chart
[S]	Secondary chart
[Z]	Zoom

There is also an [X] button, on in the upper right under the Title area. It should not be confused with the traditional Close button, which is not normally found in mobile applications. Instead it toggles on and off All of the Form Table and Row Data areas at once. So if you want to have the charts occupy the entire display, press the [X] button. Depending on what intermediate state the Row options are in, you may have to press it twice to toggle all of the Table data on or off.

These mnemonic letters changes from culture to culture as the terms they are meant to invoke change. Below is a table of the letters we use for the different cultures, and the term we were trying to create a mnemonic for.

Espaniol

Button	Table Areas
[F]	Table Form (Formar) Areas
	Table Row Data Areas
[T]	Time (Tiempos)
[M]	Samples (Muestra)
[C]	Calculated (Calculado) value
[P]	Process (Proceso) Indices
[A]	Alarms (Alarmes)
[N]	Notes (Notas)
	Chart Area
[P]	Primary (Primario) chart

Portuguese

Button	Table Areas
[F]	Table Form (Formato) Areas
	Table Row Data Areas
[T]	Time (Tempo)
[A]	Samples (Amostras)
[C]	Calculated (Calculado) value
[P]	Process (Processo) Indices
[A]	Alarms (Alarmes)
[N]	Notes (Notas)
	Chart Area
[P]	Primary (Primär) chart

[S]	Secondary (Secundario) chart
[Z]	Zoom

[S]	Secondary (Secundário) chart
[Z]	Zoom

French

Button	**Table Areas**
[F]	Table Form (Forme) Areas
	Table Row Data Areas
[T]	Time (Temps)
[E]	Samples (Échantillons)
[C]	Calculated (Calculé) value
[P]	Process (Processus) Indices
[A]	Alarms (Alarmes)
[N]	Notes (Noter)
	Chart Area
[P]	Primary (Primaire) chart
[S]	Secondary (Secondaire) chart
[Z]	Zoom

Duetch

Button	**Table Areas**
[F]	Table Form (Forumular) Areas
[Z]	Time (Zeit)
[P]	Samples (Proben))
[B]	Calculated (Berechnet) value
[V]	Process (Verfahren) Indices
[A]	Alarms (Alarm)
[N]	Notes (Notiz)
	Chart Area
[P]	Primary (Primär) chart
[S]	Secondary (Sekundär) chart
	[Z] Zoom

Italian

Button	**Table Areas**
[M]	Table (Modulo) Form Areas
	Table Row Data Areas
[T]	Time (Tempo)
[E]	Samples (Esempio)
[C]	Calculated (Caclcolato) value
[P]	Process (Processo) Performance Indices
[A]	Alarms (Allarmi)
[N]	Notes (Nota)
	Chart Area
[P]	Primary (Primario) chart
[S]	Secondary (Secondario) chart
[Z]	Zoom

In addition to the buttons, there are a several UI features found in the Chart and Table areas. A simple popup tooltip displays if you press on a data point in one of the charts. There you can get the current time, and sample values associated with a sample interval. It is most useful if you have collapsed the Table part of the display, otherwise it is just a repeat of the data found there. If you press on an item in the Notes row marked with “Y”, you will see a popup of a note that was entered for that sample interval. And if you press on an item in the Alarm row, when that item is marked as being in alarm, a summary of what SPC chart violation caused the alarm is displayed in a popup window.

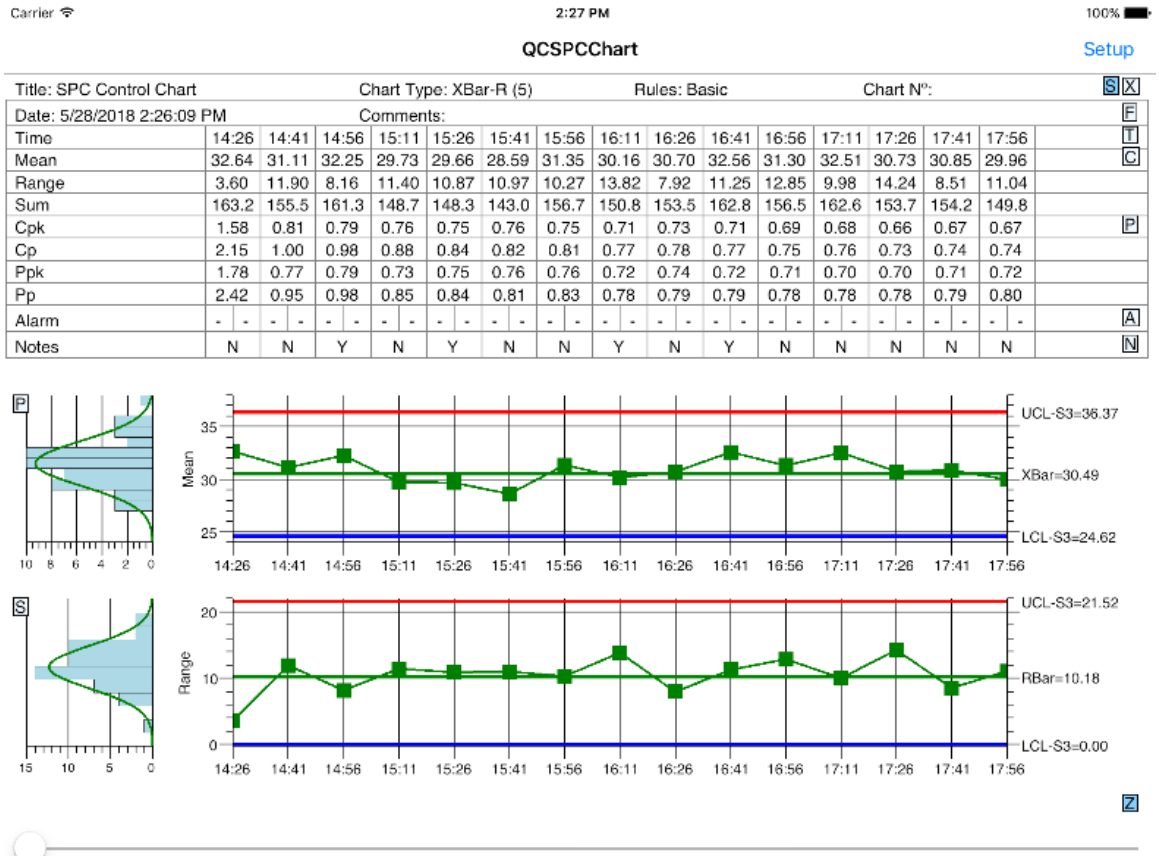
Setup Menu Options

Further customization of the SPC Chart, including input of your own data, is done using the Setup menu options. The Setup menu displays differently, depending on which platform you are using (IOS, Android or Microsoft UWP (Universal Windows Platform). These platforms are normally associated with the following devices

IOS	Exclusively products from Apple (iPads and iPhones)
Android	A wide range of manufacturers make Anroid compatible devices, including Google, Samsung, HTC and many others. This includes phones, tablets and Chromebooks.
UWP	The Microsoft UWP is mostly for systems running Windows 10 or later, including Windows desktop machines and Microsoft Surface tablet/laptop hybrids. This software is not compatible with in systems prior to Windows 10.

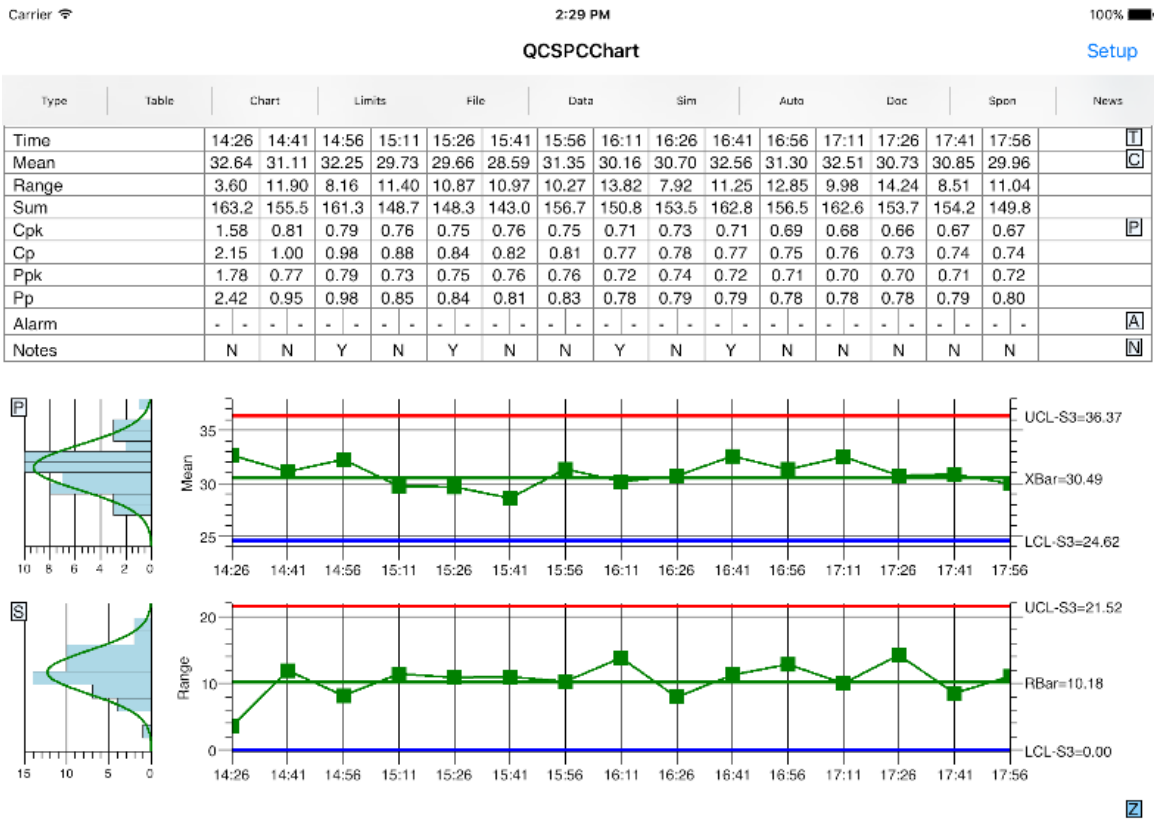
Setup menus running on the different platforms.

IOS



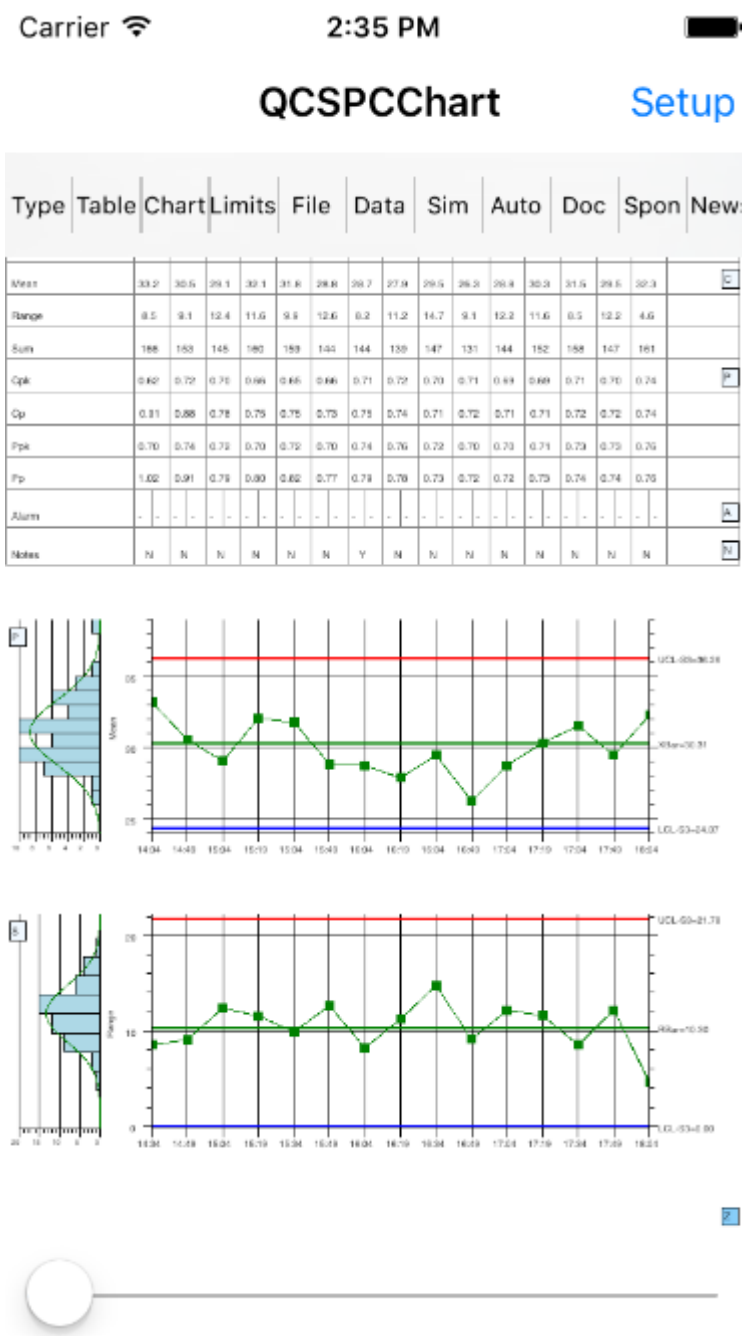
Under IOS, the Setup menu item is displayed in the upper right corner of the display.

The Setup menu is invoke by selecting the Setup item on the top right of the screen. That will display the menu items on the line immediately below.



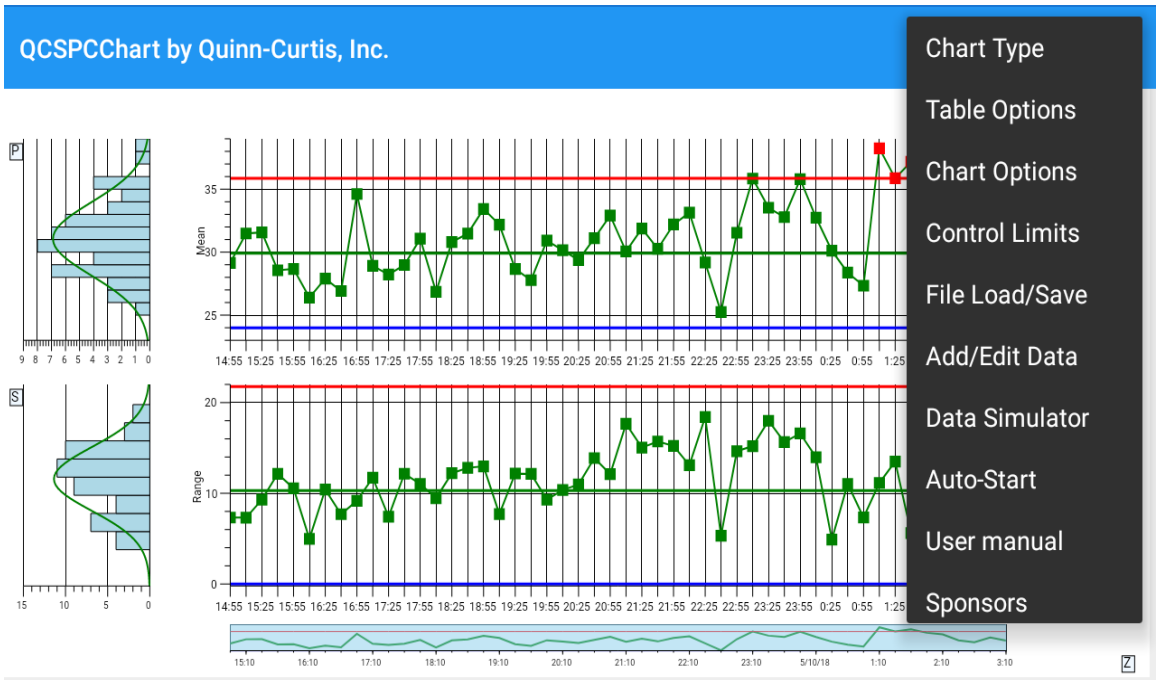
If you select the Setup menu item, a list of sub-menu items are displayed across the top, directly underneath.

Note that under IOS the Setup Menu items run across the top of the display, directly under the Title area. Toggle the Meun items off by selecting the Setup Item again. If you use a narrow IOS device (iPhone 6 for example), in portrait mode, the Menu items will be abbreviated to just a few characters so that all of the menu items still fit on the screen.



When using the software under IOS, on a phone in portrait mode, the software will abbreviate the menu items to make them all fit in the limited amount of space available.

Android



Under Android, when you select Setup, the menu items are displayed along the right hand edge of the display.

Click on the Setup […] icon in the upper right corner of the screen, in the Title area, to display the Setup Menu items.

UWP

Under Windows (UWP), when you select Setup, the menu items are displayed along the right hand edge of the display

Click on the […] icon in the upper right corner of the screen, in the Title area, to display the Setup Menu items.

There are ten setup options you can select from the Setup menu. These are;

Chart Type	Specify the SPC chart type, and sample size for your application. You can also change the automatically selected culture your device uses when displaying chart text.
Table Options	The text used in the Table form (topmost) part of the table may not match your application, so you can customize the table captions and text here.
Chart Options	You can adjust the x-axis labels to use Timestamps, or batch number values. You can turn on/off the frequency histogram charts to the left of the Primary and Secondary SPC charts. And you can adjust how the SPC A, B and C control zones are displayed (lines, or filled).

Control Limits	Here you can specify how you want the SPC control limits calculated. You can choose to have the software calculate the control limits, depending on the SPC chart type, number of samples, and the raw data, or you can manually specify your own control limit values. You can use chose to use the standard ±3 Sigma SPC control chart rules, or yu can select a more advanced ruleset. You can also specify Specification Limits for your SPC chart. These values must be supplied by you.
File Load/Save	You can save or load an entire setup, including the raw data if you want, to your devices local or external storage. You can also choose to export or import your sample data using a CSV (Comma Separated Value) format. And you can save an image capture of your current SPC Chart so that you can include it in a report, or print it. The software does not support printing of the SPC charts directly from device to the printer at this time.
Add/Edit Datapoints	Here is where you can start a new set of data for your chart, entering it sample interval by sample interval. You can scroll back and forth through the data in order to edit it. You can edit, insert or delete sample records at any point, and also clear the data to any empty state.
Data Simulator	For teaching purposes, it is not necessary to spend all that time entering in data values, one at a time. The Data Simulator will generate multiple sample records using just a mean and standard deviation value. This way you can generate the data for a 100 sample interval chart in just one button press.
Auto-Start	Once you get started with the software, you will not want to go through replacing our default chart with your own, each time you start the app. Once you create a chart setup with data values, you can save that to be the chart which is loaded whenever the application is invoked.
User Manual	Invokes the browser on your device and display this, the User Manual for the software.
Sponsors	This is a short list of advertisers we are using to sponsor the product. This may or may not be enabled for your installation.

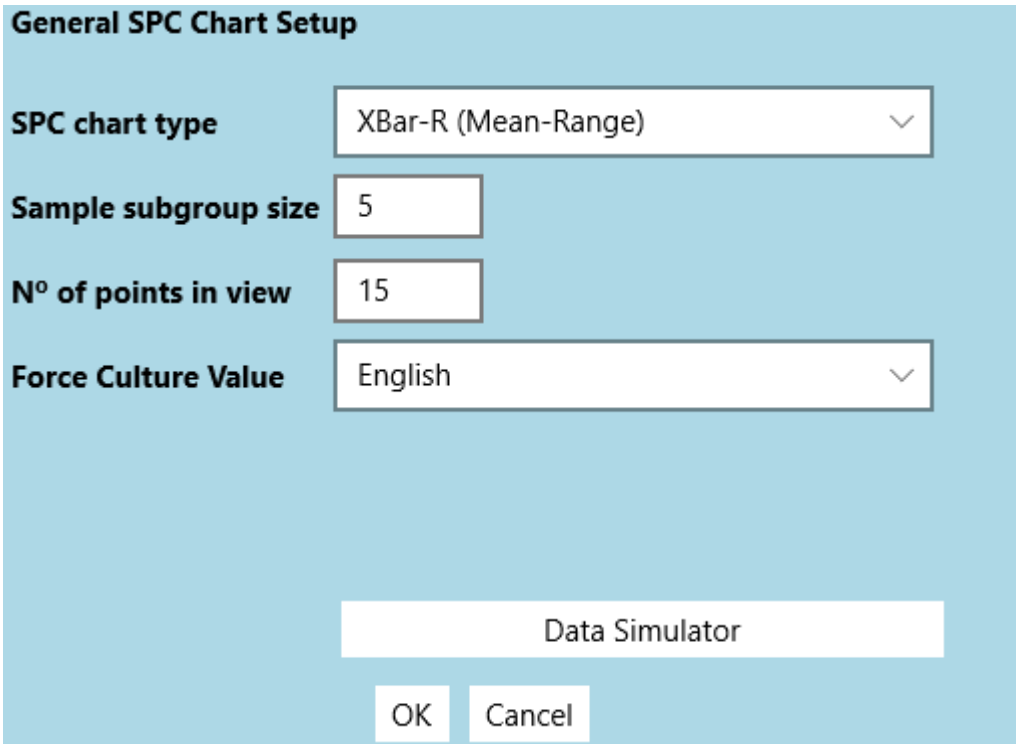
News/About	This is a list of press releases associated with the product. It also includes a Suggestions box you can use to relay us your feedback. This may or may not be enabled for your installation.

The last two, Sponsors and News/About may or may not be enabled for your installation. But they contain nothing you need for the setup of an SPC chart.

In the next section we will go into more details about the Setup options.

Setup Options

Chart Type



The Chart Type form specifies some basic chart information: the SPC chart type, the sample subgroup size, the number of sample intervals displayed on the display at once, and the culture value.

SPC chart type [Xbar-R (Mean-Range)]

If you don't change anything, the default SPC chart type is the Xbar-R chart, also known as the Mean-Range chart. Since that is the most common of the SPC chart types you may very well want that type. But there are many other SPC chart types you can access from the from SPC Chart Type drop down list.

Variable Control chart types

Xbar-R (Mean-Range)
Xbar-Sigma (Mean-Sigma)
I-R (Individual-Range, X-R)
Median-Range

Attribute Control chart types

p-chart (Percentage Defective)
p-chart (Fraction Defective)
np-chart (Number Defective)
c-chart (Number Defects)
u-chart (Number Defects)
DPMO-chart (Number Defects/Million)

Further discussion of each of these chart types is found in Chapter 2.

Sample subgroup size [5]

The chart types have certain constraints regarding sample size. You cannot create an SPC chart with a sample size it is not compatible with. For example, the Variable Control chart types (Xbar-R, Xbar-Sigma and Median-Range) require a minimum of two samples per sample interval (sample subgroup size), and preferably at least three. There is no real maximum, but for real-world applications a logical sample size of 5-20 is usually the maximum. The I-R chart must use a sample subgroup size of 1.

The Attribute Control charts total defects for a product within the sample interval, so the sample size rules are different. In this case, in order to maintain the SPC assumption that defects follow the normal approximation of the binomial distribution, you want the number of defects you are counting to be on the order of 5 per sample interval. If you average 2% of your samples with defects, you should plan on a sample size of at least 250 samples per sample interval, i.e. 250 * 0.02 produces a defect rate of 5 defects per sample interval. So in that case, you would enter 250 as the number of samples per subinterval (the default for Attribute control charts is 100). You can violate these guidelines if circumstances place constraints on your choice of a sample size. But you should be well versed in SPC in order to do that.

If you have data already loaded into the app, it already has an implicit sample subgroup size built in it. Our default XBar-R control chart sample dataset uses a default sample subgroup size of 5. This means you cannot chose an I-R chart type to use with that data, because that chart type requires a sample subgroup size of 1. If you insist on applying the I-R chart to the data, the software will truncate the sample subgroup size of the working dataset to 1. Only the first sample per subgoup will be saved. Also, if you select one of the Variable control charts with a 2 sample subgroup size minimum (Xbar-R, Xbar-Sigma and Median-Range), but the current dataset has a sample subgroup size of 1, the software will automatically convert the SPC chart type to I-R, because that is the only Variable control chart type which matches the data.

If you are changing between the I-R chart type, and the other Variable chart types, you should reset the data to empty using the Data Simulator button, then Clear Data at the top of that dialog. If you don't want to return to an empty chart, you can fill up the chart with simulated data from the Data Simulator dialog.

Nº of points in view [15]

Most SPC software displays a limited number of subintervals at a time. Otherwise the data points in the chart will start to overlap. And the data columns in the table of the chart will start to overlap long before that. The value to use in this field depends on the display width of your device. We have tested this software for a wide range of devices, both portrait and landscape mode, and feel that a value of 15 is a good trade off between readability and data density. But if you are using a phone where the display is very narrow, you can decrease this value to 10 or even 5, to prevent the columns from overlapping. If you are working with a large, wide, tablet or desktop, you can increase the value to 20 or 25 in order to view more data points in a screens worth of data. You use the slider and/or the Zoom option to scroll backwards and forward through the entire dataset, regardless of what you set this value to.

No matter where you set this value, you can use the Zoom option to override it temporarily in order to look at a large number of data points. In that case the table will close down, in order to prevent the columns from overlapping. If you toggle off the Zoom option, the charts and table will revert back to the number of samples specified in this field.

Force Culture Value [Default]

Your device has a default culture associated with it. When this software starts up for the first time on your device, it will use the default culture value to initialize the text used throughout the app. As of this writing, we have included text for (English, Spanish, Portuguese, French, German, and Itlaian). You can override the default culture value using this field. You will need to close the app and restart it in order for the new culture setting to go into effect, and load all of the culture specific text. This only affects our app, it will not affect the culture value used by any other app. If you have an issue with any of the translated text we use in the app, please send us a note, either by email (qcspcchart_mobile@quinn-curtis.com) or in the suggestion box found in the News/About option.

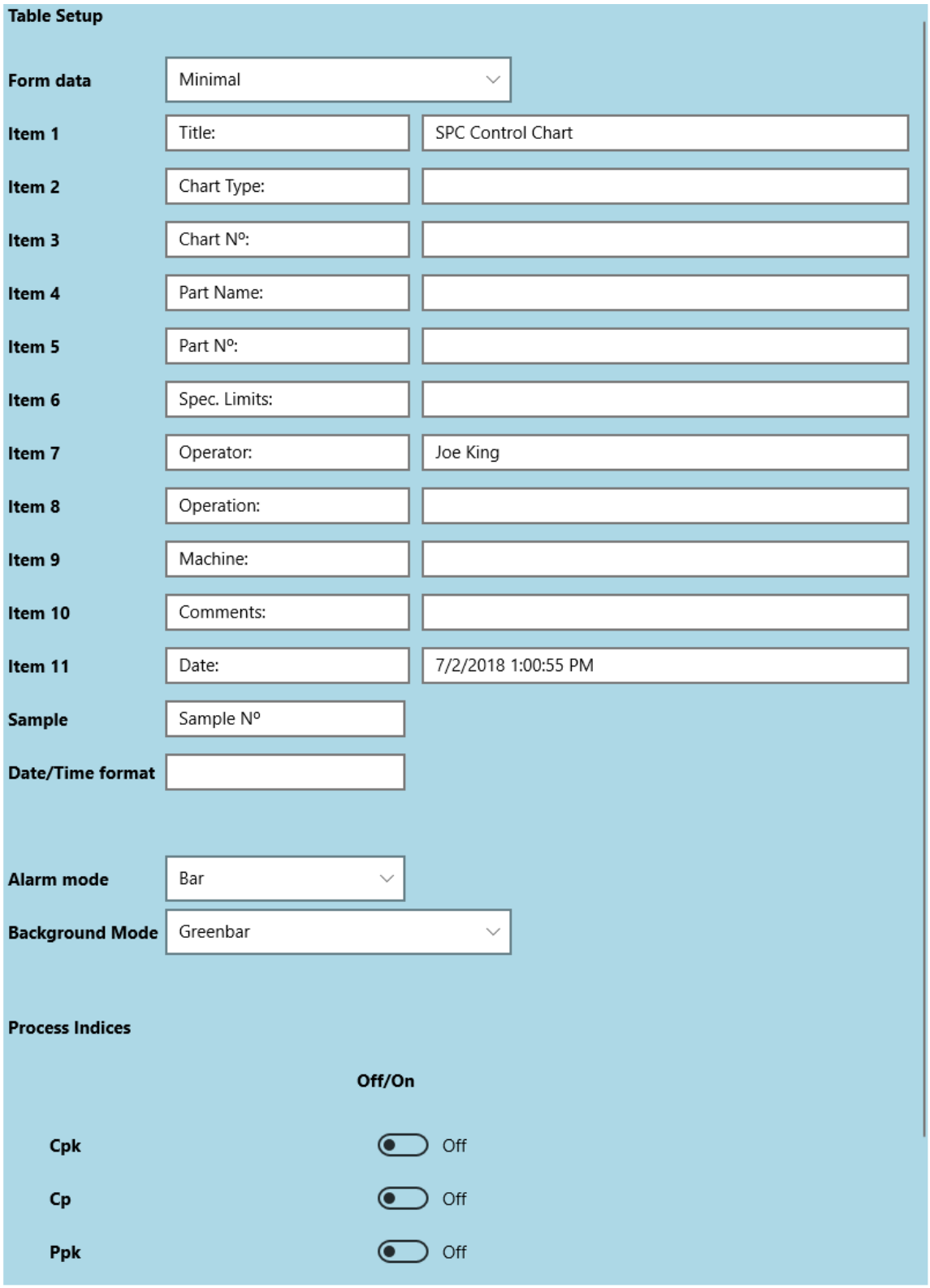
Changes to this setup page will only go into affect if you press the OK button at the bottom.

[Data Simulator] Button

This will take you to the Data simulator screen, where you can simulate sample data for your chosen chart type. You can specify the mean and sigma of the distribution the sample data is selected from.

Table Setup Options

The text used in the Form area (topmost) part of the table may not match your application, so you can customize the table captions using these options.



The Table setup form specifies the text (strings) used for the Table form captions and data. It also specifies which Process indices you want displayed in the Table data area.

Form data **[Minimal]**

There can be up to four lines of information about the chart at the top of the display. Use this list box to pick how many lines are displayed.

None	No lines of form data are displayed
Minimal	Two lines of form data are displayed separated into the following default items: Title, Chart Type, Rules, Chart No., Date and Comments.
Medium	Three lines of form data are displayed separated into the follow default items: (all of the items listed under Minimal), plus the items Part Name, Part No., and Spec Limits.
Maximum	Four lines of form data are displayed separated into the follow default items (all of the items listed under Minimal and Medium) plus the items Operator, Operation and Machine.

The item captions (Title, Chart Type, Rules, Chart No., Date and Comments, etc.) are not fixed, and can be changed to any text that you want, to match the information you want displayed in the SPC Chart for your process.

Items 1 to 11

Each item has a default caption and following text. In most of the fields the default form text value is blank. The default captions, which are culture dependent, can be changed to anything that you want.

	Default Caption	**Default Form Text**
Item 1	Title:	[SPC Control Chart]
Item 2	Chart Type:	[Leave blank, filled in automatically]
Item 3	Chart Nº:	
Item 4	Part Name:	
Item 5	Part Nº:	
Item 6	Spec. Limits:	
Item 7	Operator:	[Joe King]
Item 8	Operation:	
Item 9	Machine:	
Item 10	Comments:	
Item 11	Date:	[Today's date, you can change]

Sample **[Sample No.:]**

If the Samples rows are turned on in the column data part of the table, The caption Samples No. appears as the row header for each sample row. The words “Sample No.” can be changed to anything that you want.

Date/Time Format []

The default value for the time stamp column is a simple hour:minutes 24-hour format (15:23 for example). If this box if left blank, that format is used. You can change the format to any valid date/time format using the sample interval time stamp Year, Month, Day, Hour, Minute and Second. The format is specified using a string which follows the standard Microsoft date/time formatting rules, which you can study on their web site at: https://docs.microsoft.com/en-us/dotnet/standard/base-types/custom-date-and-time-format-strings.

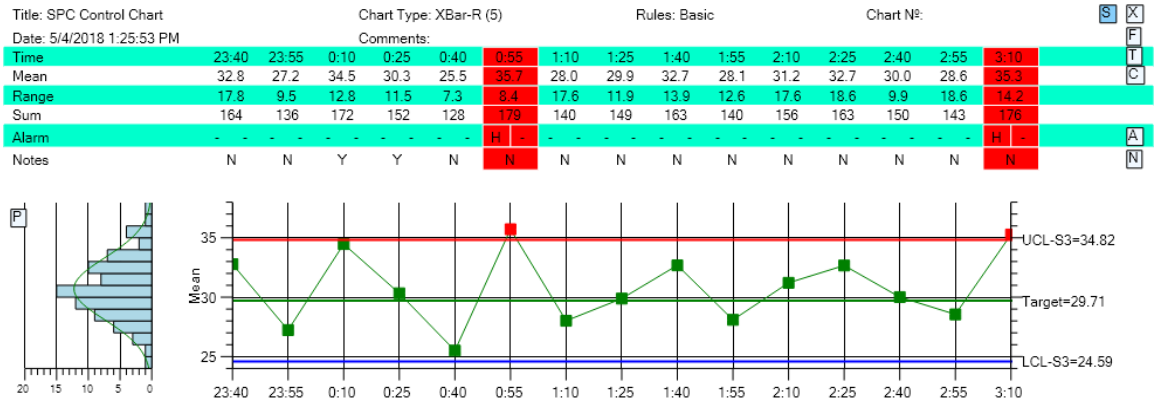
Here are some common date/time formats you might want to try.

Format	Example	Description
H:mm:ss	23:12:23	24 hour:minute:seconds
h:mm:ss	11:12:23	12 hour:minute:second
H	23	24-hour
M/dd/yy	7/19/18	Month/day/ 2-digit year
M/dd/yyyy	7/19/2018	Month/day/ 4-digit year
d/MM/yy	19/07/18	day/Month/ 2-digit year
H:mm:ss d/M/yy	23:12:23 19/7/18	24-H:min:sec day/Month/ 2-digit year
H:mm M/dd/yy	23:12 7/19/18	24-H:min Month/day/ 2-digit year

Important consideration

The resulting time stamp must fit within the column width of the table, which is normally sized to a width of 6-10 characters. If you specify a format string which uses too much space (H:mm:ss d/M/yyyy for example), the time stamp columns of the table will overlap. The only solution to this issue to reduce the number of sample intervals shown on the screen at once, using the **Chart Type** setup page, property **Nº of points in view**. Or you can specify a date/time format string that isn't as wide.

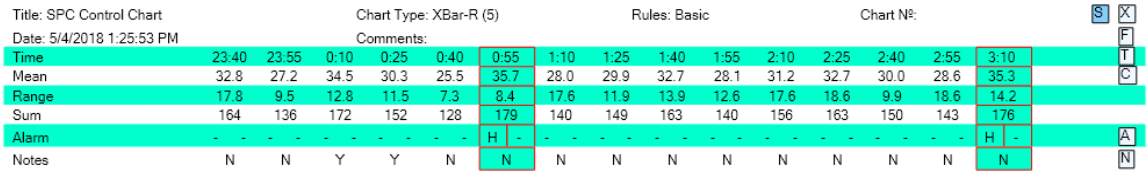
Alarm mode [Bar]



The column in the Table data area, representing a sample interval, can be highlighted so that you take notice.

When a sample interval violates the specified control limits it is considered to be in alarm. Use the Table alarm mode option to set which emphasis mode you want for highlighting the table column data when an alarm occurs in the associated sample interval. The emphasis has can take following forms:

Text	The normally black text for the column can will changed to the alarm color
Bar	A semi-transparent box, filled in the color associated with the alarm, is overlaid over the column text
Outline	A rectangle (the outline of the Bar in the previous option) is drawn around the column text
None	Use the None option if you do not want any alarm highlighting in the Table column data area.



The column in the Table data area can be highlighted using a solid background color, an outline box, or just a simple color change for the text in that column.

Background mode [Greenbar]

The background area of the table can take on three modes:

Greenbar	Alternating green and white bars. See above for an example.
Plain white	A simple white background.
White with grid lines	A white background with a grid. See below for an example.

Title: SPC Control Chart — Chart Type: XBar-R (5) — Rules: Basic — Chart №: — S X

Date: 5/4/2018 2:16:03 PM — Comments: — F

Time	14:16	14:31	14:46	15:01	15:16	15:31	15:46	16:01	16:16	16:31	16:46	17:01	17:16	17:31	17:46	T
Mean	32.4	27.1	28.6	29.0	30.4	31.7	29.5	26.2	29.0	34.0	33.3	29.7	27.0	28.7	26.8	C
Range	11.7	14.1	13.9	10.8	10.3	9.9	4.8	4.4	11.8	5.8	8.5	11.4	12.3	12.9	7.0	
Sum	162	135	143	145	152	159	148	131	145	170	166	148	135	144	134	
Cpk	0.502	0.586	0.548	0.569	0.605	0.649	0.706	0.727	0.709	0.778	0.796	0.787	0.763	0.742	0.742	P
Cp	0.664	0.601	0.586	0.614	0.638	0.658	0.719	0.777	0.761	0.795	0.804	0.792	0.777	0.761	0.777	
Ppk	0.508	0.558	0.565	0.611	0.658	0.691	0.736	0.714	0.693	0.722	0.732	0.738	0.717	0.703	0.697	
Pp	0.671	0.572	0.605	0.660	0.693	0.701	0.750	0.762	0.743	0.737	0.739	0.742	0.729	0.721	0.730	
Alarm	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	A
Notes	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

The background for the table rows can use alternating colors (white and green), a plain white, and a white with grid lines.

Process Indices

In SPC, a manufacturing process is often subject to statistical analysis to calculate a simple measure of the overall process capability and performance. The Process Capability measure is generally referred to as Cpk with variants called Cp and Ck. The Process Capability (Cpk) measure is meant to be used on a process that is considered to be in statistical control. The Process Performance measure is meant to be used on a process which is in startup, or is still seeking statistical control. Formulas are found for each are found in Chapter 2. A new process measure is calculated for each sample interval in the chart, showing a running view of how the process measure changes over time. Turn Off/On a specific process measure using the toggle switch to the left of each Process Measure type.

Cpk	[Off / On]
Cp	[Off / On]
Ppk	[Off / On]
Pp	[Off / On]

Important Note - Cpk, Cp, Ppk and Pp calculations require Upper Spec Limit (USL) and Lower Spec Limit (LSL) values be set. You must set those in the Control Limit setup option, otherwise the results are meaningless.

Chart Options

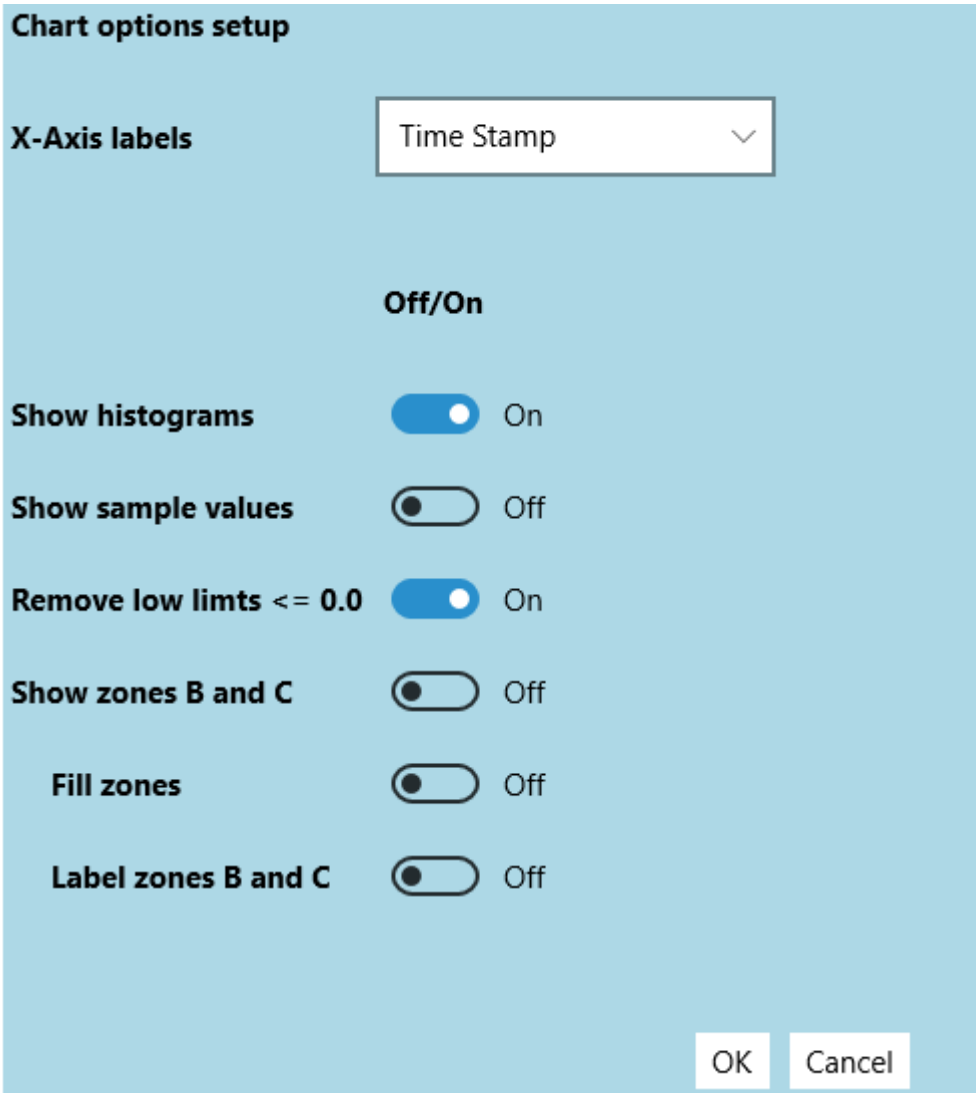


Chart specific options, for the Primary and Secondary charts, are set using the Chart Options setup form.

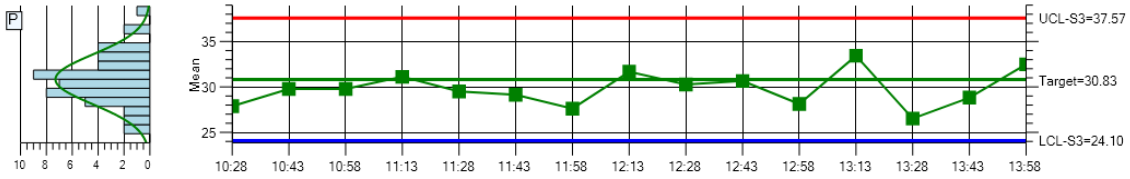
In order to minimize the number of setup options, we have intentionally minimized the user control over many chart features. Chart attributes such as background colors, line colors, and thickness, bar colors, text size and colors, symbol size and colors have all been fixed at values which maximize contrast and readability across a wide range of mobile devices. Here are the chart options you can change.

X-Axis labels **[Timestamp]**

There are three x-axis label modes you can chose from: Timestamp, Batch ID and Batch No. Use the list box to chose which mode you want.

Timestamp	When data is entered for a sample interval, it is required that you provide a date/time timestamp. The timestamp can be used to label the x-axis tick mark for the associated sample interval data.
Batch ID	You can enter an optional text to identify a sample interval. The Batch ID is an simple short (3-6 characters), text descriptor which is used to mark the batch. In Batch ID mode, this text descriptor is used as the x-axis tick mark label in place of the timestamp.
Batch No.	Each sample interval has a integer position index in the overall dataset, starting at 0 and continuing to N-1 for a dataset with N sample intervals. In Batch No. mode, this integer value is used as the x-axis tick mark label in place of the timestamp.

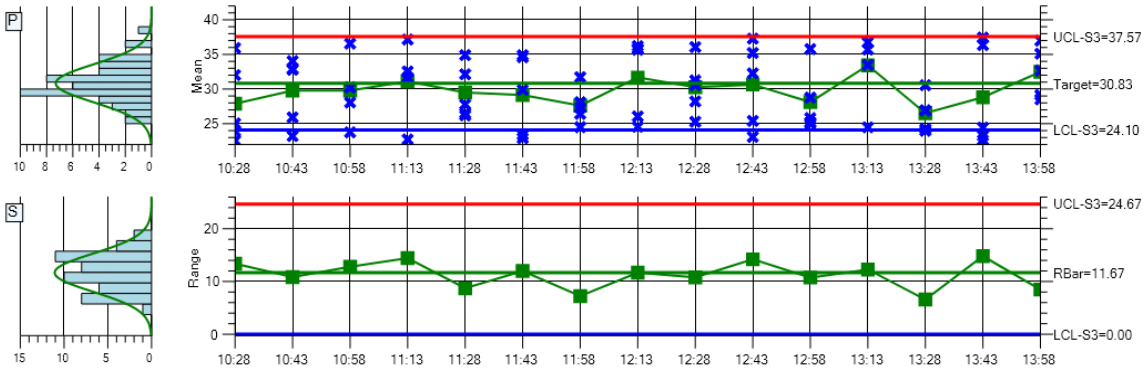
Show histograms [Off / On]



Use the Show histograms switch to turn Off/On the sample data histogram to the left of the chart.

To the left of the Primary and Secondary charts there is a frequency histogram chart of the sample data. Turn this feature on and off using this option.

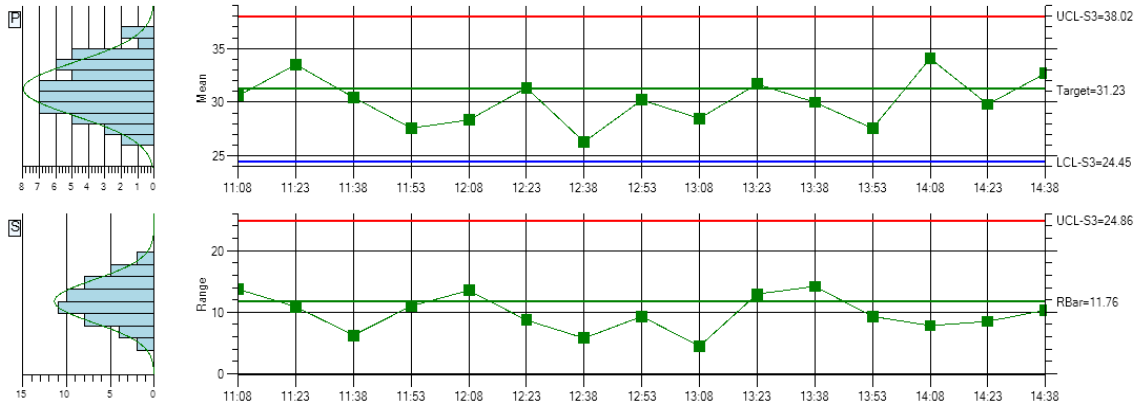
Show sample values [Off / On]



Use the Show sample values switch to turn Off/On the display of individual sample values (the X scatter plot symbols in the picture above) at each sample interval.

Normally, only the mean (or median value in the case of a Median-Range chart) value is plotted for each sample interval. You can always look at the exact values for individual samples in the table column data for the sample interval. You can also display the individual sample values in the Primary chart by toggling this option On. Sample values appear with the X symbol.

Remove low limits <= 0 [Off / On]



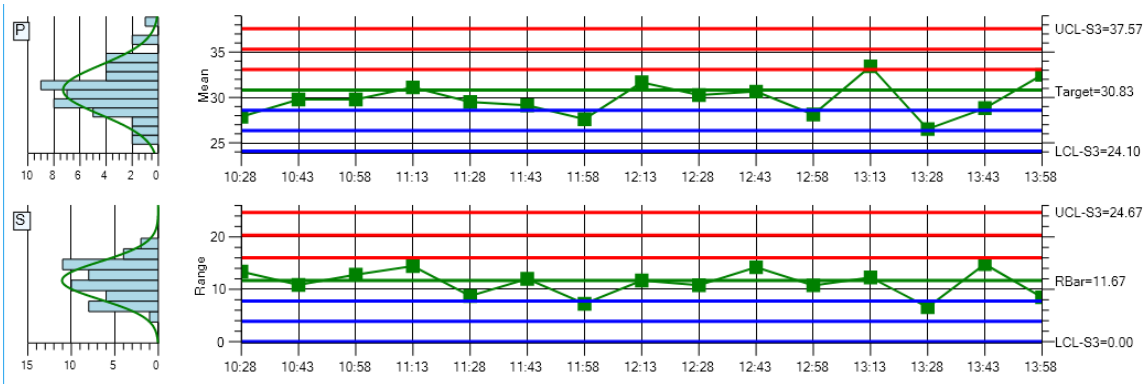
Many times the low control limit (LCL) is calculated as <= 0.0 in Variable and Attribute control charts. If you do not want that limit to show, at the 0.0 value, set the Remove low limits switch to Off.

Some of the Primary charts of Attribute control charts, and the Range charts of the Variable controls charts produce control limits <= 0.0. There can be cases where you want a control limit at <=0.0, and others where you do not. In the example above this

option is enabled, and it removes the control limit at 0.0 for the Secondary Range chart of an Xbar-R chart. It does not show the control limit line, limit value label on the right, and the software does not evaluate the control limit when checking for control violations.

Show zones B and C [Off / On]

Use this option to turn Off/On the display of control lines for ±2 Sigma level and the ±1 Sigma Level.

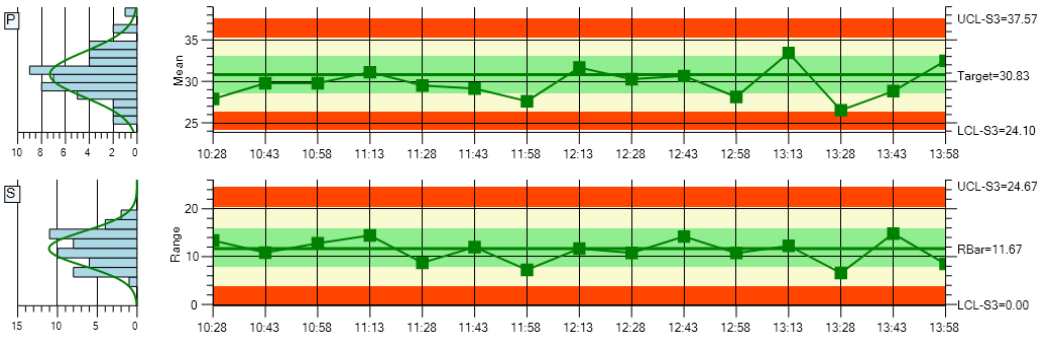


SPC chart users, particularly those using name control rules such as the Western Electric (WECO) rules, want to see the +-2 sigma and +-1 sigma control lines, because they are often used in control rule evaluation.

SPC Charts using Basic Rules normally show control lines at the ±3 Sigma limit levels. However, many users like to also see control lines for the ±2 Sigma and ± 1 Sigma level. The banded area between +2 Sigma and +3 Sigma (and -2 Sigma and -3 Sigma) is often referred to as Zone A. The banded area between +1 Sigma and +2 Sigma (and -1 Sigma and -2 Sigma) is referred to as Zone B. And the banded area between the target line and +1 Sigma (and the target line and -1 Sigma) is referred to as Zone C.

Important Note – If you select the WECO or WECO + SUPP. Control rule option in the Control Limits Setup section, control lines at ±1 and ±2 sigma are automatically enabled, since the WECO control rules explicitly use those limit levels in alarm calculations.

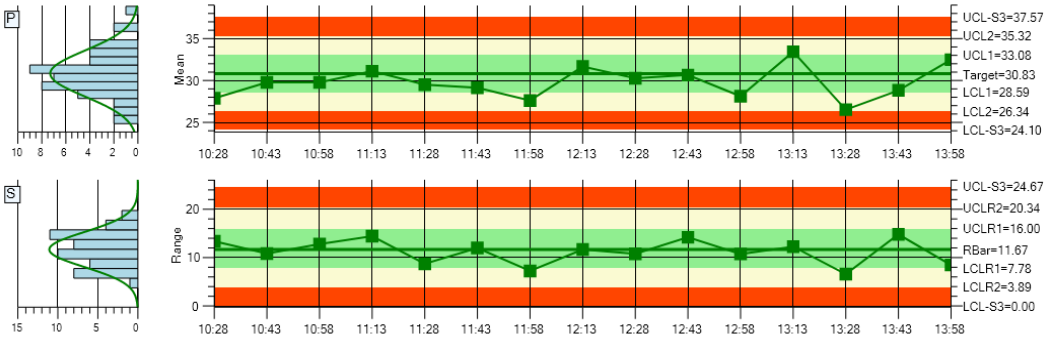
Fill zones **[Off / On]**



SPC chart users often like to see the A, B and C control zones filled in with a transparent color.

Fill the area between the control lines (representing Zones A, B and C) with a semi-transparent color.

Label zones B and C **[Off / On]**



Small charts and many control lines can lead to overlap of the limit labels used on the right-hand side of the chart. So, you can leave the lines in place, and just turn off the interior (+-2 and +-1 sigma) limit line labels.

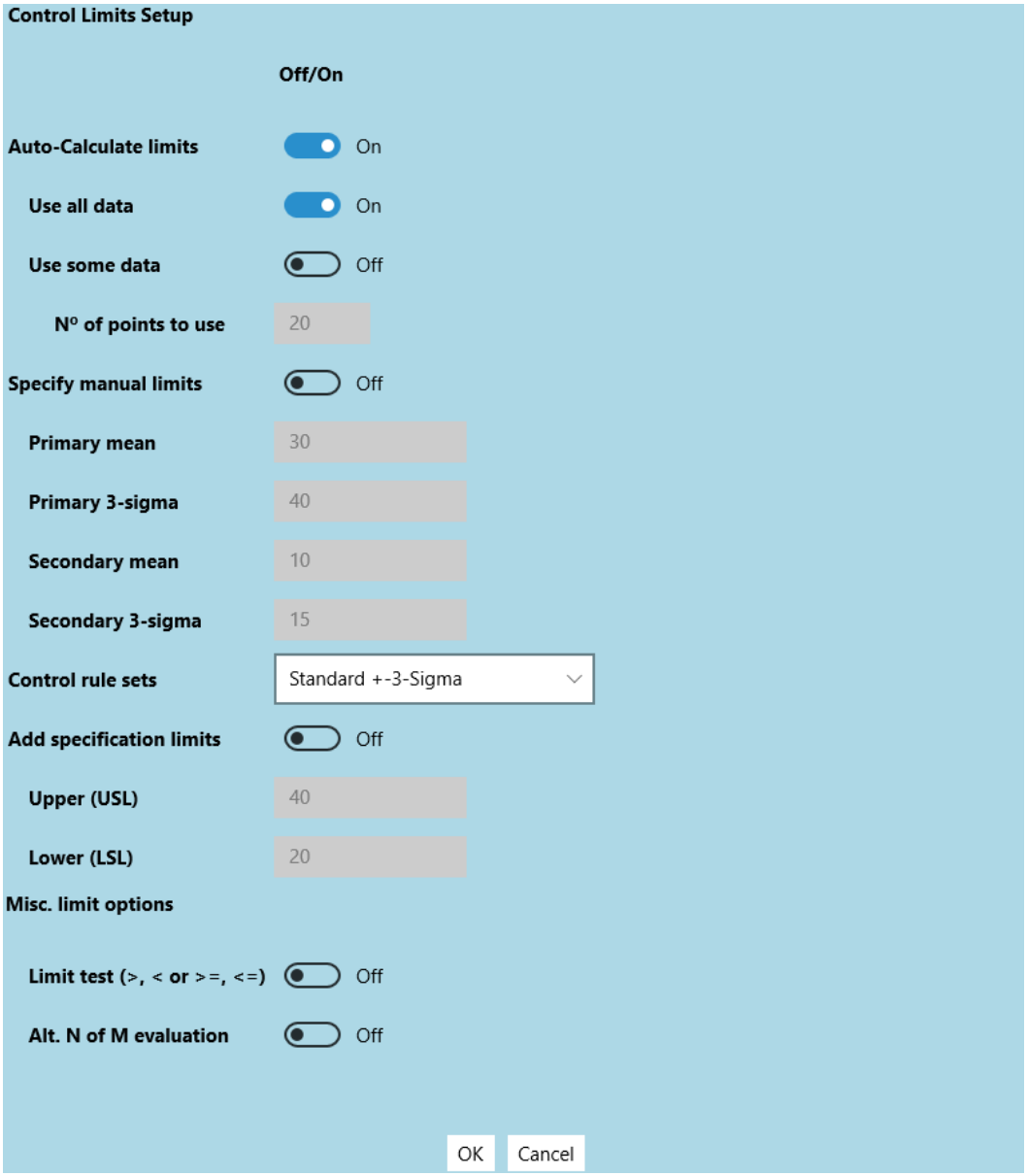
The values of the control lines at ±3 Sigma are always labeled next to the y-axis on the right hand side of the Primary and Secondary charts. But you can turn Off/On the labeling of control lines at ±1 and ±2 Sigma. If you label the interior controls lines, and the control lines are close together, this can cause the labels to overlap, which will make them hard to read.

Defect Opportunities per unit (DPMO) [1]

DPMO charts use an important parameter known is the *defect opportunites per unit*. The default value for the parameter is 1. So if you are using 1 as the the value of *defect opportunites per unit* in your chart, you don't need to do anything. If your value is greater than 1, you need to specify that in using this property. If the current chart type is not a DPMO chart this field will not display in the setup dialog.

Control Limits

Control limits are what define and SPC Chart. Without them, the charts are just plots of sample values, with no indication of whether or not the sample values are good, acceptable or bad. See Chapter 2 for the formulas used to calculated SPC chart control limits.



Control limits can be auto-calculated, or manually set to already known values.

Auto-Calculate limits [Off/On]

Every SPC chart type has a unique way of calculating control limits. Turn this switch On if you want the software to calculate the control limits based on your current data. This option is mutually exclusive with the Specify manual control limits option below.

Use all data [Off/On]

You can use all of the data in the current dataset to calculated the control limits to apply to the dataset. This option is mutually exclusive with the Use some data option below.

Use some data [Off/On]
You can limit the data used in the Auto-Calculate control limits calculation. For example, you can calculate the control limits using the first 20 sample intervals of your dataset, and apply the limits to the remaining intervals of your dataset. This option is mutually exclusive with the Use all data option above.

Nº of points to use [20]
Specify the number of sample intervals, starting from the beginning of the current dataset, to use in calculating the control limits.

Specify manual limits [Off/On]
You may already know your control limits, because of previously collected data for your process. In that case you can enter the control limit values directly. This option is mutually exclusive with the Auto-Calculate control limits option above.

Primary mean (or target value) [31]
Enter the mean value, for the Primary chart.

Primary 3-Sigma [37.8]
Enter the value of the +3 Sigma control limit for the Primary chart. Make sure you enter the +3 Sigma control limit value, and not the +3 Sigma value itself. The +3 Sigma control limit value is the Primary mean (or target) value plus the +3 Sigma value.

Secondary mean (or target value) [11.5]
Enter the mean value, (or target value) for the Secondary chart.

Secondary 3-Sigma [4.1]
Enter the value of the +3 Sigma control limit for the Secondary chart. Make sure you enter the +3 Sigma control limit value, and not the +3 Sigma value itself. The +3 Sigma control limit value is the Secondary mean (or target) value plus the +3 Sigma value. Also, do not use the +3 Sigma value from the Primary chart. The Secondary chart is going to have its own, unique +3 Sigma value.

For both the Primary and Secondary charts, the -3 Sigma control limits are set assuming symmetrical ± control limits, where the -3 Sigma control limits is set equal to the expression

-3 Sigma control limit = [target] – ([+3 sigma control limit] - [target])

(If you are unsure of what manual control limits to set, use the Auto-calculate control limits option instead.

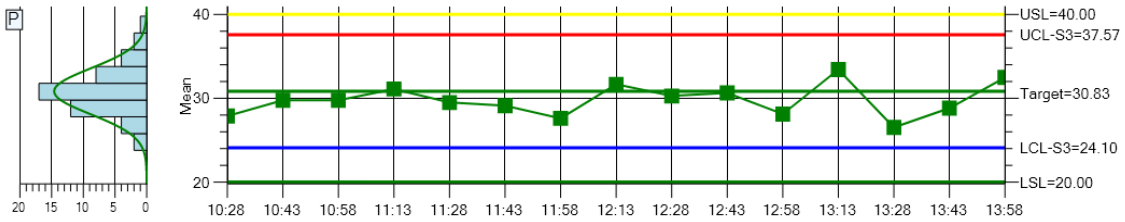
Control rule sets [Standard ±3-Sigma]

Regardless of how the control limits are set, automatic or manual, you can specify how those control limits are applied to the underlying data in order to determine whether or not an alarm condition is met. There are three options.

Standard ±3 Sigma	The software looks to see if the measured variable is outside of the ± 3 Sigma limits.
WECO	The software applies a more advanced ruleset, which includes the ± 3 Sigma limits as the first of four different tests. The other rule tests include 2 of 3 > 2 sigma, 4 of 5 > 1 sigma, and 8 points out of 8 points on the same side as the target (or centerline) value. For a more detailed description of these test see Chapter 4.
WECO + SUPP.	This rule set extends the WECO ruleset above to include four more tests, looking for trending, oscillation, stratification, and banding in the measurement data. For a more detailed description of these test see Chapter 4.

Add specification limits

Specification limits are not the same as sigma-based control limits. The sigma-based control limits are a result of the normal variances of the machines used in the manufacturing process. Specification limits are the tolerance allowed in the finished product to decide whether or not the product meets its targeted quality goals and end-user acceptance. Normally, specification limits for a product in a Six Sigma controlled manufacturing process are going to outside of the ±3 sigma limits. Because who wants a manufacturing process which is incapable of consistently producing a product which meets the quality goals, as specified by the specification limits.



Specification limits are often combined in the same chart with SPC control limits.

Upper (USL)	[40]
Lower (LSL)	[20]

Important Note: The Upper and Lower Specification limit values are also used in the Performance measures calculations for (Cpk, Cp, Ppk and Pp).

Misc. limit options

Limit test (<,> or <=, >=) [Off]
When testing a value against a control limit, there is a choice as to whether or not the test includes the equality test or not. The default uses the > operator for greater than tests, and the < operator for less than tests. Set to true if you want to use the >= test, and the <= test instead.

Alt. N of M test [Off]
When using the N of M control rules found in the WECO control rule set (and many others), there is a situation that can occur where you have 2 of 3 (or 4 of 5) of the most recent sample intervals fail the N of M test, yet the most recent sample interval passes the test when evaluated individually. In the default mode, the current sample interval still shows an alarm condition, because it did not pass the N of M test in a strict sense. There is an argument to be made though, that since the current sample interval is not in alarm, the N of M test should be overridden, the current sample interval should be shown as not in alarm. We don't won't to argue the point. If you want the strict N of M test, leave the Alternative N of M test property at its default value of Off. If you want the alternative evaluation method, set it On.

File Load/Save

The three different platforms supported by this software (IOS, Android, and UWP) all have different rules regarding file access to the underlying device. In the case of UWP a general file picker, familiar to desktop users, is available to help when loading and saving files. IOS and Android are harder to deal with, because they purposely restrict program access to the file system, except for limited access to a local folder and perhaps a Downloads or Documents folder. Because of this, the dialog page for the File Load/Save option is dependent on the platform you are using.

Load/Save of chart setup

Every property that you set in the setup pages of the app can be saved to a setup file, so that you can load the exact same chart setup in the future. As part of the setup, you can also include the raw sample data you use in the chart, so that is saved along with the chart setup. If you want to apply the setup to completely new data, you don't need to save the

data, though you might want to anyway. You are only a button click away from clearing the data back to an empty state.

The setup data is saved as a text file using a well know industry standard for data exchange known as JSON, which stands for JavaScript Object Notation. JSON is basically a text file with simple formatting rules for declaring name-value pairs of text, numeric, date/time, boolean, and array properties. You can look at the resulting text for one of the setup *.JSON files using a text editor to see its structure.

When you save a chart setup file always give it the JSON extension.

Import/Export of sample data

Sample data can be loaded independently into an already configure chart setup. So you can load a chart setup with no data, and then import a new set of data from simple text file. The Import/Export data file uses a simple text file format known as CSV, which stands for Comma Separated Values. In the CSV format used by this software, each row of the file represents a new sample interval. Each row is divided into columns using the "," symbol. Each column contains either a date/time value, a numeric value, or a text value. The text values are delimited using the quote (") symbol to differentiate them from numeric values. The first seven rows of a typical CSV file for use with this software looks like.

,,2018-06-01 13:34:28Z, 24.96, 28.52, 35.65, 27.58, 29.61
,,2018-06-01 13:49:28Z, 25.87, 31.62,2 9.60, 35.88, 34.66
,,2018-06-01 14:04:28Z, 30.54, 37.43, 30.66, 34.16, 27.68
,,2018-06-01 14:19:28Z,34.63,25.38,26.18,24.74,34.28
,,2018-06-01 14:34:28Z,27.88,27.19,35.78,35.34,36.12
,,2018-06-01 14:49:28Z,25.95,34.57,28.89,29.80,34.85
,,2018-06-01 15:04:28Z,35.40,29.68,23.21,37.10,24.85
Note for sample subgroup #7. Lathe cutting tool broke. Replaced with new- Aeon cutting tool.,,2018-06-01 15:19:28Z,29.81,29.76,24.13,23.86,23.32

The data values, columns 3 to 7, have been truncated to show only two decimals, to make the data easier to read.
The columns are organized in the following manner:

Column #1	A note for the sample interval. Leave empty if there is no note.
Column #2	The x-axis tick mark custom ID for the sample interval. Leave empty if you are not using x-axis tick mark custom Ids.

If column #1 and/or column #2 are left empty, you must till include the comma as a column separater.

Because the example above only has one note (the last row), and does not use x-axis tick mark custom ID's, the first two columns for most of the rows are empty.

Column #3	A Date/Time stamp, in database sortable format (Microsoft DateTimeFormatInfo.UniversalSortableDateTimePattern (which is "yyyy'-'MM'-'dd HH':'mm':'ss'Z'". According to Microsoft, this pattern is culture independent.
Column #3 to N + 2	These columns represent the N sample data values for the given sample interval.

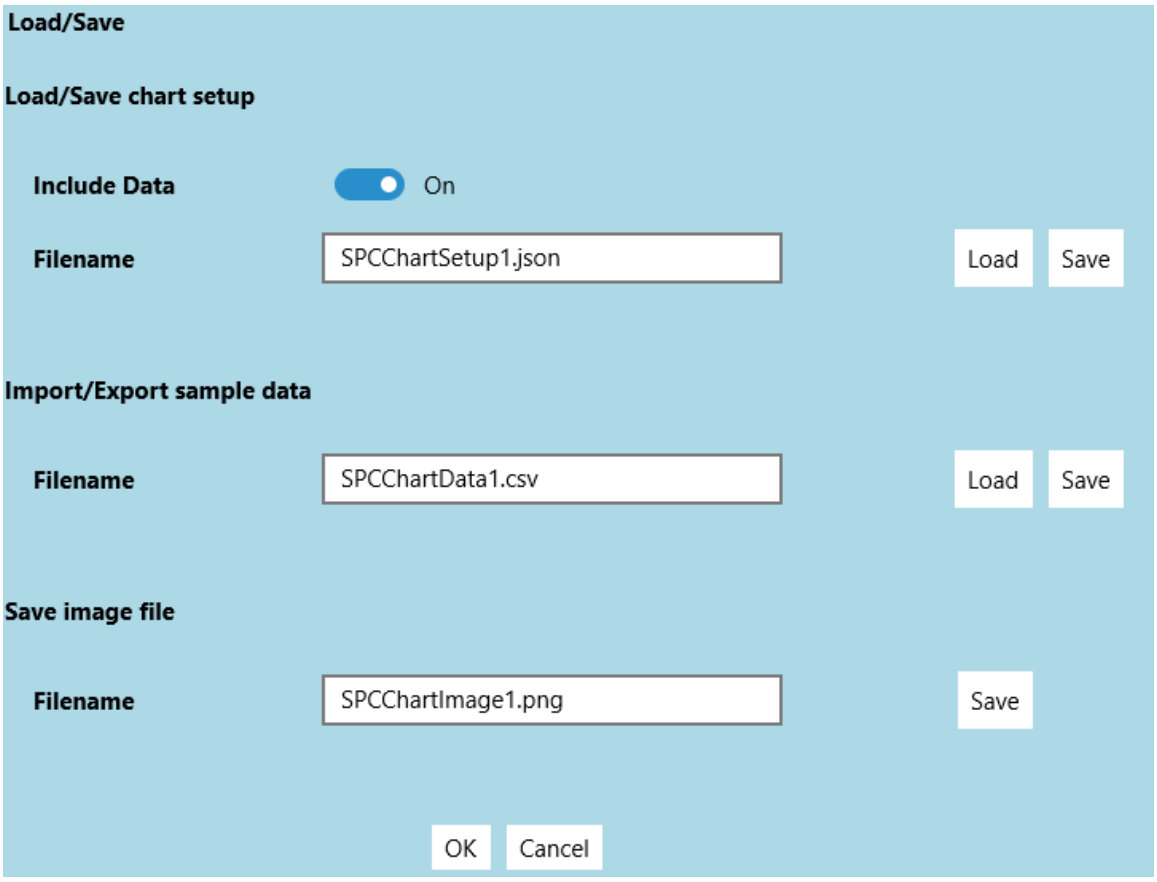
The Import/Export data files should always use the extension *.CSV. Export a data file and look at one with a text editor (Notepad or equivalent) to see an example of the format.

Important Note - For non-English users of this software there are a couple of things to be aware of. Regardless of the culture the app is using (English, Spanish, Portuguese, French, German or Italian), the CSV file MUST use numeric values which use a period "." decimal delimiter, and not a comma "," as is common outside of the English cultures. Otherwise the commas of the decimal delimiters get mixed up with the commas used as column separators and the data will not be loaded properly. And the comma column separator must be a comma, and not a semicolon which is used in some CSV implementations. You will see that in general the software adapts to normal culture guidelines for the display of numeric data in the chart displays. But the CSV file format is an exception. Regardless of the culture setting, it will always export data using the English CSV convention, and any imported data must also use the English convention. Also, in order to avoid issues regarding culture specific differences in time/date formats, we use the Universal, database sortable, time/date format (2018-04-25 15:30:00Z).

Save Image File

Printing is still problematic using the current generation of cross platform tools we are using to write this software. So this release of the software does not directly support printing of the SPC charts from your mobile device. You may be able to print using a third party app, but we have none we can recommend at this time. What you can do is save the current chart image as a PNG file, which you can load into a document as a picture where you might be able to print it, depending on the app.

UWP users – For hardware compatible with Windows 10 Desktop and Microsoft Surface



Load/Save setup form for Windows (UWP) platforms.

Load/Save chart setup

Include data [Off/On]

When you save the chart setup, you can include the raw sample data of the chart in the setup file. Turn the switch on to enable this feature. If the data is excluded, when you load the data you will end up with a chart with no data.

Filename [SPCChartSetup1.json]

The default filename for a chart setup is SPCChartSetup1.json. If you select the [Load] or [Save] button, a file picker will be invoked, and you can traverse the file system to load or save the file wherever you are permitted.

Import/Export chart data

Filename [SPCChartData1.csv]

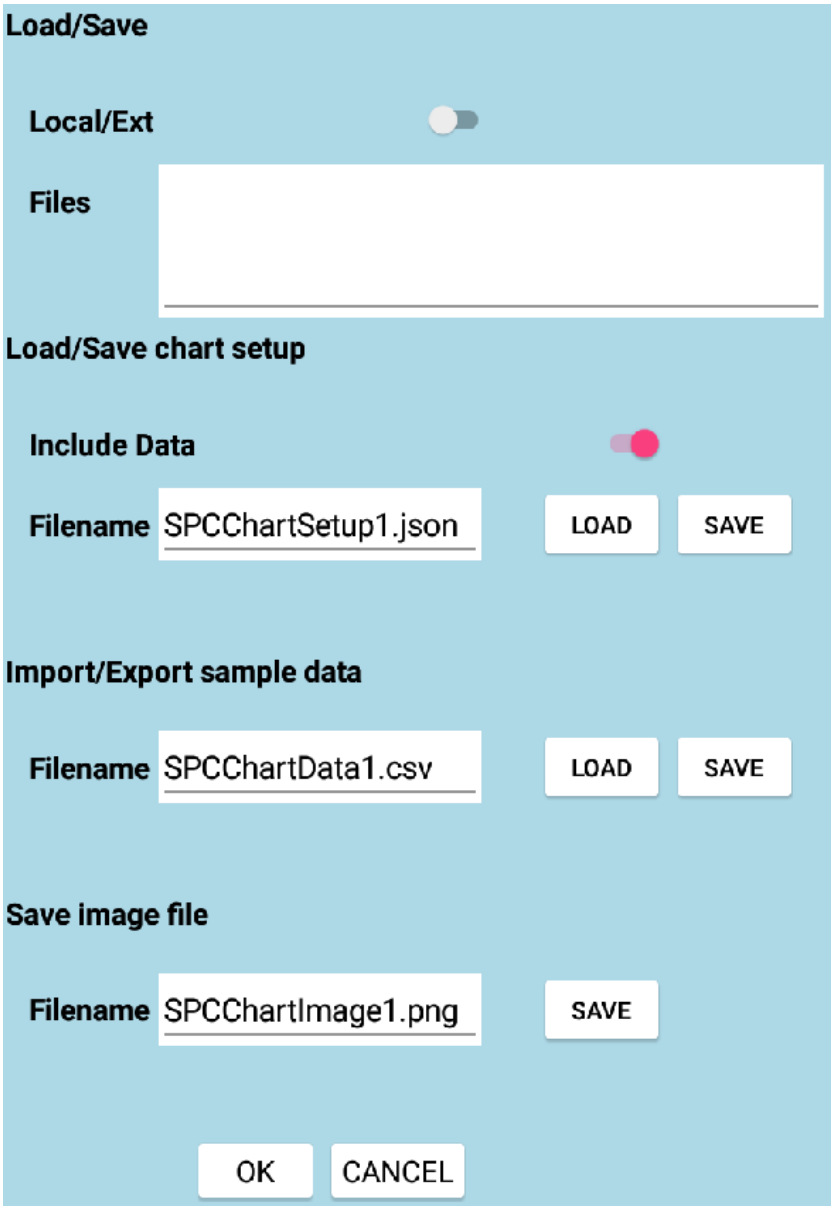
The default filename for a chart data file is SPCChartData1.csv. If you select the [Load] or [Save] button, a file picker will be invoked, and you can traverse the file system to import or export the file wherever you are permitted.

Save image file

Filename [SPCChartImage1.png]

The default filename for a chart image is SPCChartImage1.png. If you select the [Load] or [Save] button, a file picker will be invoked, and you can traverse the file system to save the image wherever you are permitted.

IOS and Android users – For hardware compatible with IOS and Android platforms.



Load/Save setup form for Android and IOS platforms.

Local<=>Ext [Off/On]

In IOS and Android versions of the software, you can save files to either the local installation folder, or to an external folder. Under IOS you can save to an external Documents folder, and under Android you can save to an external Download folder. If

you switch this option from Local to External, the actual folder location will display underneath the file list box.

Files saved with the file switch in the **Local** position are accessible only through this program. That is part of the IOS/Android security system. You may be able to find some sort of super File Manager app which lets you access these restricted files, but we do not know of any. So if you want to transfer your data, setup or image files to another computer, you need to set the switch to the Ext (External) position. Even then, the files can be hard to find. See the section below, **Accessing external files located on your device,** for examples of how to do this using IOS and Android. For the UWP version, you can save the files wherever you want using a standard Windows file picker, so it isn't an issue.

Files [SPCChartData1.csv]

The current files box is a list box. It will display all of the *.json, *.csv and *.png files found in the current file folder, as selected using the Local<=>External switch. Press on the box and the list of files will display in a popup list box. In the case of IOS, the list box appears in the lower half of the display.

If you select a file from the list box, the filename will be copied to the appropriate Filename box. If you select a filename with the *.json extension, it will be copied to the Load/Save chart setup Filename box. If you select a filename with the *.csv extension, it will be copied to the Import/Export chart data Filename box. And if you select a filename with extension *.png, it will be copied to the Save image file box.

Load/Save chart setup

Include data [Off/On]

When you save the chart setup, you can include the raw sample data of the chart in the setup file. Turn the switch on to enable this feature. If the data is excluded, when you load the data you will end up with a chart with no data.

Filename [SPCChartSetup1.json] [Load] [Save]

The default filename for a chart setup is SPCChartSetup1.json. If you select the [Load] or [Save] button, the file is loaded or saved to the folder location determined by the Local<=>External switch, using the specified filename.

Import/Export sample data

Filename [SPCChartData1.csv] [Load] [Save]

The default filename for a chart data file is SPCChartData1.csv. If you select the [Load] or [Save] button, the file is loaded or saved to the folder location determined by the Local<=>External switch, using the specified filename.

Save image file

Filename [SPCChartImage1.png] [Save]

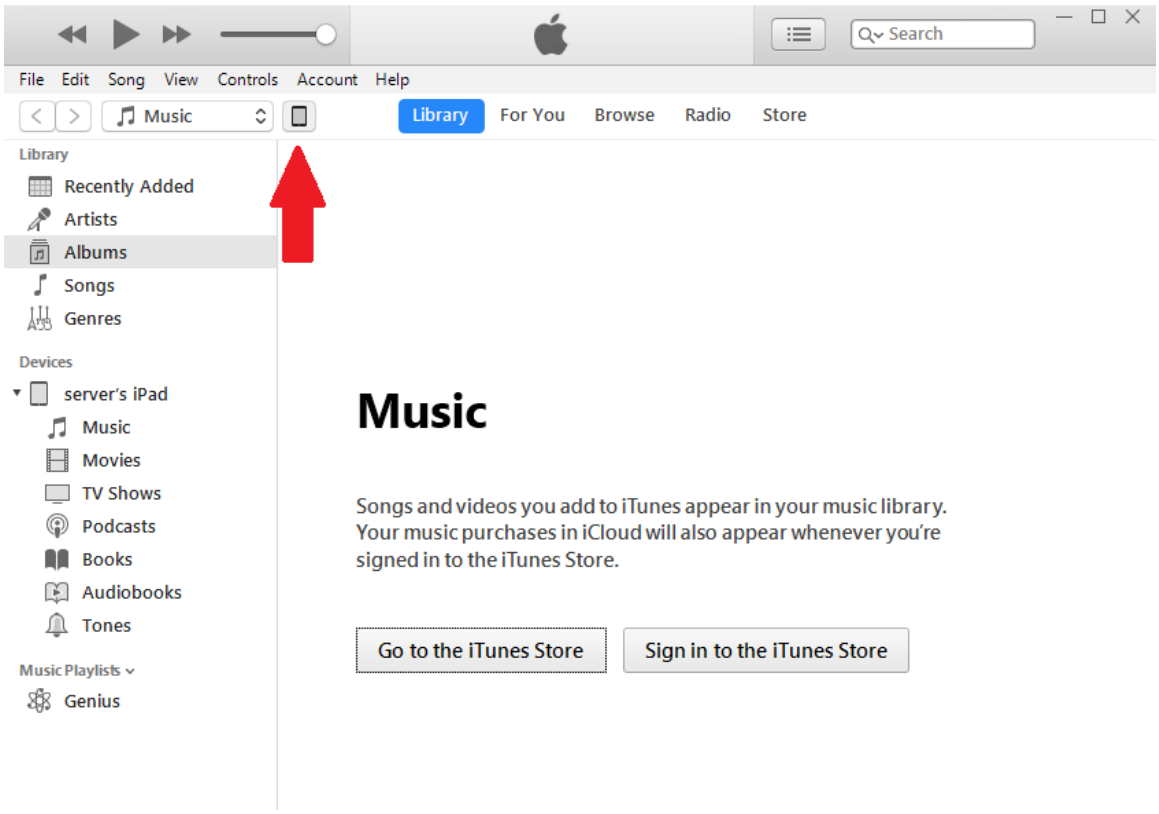
The default filename for a chart image is SPCChartImage1.png. If you select the [Load] or [Save] button, the file is loaded or saved to the folder location determined by the Local<=>External switch, using the specified filename.

Accessing Saved External Files

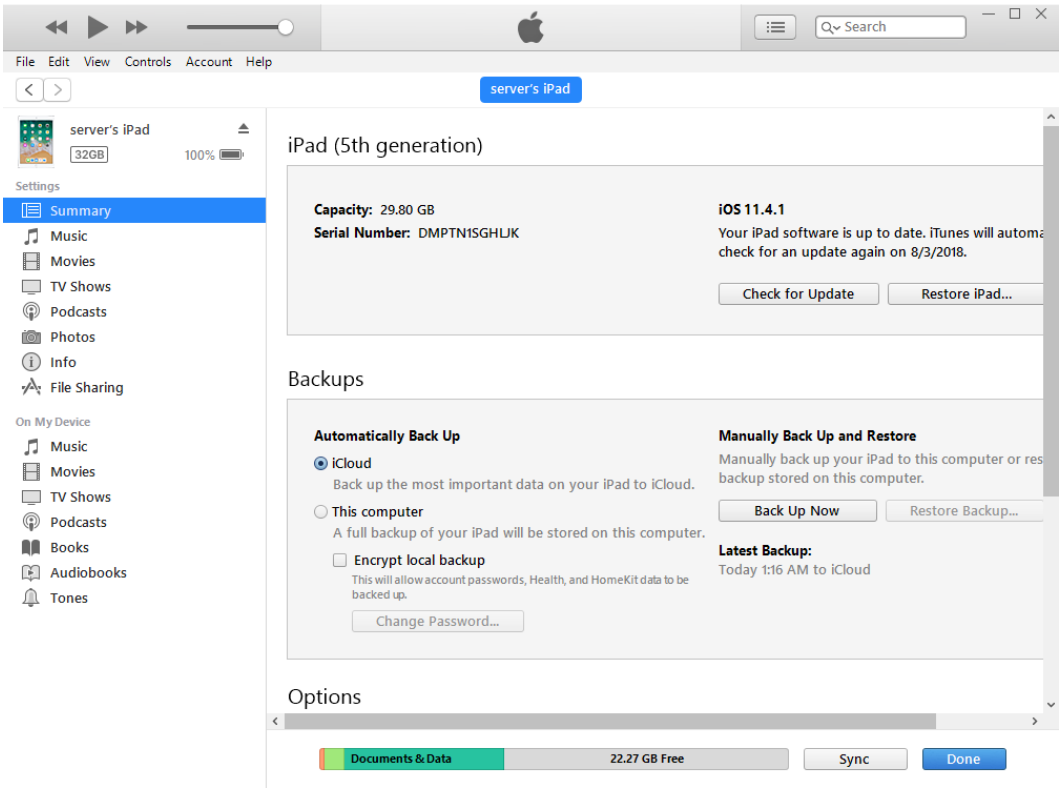
Files saved with the file switch in the Interval position are accessible only through this program. For loading and saving. That is part of the IOS/Android security system.

IOS

Connect your IOS device (iPad or iPhone) to your computer (Windows 10 or a Mac) using the standard USB to Lightning cable which came with your device. If you are using a Mac, run iTunes. If you are using Windows 10, download the Windows iTunes app and install it on your PC, and run it. The resulting screen (excepting the big red arrow) looks like:

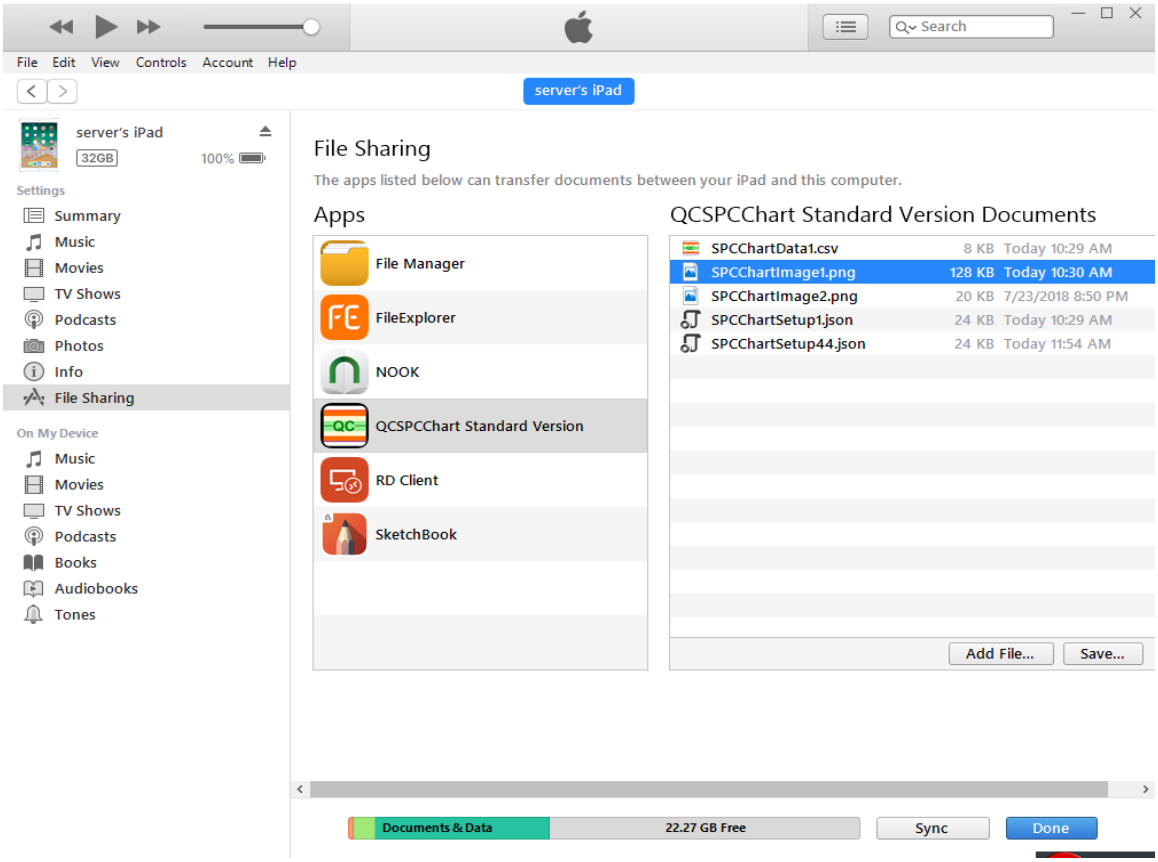


Click the device icon, which is what the big red arrow is pointing to. The screen will change to:



Click on the **File Sharing** item in the column on the left of the window.

You should see something like:

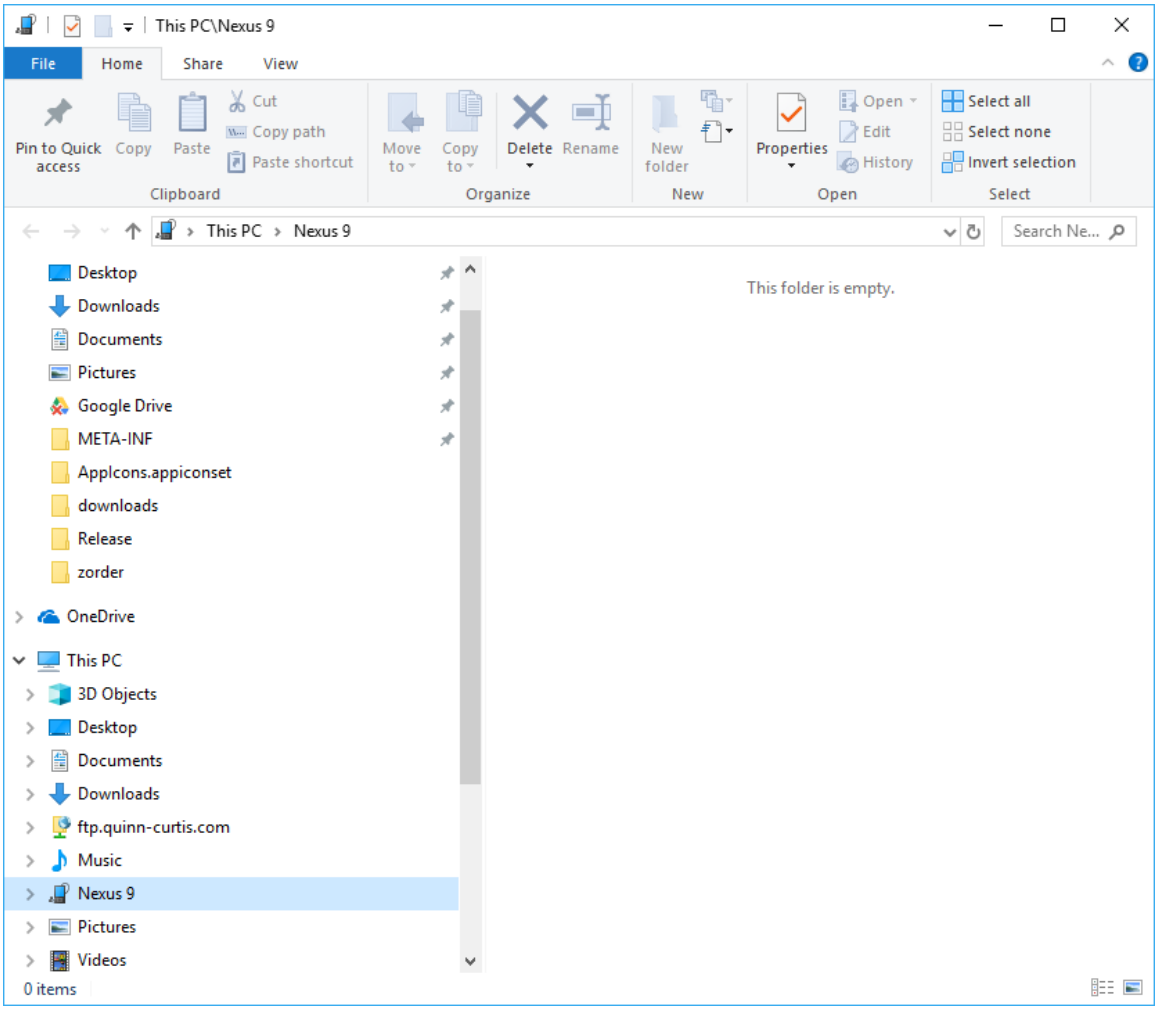


QCSPCChart Standard Version (or QCSPCChart Free Version) will be one of the items listed under **File Sharing | Apps**. Go ahead and select that. You will then see a list of files located in the QCSPCChart's Document folder. You can click and drag those files to copy them to the host PC. The opposite is also true, you can click and drag files from your PC to the QCSPCChart Documents folder.

Android

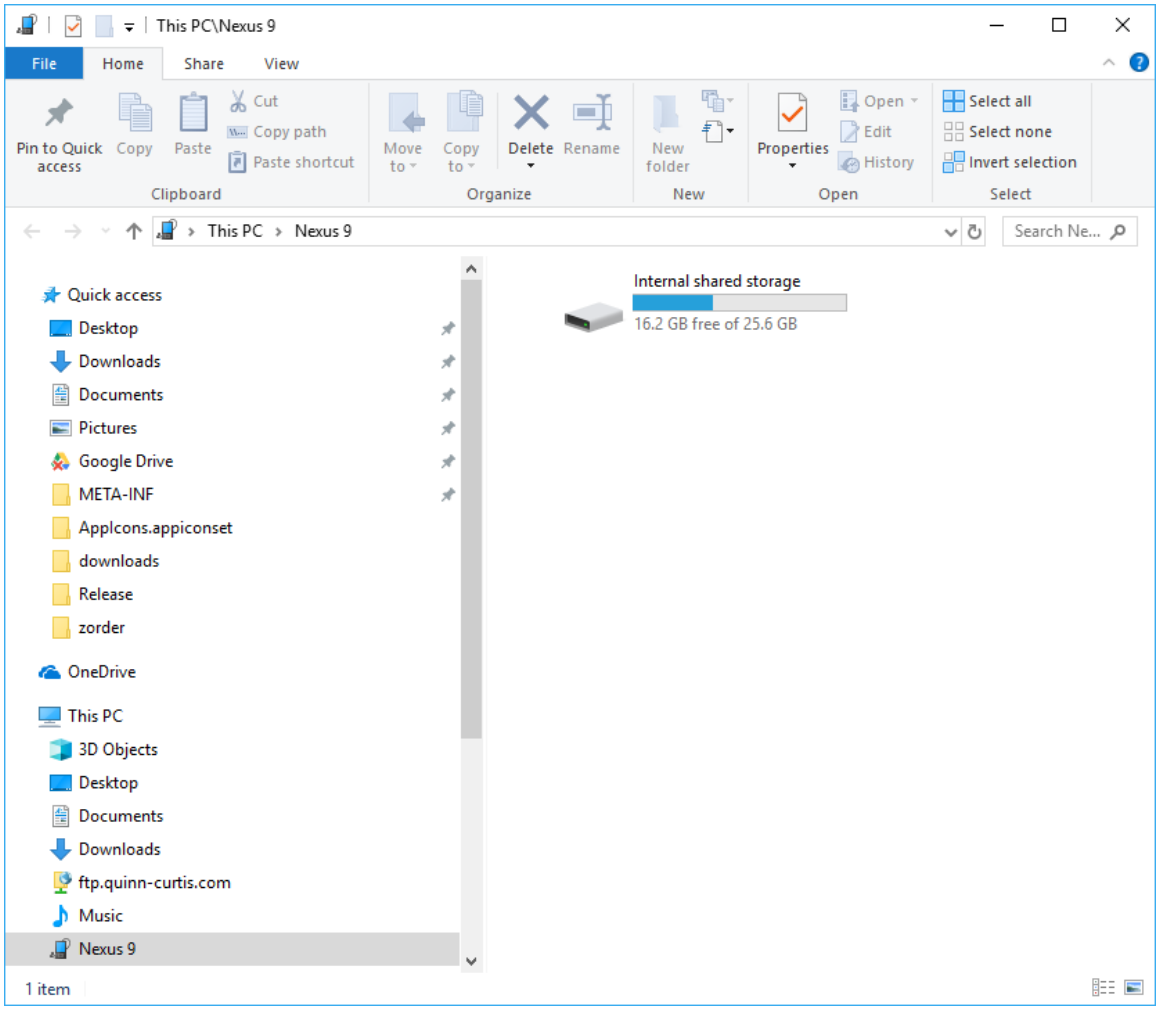
When the App starts for the first time, it will ask you if you will give the program permission access to the devices storage. You will need to give it this permission if you expect to be able to use the External files option. From that point on you will not need to give it permission.

Connect your Android device (tablet or phone) to your computer (Windows 10) using the standard USB to charging/data transfer cable which came with your device. When the PC asks what you want to do with the connection, tell it you want it for File Transfers.

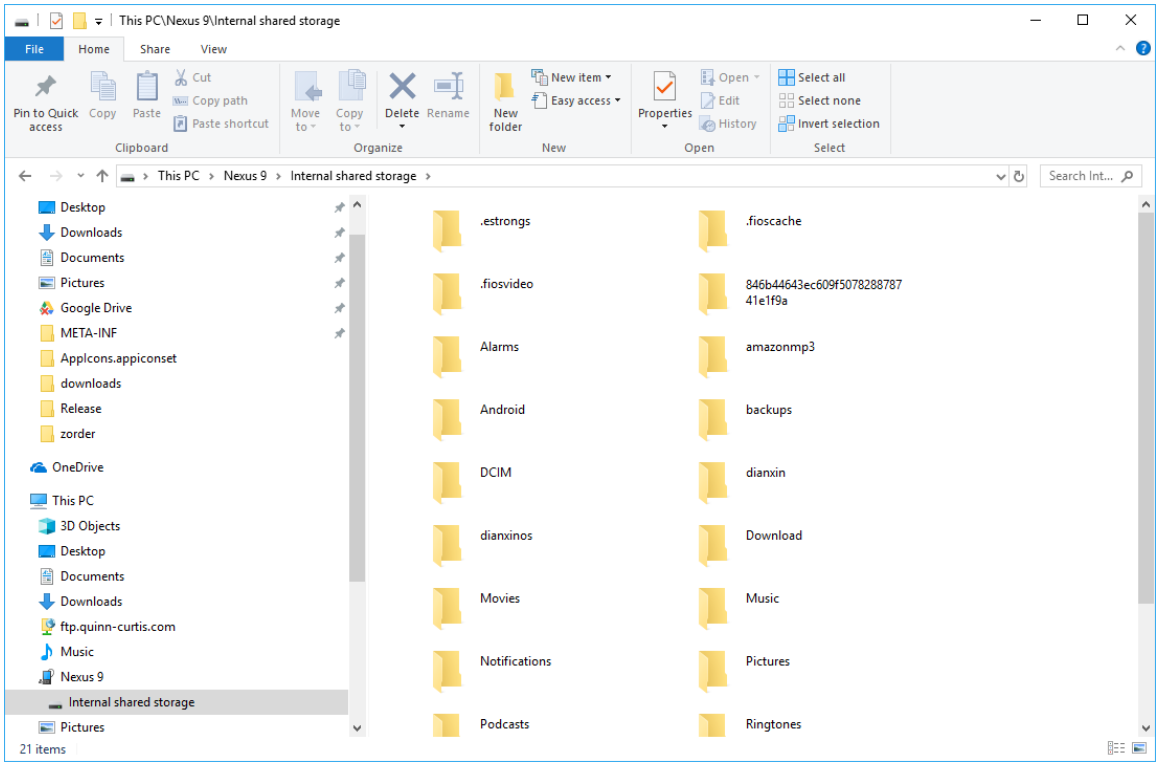


Go to the PC File Explorer and find your Android Device under This PC – Nexus 9 in this example.

You may or may not see a storage icon on the right (Internal shared storage). Android seems to be irregular about this. If you don't see the storage icon, go to your Android Device and swipe down from the topmost left of the screen. At the bottom or the drop down window you should see Android System | USB (charging this device) – Tap for more options. Give a tap and choose the Transfer files option. If that works, you should then see an update on your PC which shows the Storage icon for your Android device.



Then, double click on the Internal shared storage icon and you will see folders and files you have access to on the Android device.

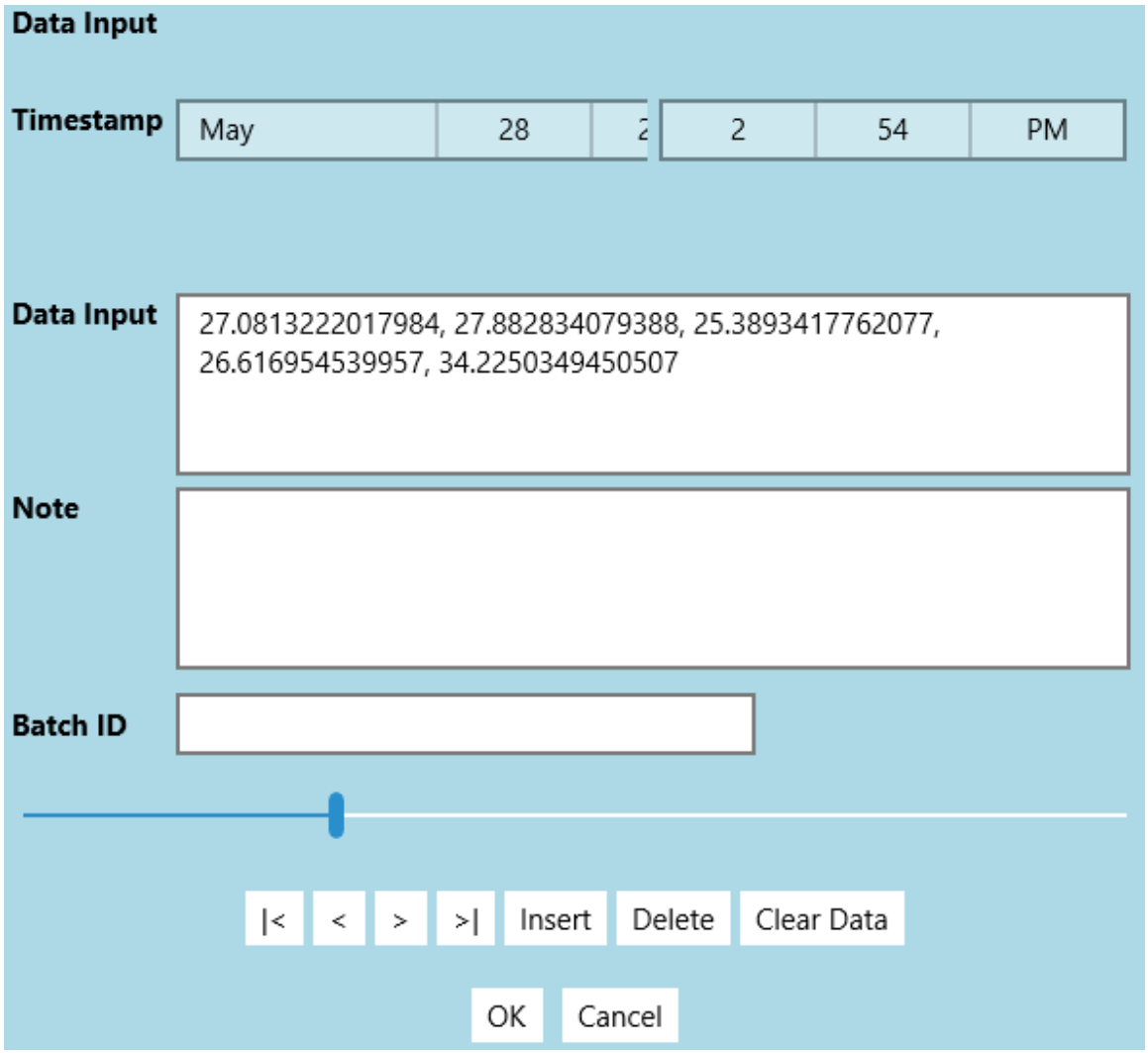


Any files you save using the External mode can be found in the Download folder.

Do it wirelessly

An easier method is to just download an Android File Manager App, such as ES File Explorer. Setup a shared folder on your PC and connect to it wirelessly using ES File Explorer using the Network | LAN function. You may need to find someone with a little Network experience to do this for you. Locate the Download folder on your Android device (Local | Download). You can then copy from the shared PC folder to/from the Android Download folder.

Add/Edit Datapoints



Sample data for each sample interval can be added, or edited using theAdd/Edit Data input form.

The Add/Edit Datapoints option is the way you manually enter sample data into the app. It is organized to show one sample interval, or record, at a time. At a minimum a sample record consists of a timestamp, and sample data for the sample interval. Optionally you can add a Note and a Batch ID for the sample interval.

Timestamp [Date] [Time]

Specify a date, and a time, for the sample interval by selecting both the Date picker field, and then the Time picker field.

Data input

In the Chart Type setup dialog you entered in the sample subgroup size. Here you need to enter a number of sample values to match. Since it is possible that something happened

which invalidated a partiuclar value within a sample group. In that case you can enter the text “Bad_Value”, or null, for the bad data value, as in the example below. Once you enter the record into the dataset, by moving to the next record, when you go back to the record with the bad, or null value, it will always display as “Bad_Value”.

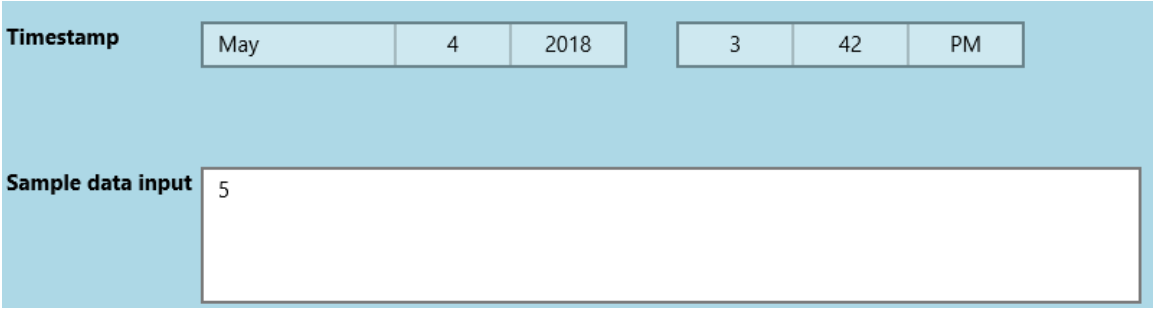
35.98141770972, 32.0709203554182, 23.060560436249, 26.6689362116945,
Bad_Value

Adding data for Variable control charts

Variable control charts (Xbar-R, Xbar-Sigma, Individual Range, Median-Range, etc.) all use measurement data converted to floating point numbers. The sample subgroup size will vary from 1 to 20 or more, depending on the chart type and and process characteristics. The data examples above are specifically for a Variable control chart using a sample subgroup size of 5. The sofware will expect 5 sample values for every sample interval.

Adding data for Attribute control charts

Attribute control charts (p-chart, u-chart, np-chart, c-chart, DPMO-chart) are different than Variable control charts. In those cases, a sampled product will have one or more defects, and this is a binary (true/false) property. In practice, a batch of product is pulled out for testing. For example, a 100 or more products are separated out for testing, and 100 would considered the sample subgroup size. Then the defects within that sample group are counted. There are two ways to count the defects, depending on the Attribue control chart type. In the p-chart, and np-chart, the number of defects are counted, regardless of whether a part as more than one defect. In the u-chart, c-chart and DPMO-chart, the number of defects are counted. If one part has ten defects, that still counts only one one defective part. Only the total (either number of defects, or number of defective parts) is entered as a value in the SPC chart dataset. And that total will always be an integer value. So, even though the sample subgroup size is 100, you only enter one whole number value, the defect number. So, if you are creating an Attribute control chart, the data editor will always show one value per sample interval, which is an integer measure of defects for that sample interval.



The attribute control charts only use a single data value for each sample interval.

In the example above, 5 defects (or defective parts) were entered for the sample interval. Even though the sample subgroup size for this Attribute control chart may be 100, you still only enter one value.

Note

There may significant event during the sample interval which needs explaining. You can enter that in the Notes field.

Batch ID

Under the Chart Options dialog, you specified the x-axis labeling mode: timestamp, Batch ID, or Batch No. If you selected Batch ID, the value of this field will show up on the tick mark of the x-axis associated with this sample interval.

[Scrollbar]

You quickly scroll to any sample interval using the scrollbar.

[|<] [<] [>] [>|] [Insert] [Delete] [Clear all data]

where:

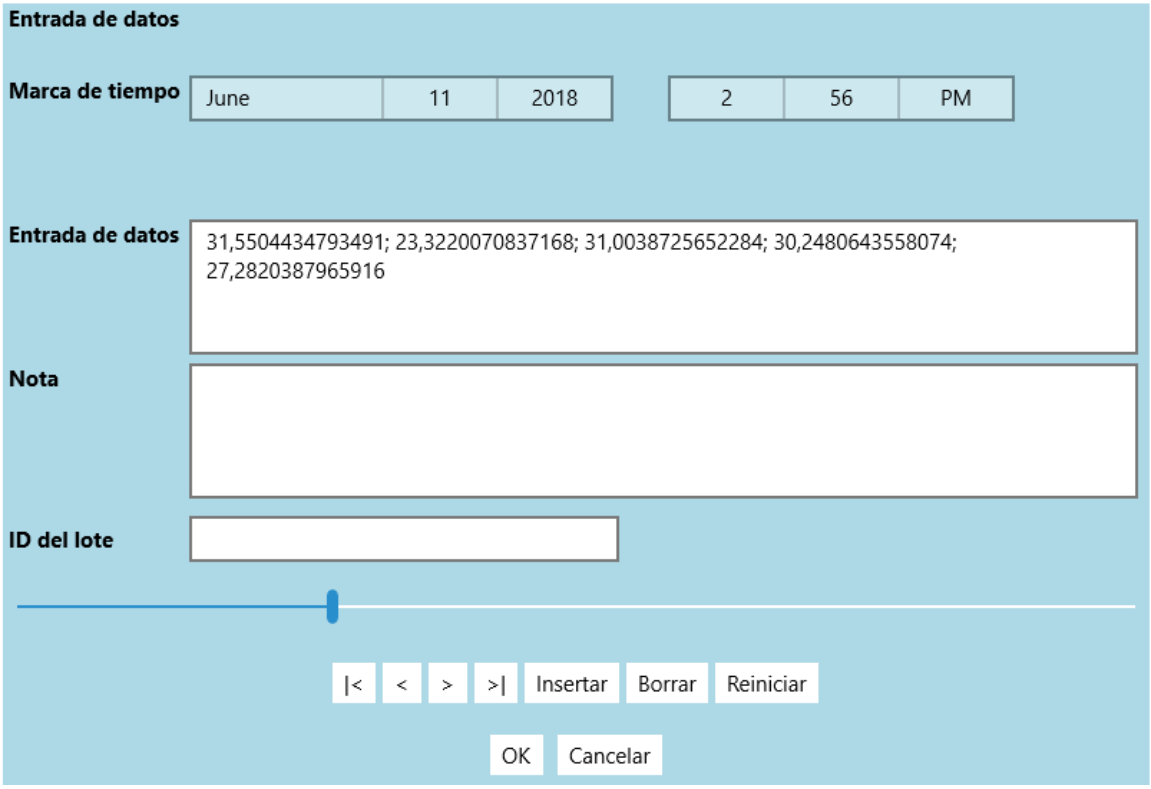
[|<]	Move to the first record in the dataset
[<]	Move one record earlier in time
[>]	Move one record later in time
[>|]	Move to the last record in the dataset
[Insert]	Insert a blank record at the current location
[Delete]	Delete the current record
[Clear data]	Clear (reset to empty) the current dataset

Special Note - Cultures which use a comma “,” as the decimal point in a floating point number.

You will notice that in the data field, the English version of the software, shown in the previous picture, uses a period (“.”) for the decimal point in the data values. And the data values are separated by a comma (“,”). This won't work in cultures which use a comma (“,”) as the decimal point. In those cases, the software uses the comma as the decimal point, and uses a semicolon (“;”) as the delimiter between data values. So the resulting line of data input will look something like:

35,98141770972; 32,0709203554182; 23,060560436249; 26,6689362116945; 33,92543770972

For Spanish cultures this results in a Add/Edit Data input form which looks like this.

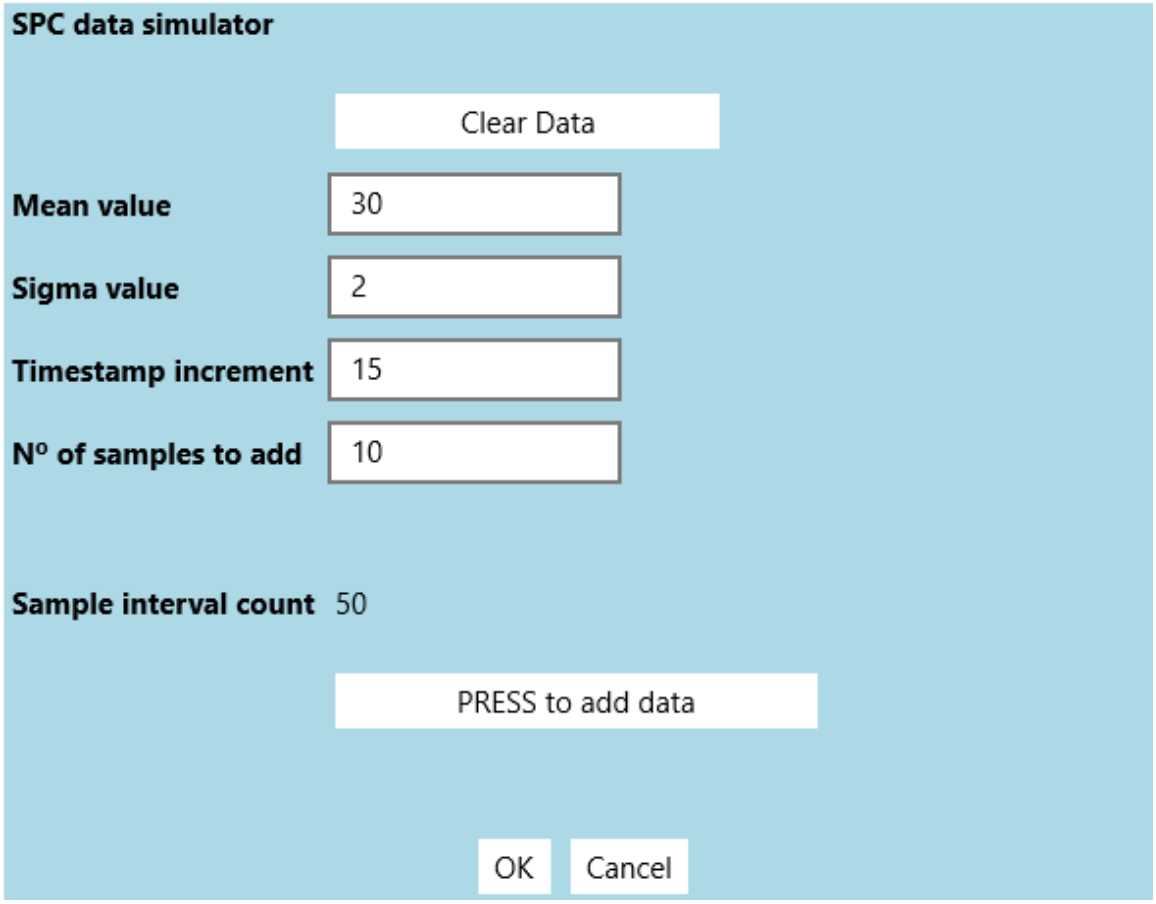


Cultures where the comma (",") is used as the decimal point, use a semicolon (";") for the delimiter between sample values.

While the Add/Edit Data form does adopt the host cultures convention regarding the decimal point, that does not carry over to the Import/Export of data in the File Load/Save form. In order to make the exchange of data files universal, the Import/Export methods always use the period as the decimal point, and the comma as the value delimiter in data files.

Data Simulator

If you are using the software to monitor a real-world process, you will need to enter your data using either a file import method, or manually using the Add/Edit Data option. But if you are just trying to learn about SPC charts, there is the data simulation option.



The data simulator generates random sample interval data (using a normal distribution), using the specified mean and sigma value.

Using the data simulator you can create a randomized dataset for simulated process using just a few parameters. Since the simulated sample data needs to match the [Sample subgroup size] property entered in the SPC Chart Type Setup option, it uses that value when simulating the data. If you are using the Free version of QCSPCChart, the maximum number of sample intervals you can simulate is 100. Anything over that is discarded.

Difference between Variable and Attribute control charts

The data simulator will automatically take into account whether your SPC chart type is a Variable control chart, or an Attribute control chart. If the chart is a Variable control chart, then N floating point sample values are simulated per sample interval, where N is the sample subgroup size. If the chart is an Attribute control chart, then 1 defect value is simulated for each sample interval, regardless of the sample subgroup size.

[Clear all data]

If you want to start with a empty dataset, select the Clear all data button.

Mean value [30]

Enter the mean value you want for the measurement variable. The simulator creates a sample subgroup with randomized values approximating the mean.
If you are displaying an Attribute control chart, pick a mean value for defects which reflects what your sample size is. For example, if the subgroup sample size is 100, you should probably have a mean defect rate of at least five to produce reasonable simulated results.

Sigma value [2]

Enter the sigma value you want for the measurement variable. This is the approximate sigma value (also known in statistical science as the standard deviation) of the process you want to simulate. Do not confuse this with a sigma control limit. The resulting +3 Sigma control limit is going to be approximately the [Mean value] + 3 * [Sigma value]. Similarly, the -3 Sigma control limit is going to be approximately the [Mean value] - 3 * [Sigma value].

Timestamp increment [15]

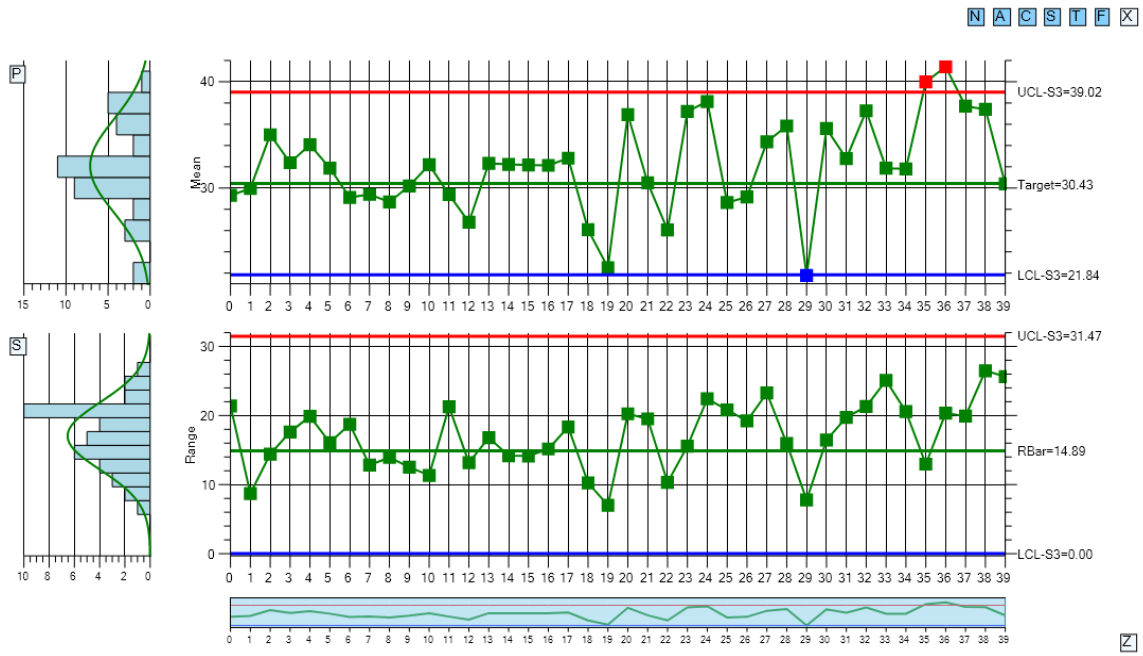
Enter a value designating minutes. Each sample interval will have a timestamp separated by this many minutes.

Nº of samples to add [10]

Each time you press the [PRESS to add data] button, the specified number of sample intervals will be added to the current dataset. It does NOT automatically clear the dataset. Instead, what you can do is add one batch of N=20 intervals of data using one set of Mean and Sigma values, (30, 2) for example, then you can change the Mean and Sigma slightly, (32, 4) for example, and append another N=20 intervals to the first batch. When setting up the automatic control limits, you can have the software calculate the control limits based on the N =20 samples in the first batch, and watch how those limits detect the process going out of control in the N=20 samples of the second batch.

Sample interval count 50

Non-editable. Tells you what the current sample interval count is. Each time you press the Add data button, this counter will increment by the value of the **Nº of samples to add** property above.



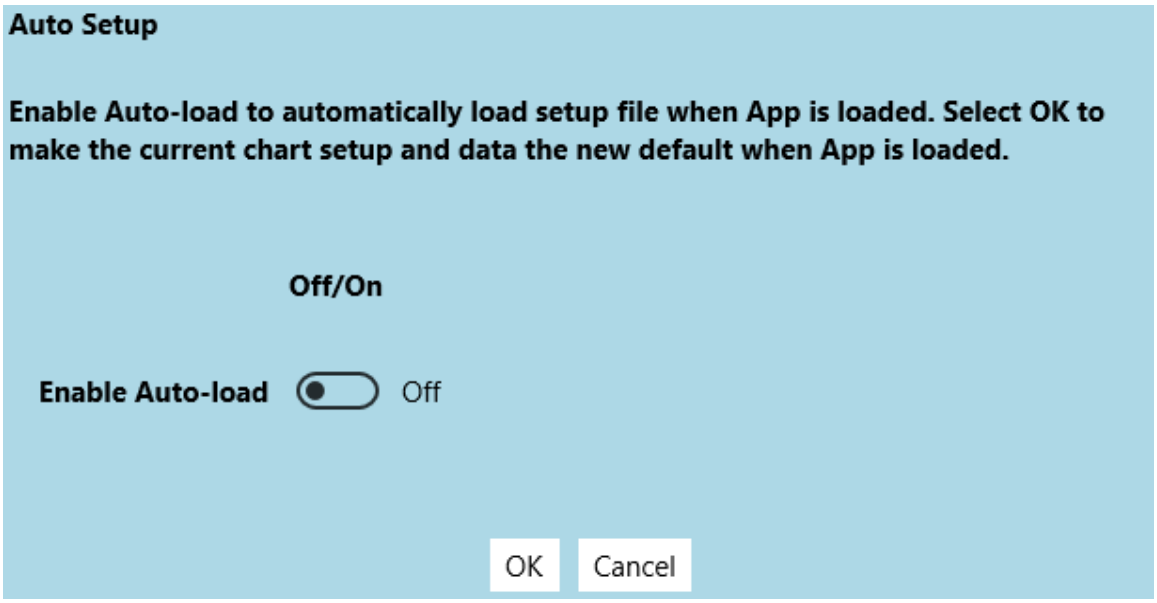
It is a useful exercise to generate N sample using one mean and sigma value, and then M sample using a slightly different mean and sigma values, to see if the original control limits pick up on the process change.

[PRESS to add data]

Each time the button is pressed, a batch of simulated sample data is added to the chart dataset. If you want to start over, select the [Clear all data] button.

Auto-Start

When the software starts, it can automatically load a startup setup file to initialize the chart. This way you don't have to start from scratch each time you want to work on a chart, nor do you even need to bother loading a previous saved setup file.



The auto-setup function enables you to pick up where you left off after exiting the program for a while.

Enable Auto-load

There two steps to enable this feature. First you must Enable auto-loading. To do that set the [Enable Auto-load] switch to On. This switch will stay On until you change it. It's state is saved as a property to local storage, and it will maintain it's current value even if the app is closed. Once auto-loading is enabled, the software will look for a setup file name RestoreSetupFile.json whenever it starts, and if it finds it, it will initialize the chart with it's values. You create the RestoreSetupFile.json setup file, based on the current setup, when you select the OK button.

[OK]

The second step is the select the [OK] button. This makes the current setup the auto-load setup. What happens is the software saves the current setup to the local installation folder under the filename RestoreSetupFile.json.

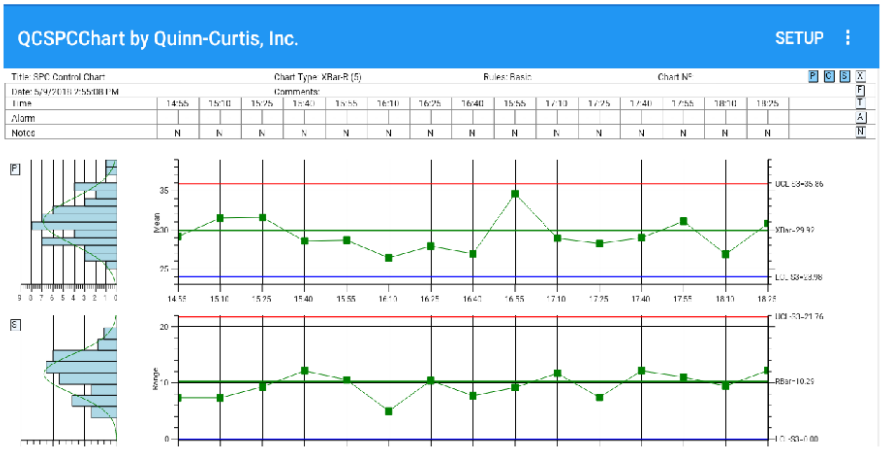
User Manual

This option invokes a browser on your device and loads this manual as a PDF file from our website. You will probably asked which browser to use to dowload the manual, and which PDF viewer to use to view the downloaded manual.

1. Introduction

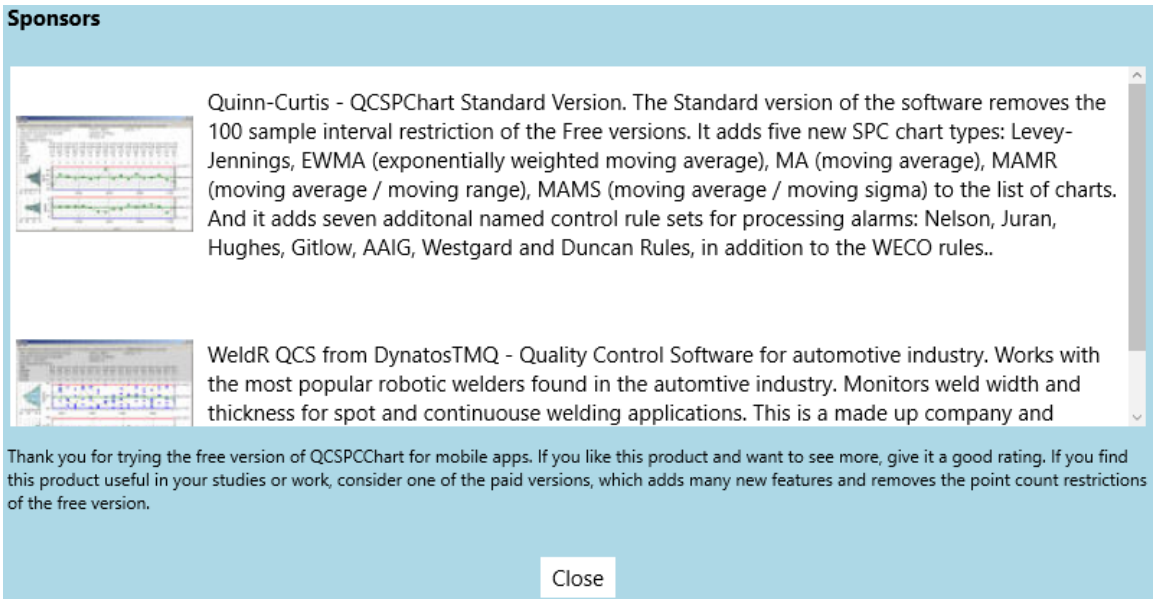
Getting Started

When you first start the software, you will see a chart which looks like this.



The User Manual is always available from our website as a PDF file: http://quinn-curtis.com/qcspcchartmobile/qcspcchartmobilefree.pdf

Sponsors



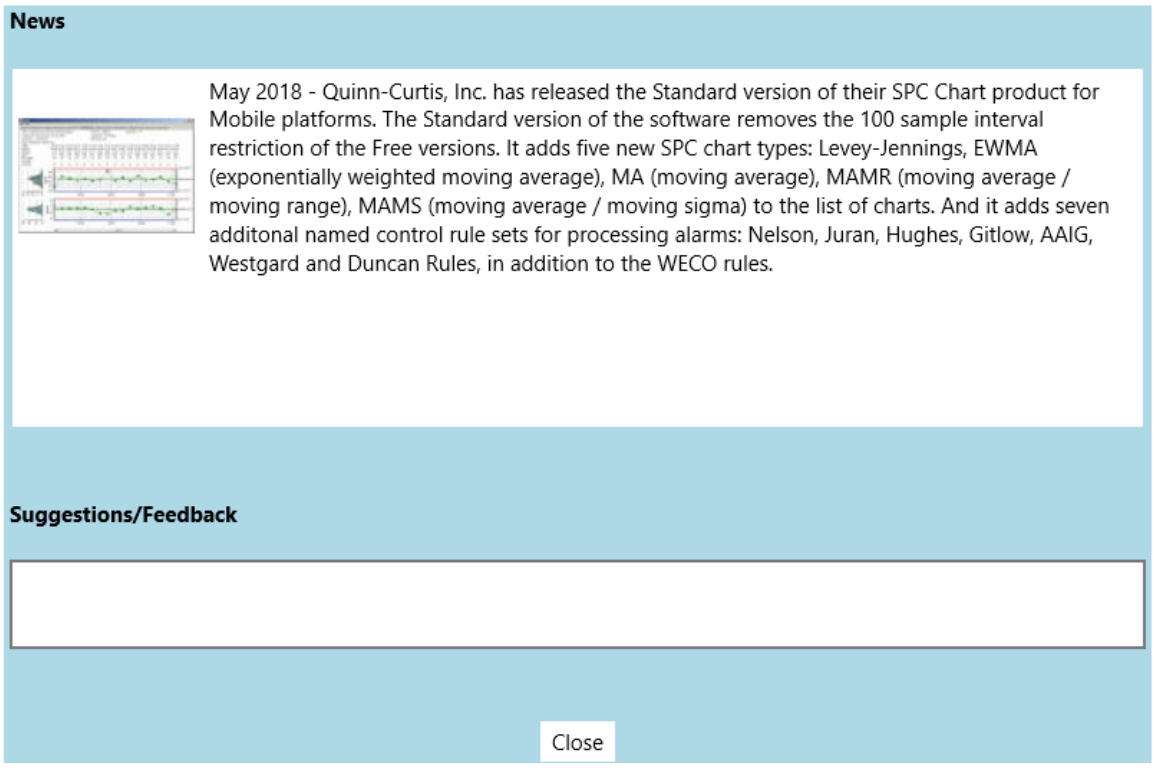
The Sponsors page will keep you up-to-date about new products from Quinn-Curtis, and from other companies which make related products.

This option may or may not be enabled at the time you download your first copy of the software. If enabled, at a minimum the dialog will show an upgrade path to other versions of QCSPCChart. Click on the ad to be taken to the website. In the future we will want to have Standard, Pro, and Ultimate versions. And it may also show a short list of paid advertisers. This is done using our own ad server and not a third party, so it will only display ads we have approved for real products from legitimate companies which are directly related to process automation and quality control. If your company falls into that category, feel free to contact us about per click advertising.

Click on the ad to be taken to associated the website using your standard browser.

News/About

This is a list of press releases associated with the product, and perhaps our sponsors. It also includes a Suggestions box you can use to relay us your feedback.



The News page will keep you up-to-date about any press releases from Quinn-Curtis and related companies. It also includes a text edit area for you to enter any suggestions you have for the product.

Select the News release item to be taken to full press release at the associated the website using your standard browser.

Customer Support

Use our user forum at http://www.quinn-curtis.com/ForumFrame.htm for customer support. There is a dedicated section (QCSPCChart Mobile Apps) for users of this product in that forum, so please post any questions there.

Free Version

You have downloaded the free version of this software. The free version has one major limitation, it will only process 100 sample intervals. If you need more than that you can move up to one of the paid versions.

Standard Version

The Standard version of the software removes the 100 sample interval restriction of the Free versions. It adds five new SPC chart types: Levey-Jennings, EWMA (exponentially weighted moving average), MA (moving average), MAMR (moving average / moving range), MAMS (moving average / moving sigma) to the list of charts. And it adds seven additional named control rule sets for processing alarms: Nelson, Juran, Hughes, Gitlow, AAIG, Westgard and Duncan Rules, in addition to the WECO rules..

Chapter Summary

The remaining chapters of this book gives additional background information about the SPC charts created by this software.

Chapter 1 is the Introduction, this chapter.

Chapter 2 describes the Variable control charts which can be created using the software: XBar-R, Median- Range, Xbar-Sigma, and I-R**.**

Chapter 3 describes the Attribute control charts which can be created using the software:: p-, np-, c-, u-charts and DPMO.

Chapter 4 describes how to implement the WECO control rules.

Appendix – List tables of constants used in SPC chart calculations.

2. SPC Variable Control Charts

Variable Control Charts are used with sampled quality data that can be assigned a specific numeric value, other than just 0 or 1. This includes, but is not limited to, the measurement of a critical dimension (height, length, width, radius, etc.), the weight a specific component, or the measurement of an important voltage. The variable control charts supported by this software include XBar-R (Mean and Range), XBar-Sigma, Median-Range, and I-R (Individual-Range, X-R).

What follows is a brief description of each of these Variable control chart, and the formulas used by the software to calculate the upper and lower 3-sigma control limits used in each of the charts. We use the formulas found in the textbook. "Introduction to Statistical Quality Control" by Douglas C. Montgomery, 6th Edition, John Wiley and Sons, Inc. 2009.

The formulas use the following common nomenclature:

SPC Control Chart Nomenclature

UCL = Upper Control Limit

LCL = Lower Control Limit

Center line = The target value for the process

$\bar{\bar{X}}$ = X double-bar - Mean of sample subgroup means (also called the grand average)

$\bar{R}$ = R-bar – Mean of sample subgroup ranges

$\tilde{R}$ = R-Median – Median of sample subgroup ranges

S = Sigma – sample standard deviation

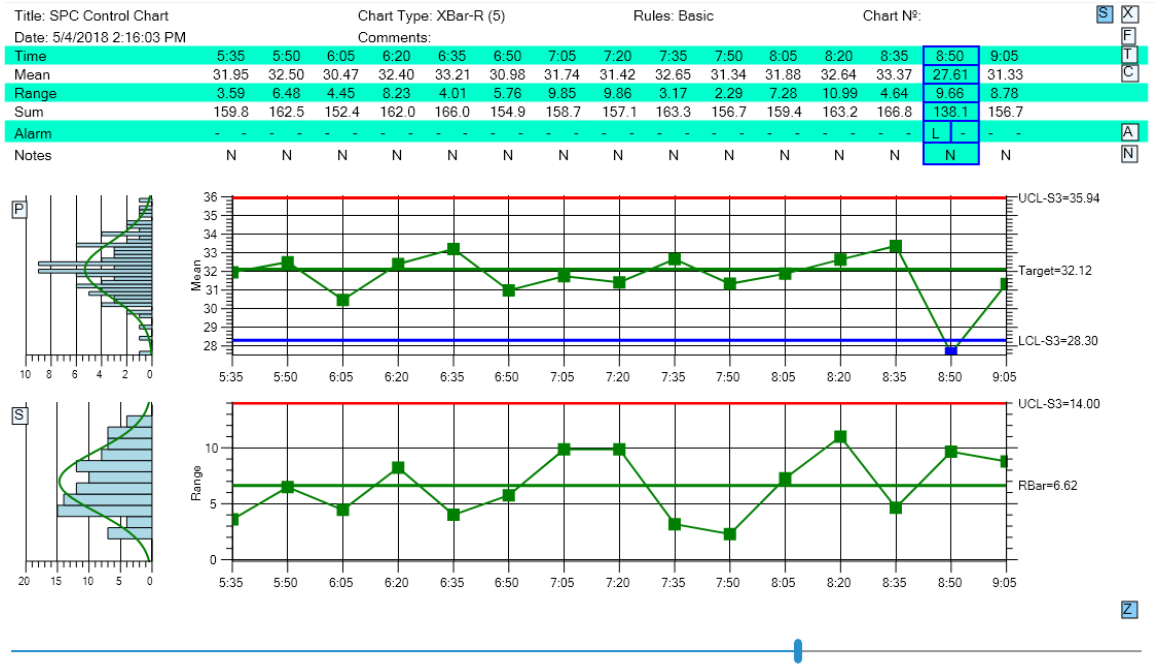
$\bar{S}$ = Sigma-bar – Average of sample subgroup sigma's

$\tilde{M}$ = sample Median

M = Median of sample subgroup medians

XBar-R Chart – Mean (or Average) and Range Chart

The XBar-R chart monitors the trend of a critical process variable over time using a statistical sampling method that results in a subgroup of values at each sample interval. The XBar part of the chart plots the mean of each sample subgroup and the Range part of the chart monitors the difference between the minimum and maximum value in the subgroup. When it comes to estimating the overall sigma of the underlying process, statistical science shows that using the range of values within a sample subgroup is more accurate than calculating the sigma value of the sample subgroup, when the sample subgroup size is <= 11.



The Xbar-R chart (first put into practice in the 1920's) is the most widely used of all SPC charts.

XBar-R Chart

Control Limits for the X-Bar Chart

$$UCL = \bar{\bar{X}} + A_2 * \bar{R}$$

$$\text{Center line} = \bar{\bar{X}}$$

$$LCL = \bar{\bar{X}} - A_2 * \bar{R}$$

Control Limits for the R-Chart

$$UCL = \bar{R} + D_4 * \bar{R}$$

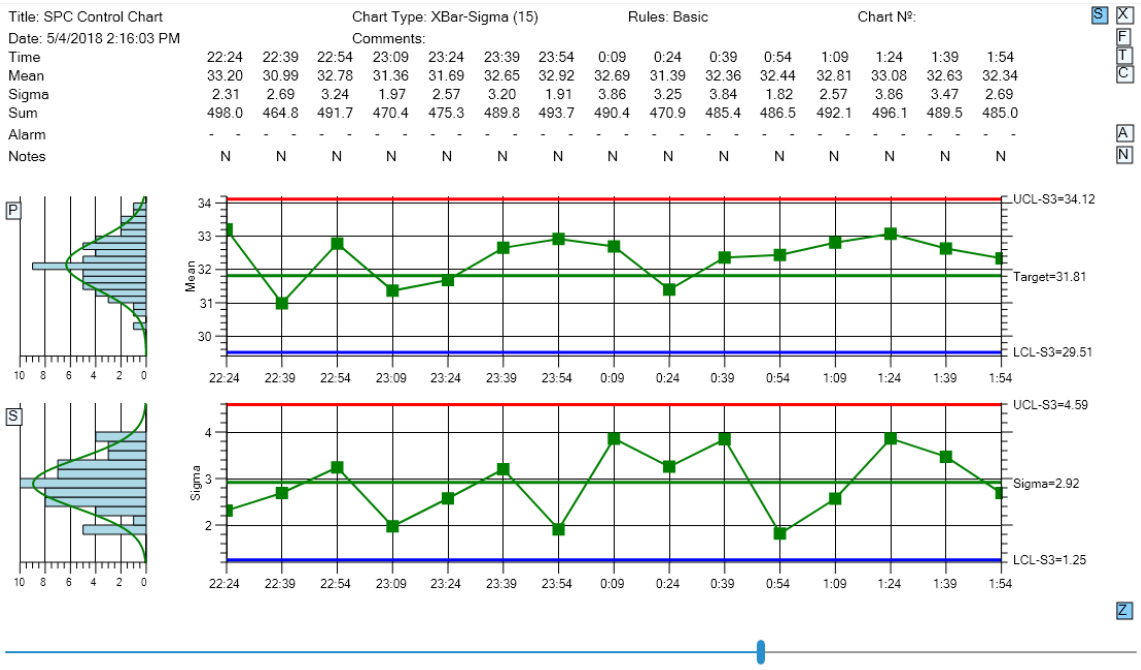
$$\text{Center line} = \bar{R}$$

$$LCL = \bar{R} - D_3 * \bar{R}$$

Where the constants A_2, D_3 and D_4 are tabulated in every SPC textbook for various sam

XBar-Sigma – Also known as the XBar-S Chart

Very similar to the XBar-R chart, the XBar-Sigma chart replaces the Range plot with a Sigma plot based on the standard deviation of the measured values within each subgroup. This is a more accurate way of establishing control limits if the sample size of the subgroup is moderately large (> 11). Though computationally more complicated, the use of a computer makes this a non-issue.



The Xbar-Sigma chart uses a standard deviation calculation as the basis for the Secondary chart.

XBar-Sigma

Control Limits for the X-Bar Chart

$$UCL = \bar{\bar{X}} + A_3 * \bar{S}$$

$$\text{Center line} = \bar{\bar{X}}$$

$$LCL = \bar{\bar{X}} - A_3 * \bar{S}$$

Control Limits for the Sigma-Chart

$$UCL = \bar{B}_4 * \bar{S}$$

$$\text{Center line} = \bar{S}$$

$$LCL = \bar{B}_3 * \bar{S}$$

Where the constants A_3, B_3 and B_4 are tabulated in every SPC textbook for various sample sizes.

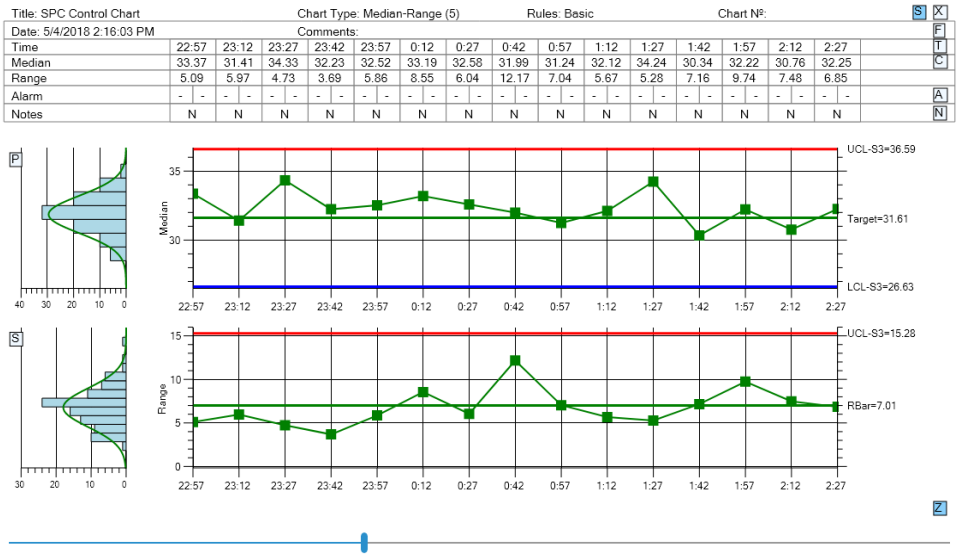
Median Range – Also known as the Median and Range Chart

Very similar to the XBar-R Chart, Median Range chart replaces the Mean plot with a Median plot representing the median of the measured values within each subgroup. In order to use a Median Range chart the process needs to be well behaved, where the variation in measured variables are (1) known to be distributed normally, (2) are not very often disturbed by assignable causes, and (3) are easily adjusted.

Median Range Chart

Control Limits for the Median Chart

$$UCL = \tilde{M} + \tilde{A}_2 * \tilde{R}$$



The Median-Range chart uses the median of a sample interval to estimate the sample interval mean.

$$\text{Center line} = \tilde{M}$$

$$\text{LCL} = \tilde{M} - A_2 * \tilde{R}$$

Control Limits for the R-Chart

$$\text{UCL} = \tilde{R} + D_4 * \tilde{R}$$

$$\text{Center line} = \tilde{R}$$

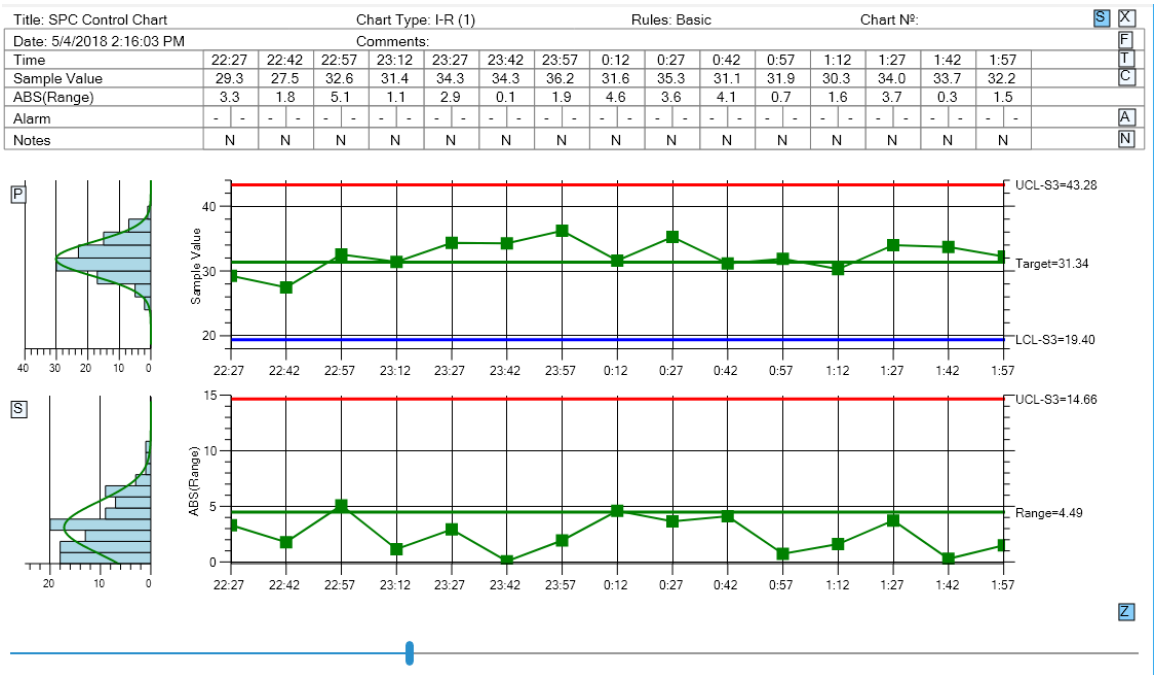
$$\text{LCL} = \tilde{R} - D_3 * \tilde{R}$$

The constants A_2, D_3 and D_4 for median-range charts are different than those for mean-range charts. A brief tabulation of the median-range chart specific values appears below

Size	A2	D3	D4
2	2.22	0.0	3.87
3	1.26	0.0	2.75
4	0.83	0.0	2.38
5	0.71	0.0	2.18

Individual Range Chart – Also known as the I-R and X-R Chart

The Individual Range Chart is used when the sample size for a subgroup is 1. This happens frequently when the inspection and collection of data for quality control purposes is automated and 100% of the units manufactured are analyzed. It also happens when the production rate is low and it is inconvenient to have sample sizes other than 1. The X part of the control chart plots the actual sampled value (not a mean or median) for each unit and the R part of the control chart plots a moving range that is calculated using the current value of sampled value minus the previous value.



The Individual-Range chart (X-R) chart uses only one sample per sample interval.

Individual Range Chart

Control Limits for the X-Bar Chart

$$UCL = \bar{\bar{X}} + E_2 * \bar{R}$$

$$\text{Center line} = \bar{\bar{X}}$$

$$LCL = \bar{\bar{X}} - E_2 * \bar{R}$$

Control Limits for the R-Chart

UCL	=	$D_4 * \bar{R}$
Center line	=	$\bar{R}$
LCL	=	0

$\bar{R}$ in this case is the average of the moving ranges.

$\bar{X}$ in this case is the mean of the samples

Where the constants E_2 and D_4 are tabulated in every SPC textbook for various sample sizes.

Adding New Sample Records for Variable Control Charts.

In variable control charts, each data value in the *samples* array represents a specific sample in the sample subgroup. In XBar-R, XBar-Sigma, and Median-Range charts, where the sample subgroup size is some fraction of the total production level, there is one value in the *samples* array for each measurement sample in the sample subgroup interval. If the production level is sixty items per hour, and the sample size is five items per hour, then the graph would be updated once an hour with five items in the *samples* array.

In an Individual-Range chart, and EWMA and MA charts that uses rational subgroup sizes of 1, the *samples* array would only have one value for each update. If the production level is sixty items per hour, with 100% sampling, the graph would be updated once a minute, with a single value in the *samples* array.

Process Measurement Indices

Performance and Process Capability

In SPC, a manufacturing process is often subject to statistical analysis to calculate a simple measure of the overall process capability and performance. The Process Capability measure is generally referred to as Cpk with variants called Cp and Ck. The Process Capability (Cpk) measure is meant to be used on a process that is considered to be in statistical control. The Process Performance measure is meant to be used on a process which is in startup, or is still seeking statistical control.

Important Note - Cpk, Cp, Ppk and Pp calculations require Upper Spec Limit (USL) and Lower Spec Limit (LSL) values be set. You must set those in the Control Limit setup option, otherwise the results are meaningless.

SPC Process Measurement Nomenclature

USL = Upper Specification Limit

LSL = Lower Specification Limit

Tau = Midpoint between USL and LSL = ½ * (LSL + USL)

=
X = XDoubleBar - Mean of sample subgroup means (also called the grand average)

$\bar{R}$ = RBar – Mean of sample subgroup ranges

S = Sigma – sample standard deviation – all samples from all subgroups are used to calculate the standard deviation S.

$\bar{S}$ = SigmaBar – Average of sample subgroup sigma's. Each sample subgroup has a calculated standard deviation and the SigmaBar value is the mean of those subgroup standard deviations.

d2 = a constant tabulated in every SPC textbook for various sample sizes.

By convention, the quantity RBar/d2 is used to estimate the process sigma for the Cp, Cpl and Cpu calculations

MINIMUM – a function that returns the lesser of two arguments

SQRT – a function returning the square root of the argument.

Process Capability Ratios (Cp, Cpl, Cpu, Cpk and Cpm)

Cp = (USL – LSL) / (6 * RBar/d2)

Cpl = (XDoubleBar – LSL) / (3 * RBar/d2)

Cpu = (USL - XDoubleBar) / (3 * RBar/d2)

Cpk = MINIMUM (Cpl, Cpu)

Cpm = Cp / (SQRT(1 + V^2)

where

V = (XDoubleBar – Tau) / S

Process Performance Indices (Pp, Ppl, Ppu, Ppk)

Pp = (USL – LSL) / (6 * S)

Ppl = (XDoubleBar – LSL) / (3 * S)

Ppu = (USL - XDoubleBar) / (3 *S)

Ppk = MINIMUM (Ppl, Ppu)

The major difference between the Process Capability Ratios (Cp, Cpl, Cpu, Cpk) and the Process Performance Indices (Pp, Ppl, Ppu, Ppk) is the estimate used for the process sigma. The Process Capability Ratios use the estimate (RBar/d2) and the Process Performance Indices uses the sample standard deviation S. If the process is in control, then Cp vs Pp and Cpk vs Ppk should return approximately the same values, since both (RBar/d2) and the sample sigma S will be good estimates of the overall process sigma. If

the process is NOT in control, then ANSI (American National Standards Institute) recommends that the Process Performance Indices (Pp, Ppl, Ppu, Ppk) be used.

3. SPC Attribute Control Charts

Attribute Control Charts are a set of control charts specifically designed for tracking product defects (also called non-conformities). These types of defects are binary in nature (yes/no), where a part has one or more defects, or it doesn't. Examples of defects are paint scratches, discolorations, breaks in the weave of a textile, dents, cuts, etc. Think of the last car that you bought. The defects in each sample group are counted and run through some statistical calculations. Depending on the type of *Attribute Control Chart*, the number of defective parts are tracked (p-chart and np-chart), or alternatively, the number of defects are tracked (u-chart, c-chart). The difference in terminology "number of defective parts" and "number of defects" is highly significant, since a single part not only can have multiple defect categories (scratch, color, dent, etc), it can also have multiple defects per category. A single part may have 0 – N defects. So keeping track of the number of defective parts is statistically different from keeping track of the number of defects. This affects the way the control limits for each chart are calculated.

What follows is a brief description of each of these Attribute control charts, and the formulas used by the software to calculate the upper and lower 3-sigma control limits used in each of the charts. We use the formulas found in the textbook. "Introduction to Statistical Quality Control" by Douglas C. Montgomery, 6th Edition, John Wiley and Sons, Inc. 2009.

The formulas use the following common nomenclature:

SPC Attribute Control Chart Nomenclature

UCL = Upper Control Limit

LCL = Lower Control Limit

Center line = The target value for the process

p = estimate (or average) of the fraction defective (or non-conforming) parts

P = estimate (or average) of the percent defective (or non-conforming) parts

c = estimate (or average) of the number of defects (or nonconformities)

u = estimate (or average) of the number of defects (or nonconformities) per unit

n = number of samples per subgroup

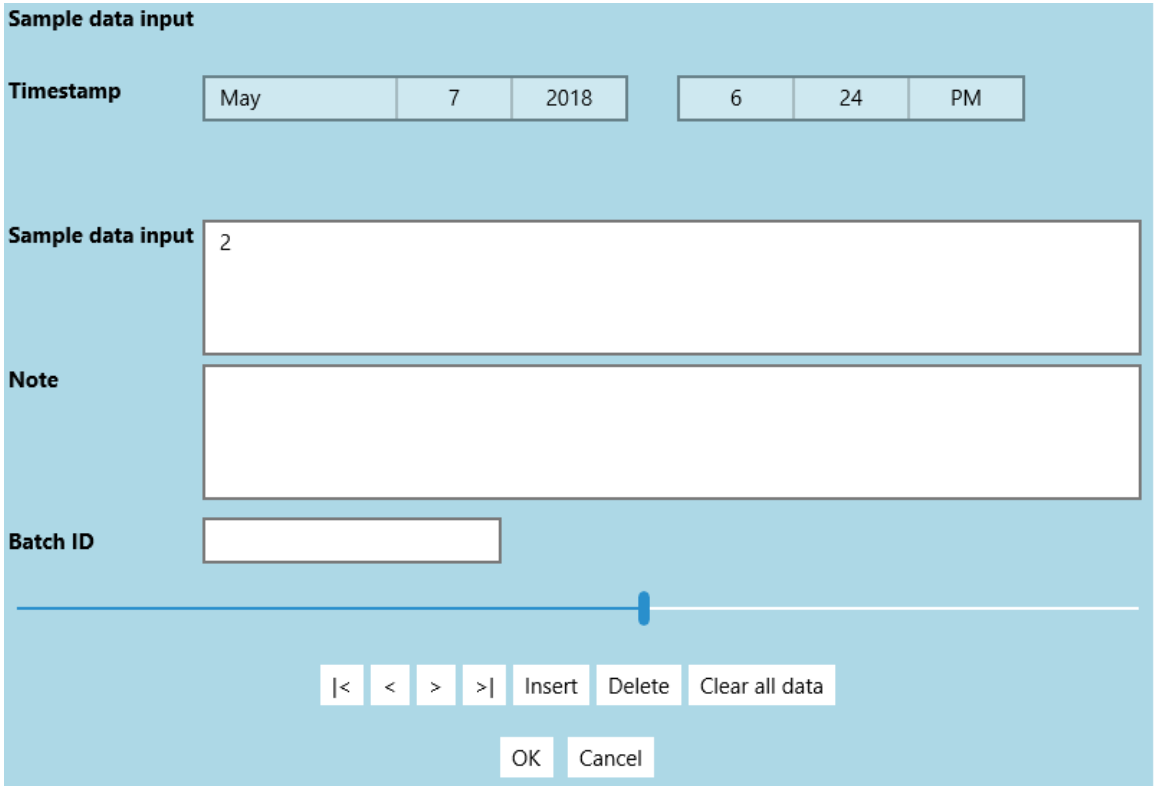
dopu = defect opportunities per unit (applies only the DPMO chart)

dpmo = defects per million opportunities (applies only the DPMO chart)
calculated as: dpmo = (1,000,000 * numberOfDefects) / (sampleSize * dopu)

up = estimate (or average) of the dpmo values

In this case the value (n * p) represents the average number of defective parts per sample subgroup. Since p is the estimate (or average) of the fraction defective per sample subgroup, n * p is the average number of defective per sample subgroup. Or you can add up all the number defective parts in all subgroups and divide by the number of subgroups, that to will reduce to the average number of defective per sample subgroup.

Attribute control charts will have a sample subgroup size of N, where N is on the order of 100, representing the number of units sampled for a sample interval. The number of defective parts (or the number of defects) will be counted, and entered as a single whole number for that sample interval. If you use the Add/Edit menu option to add your data to the chart, a typical example of the data for a typical sample interval would look like the example below.

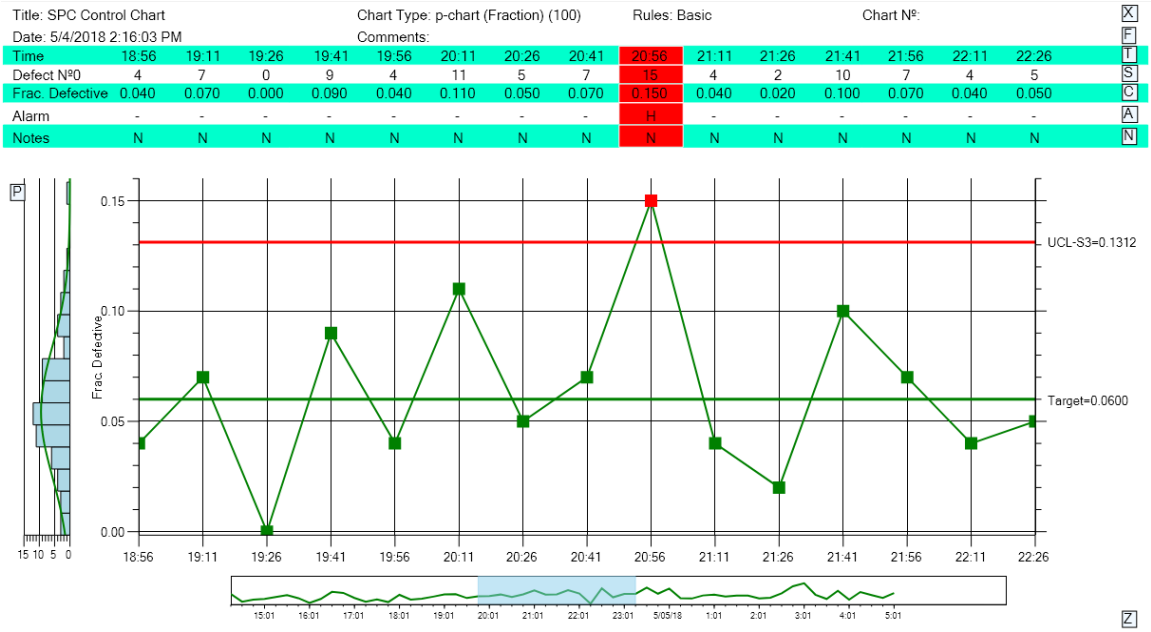


The Attribute control charts use only a single data value per sample interval.

Attribute Charts using the number of defective parts

p-Chart - Also known as the Percent or Fraction Defective Parts Chart

For a sample subgroup, the number of defective parts is measured and plotted as either a percentage of the total subgroup sample size, or a fraction of the total subgroup sample size. Since the plotted value is a fraction or percent of the sample subgroup size, the size of the sample group can vary without rendering the chart useless. For both the Fraction Defective Parts, the Percent Defective Parts, the input to the sample interval section is still the total number of defective parts, as a whole number, even though the resultant chart displays total defects as a fraction or a percentage.



The p-chart monitors the number of defective parts per sample interval.

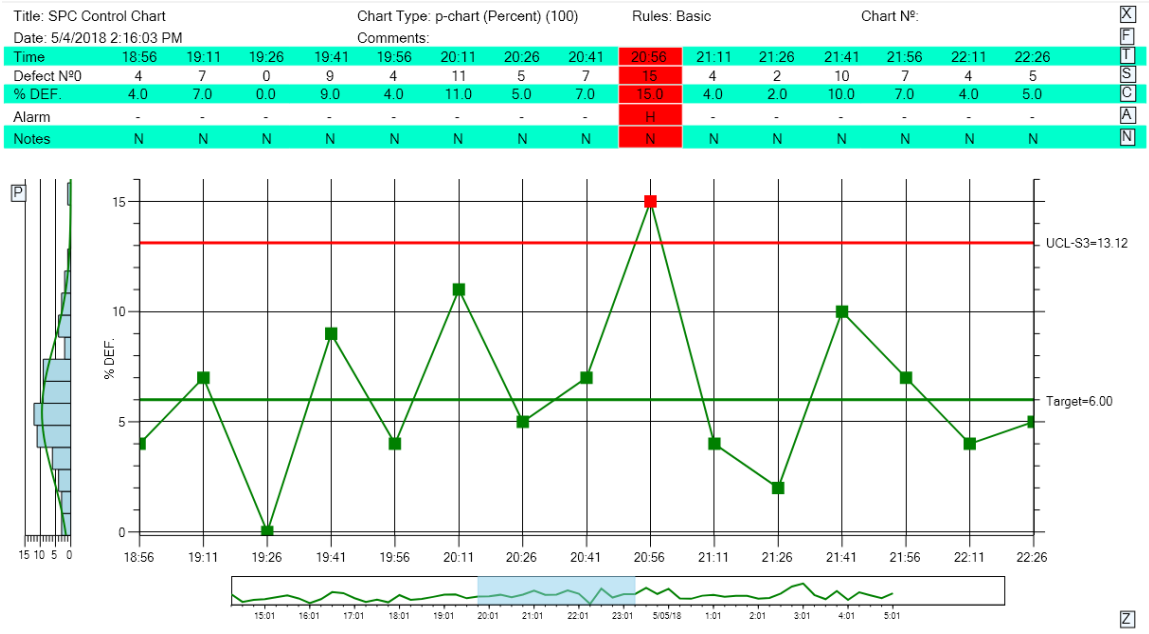
Fraction Defective Parts – Also known as Fraction Non-Conforming or p-chart

$$UCL = p + 3 * Sqrt (p * (1- p) / n)$$

$$\text{Center line} = p$$

$$LCL = p - 3 * Sqrt (p * (1- p) / n)$$

Percent Defective Parts – Also known as Percent Non-Conforming or p-chart



The percent p-chart displays the number of defective parts per sample interval as a percentage of the sample size.

.

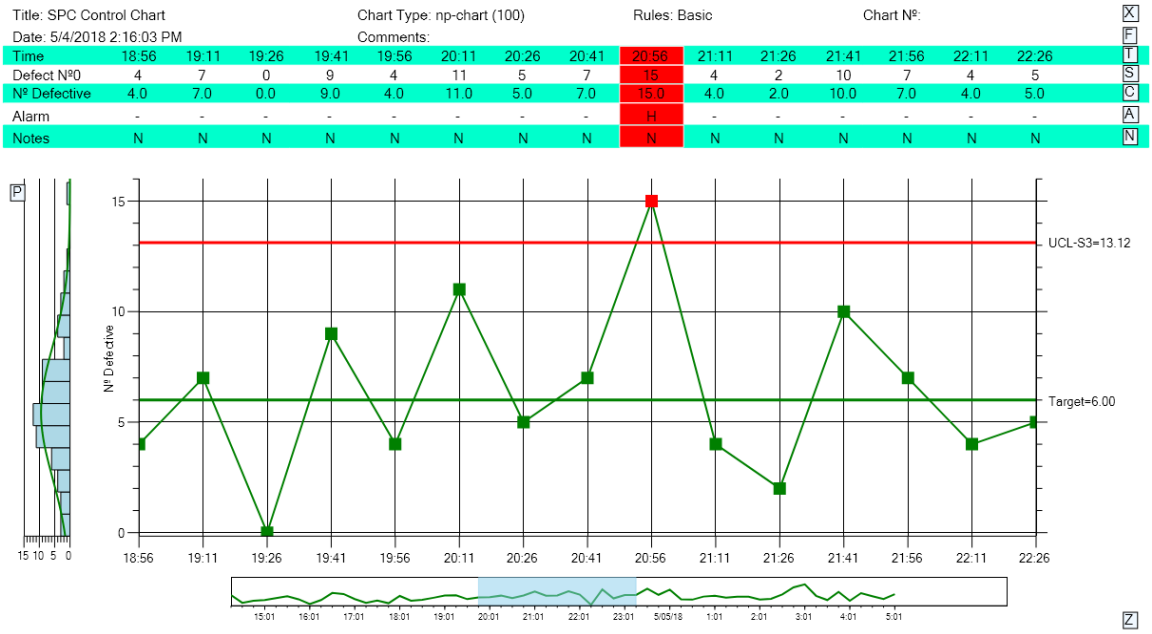
$$\text{UCL} = p + 3 * \text{Sqrt}(p * (100\% - p) / n)$$

$$\text{Center line} = p$$

$$\text{LCL} = p - 3 * \text{Sqrt}(p * (100\% - p) / n)$$

np-Chart – Also known as the Number Defective Parts Chart

For a sample subgroup, the number of defective parts is measured and plotted as a simple count. Statistically, in order to compare number of defective parts for one subgroup with the other subgroups, this type of chart requires that the subgroup sample size is fixed across all subgroups.



The percent np-chart displays the number of defective parts per sample interval as the actual number of defects.

Number of Defective Parts – Also known as the Number Nonconforming or np-chart

$$UCL = (n * p) + 3 * Sqrt\ ((n * p) * (1 - p) / n)$$

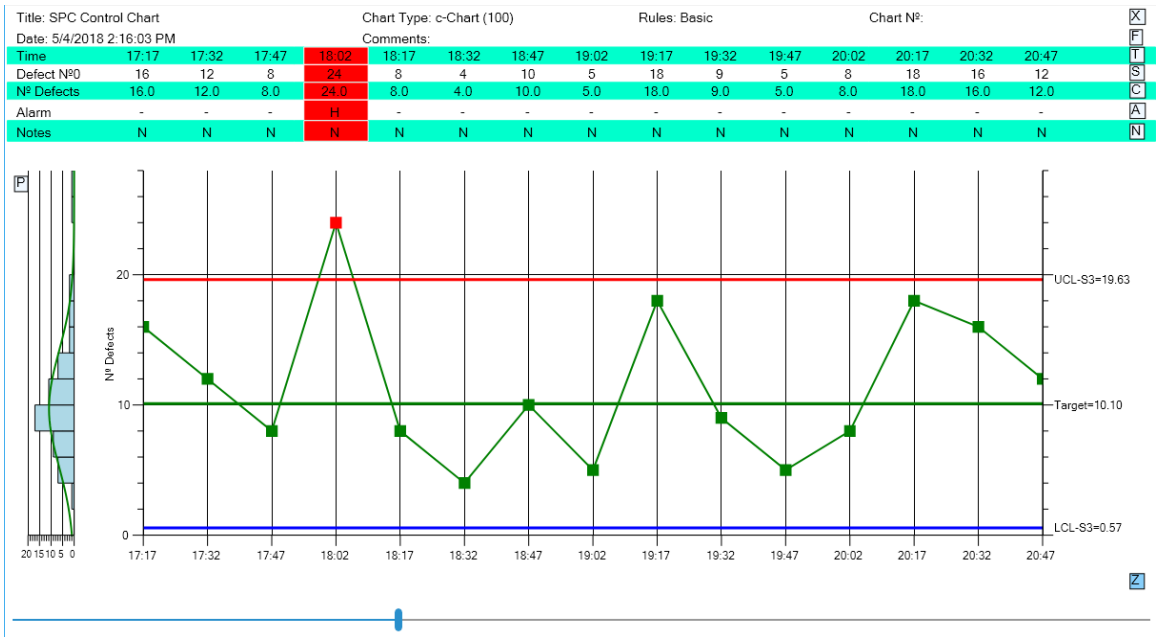
$$Center\ line = (n * p)$$

$$LCL = (n * p) - 3 * Sqrt\ ((n * p) * (1 - p) / n)$$

Attribute Charts using the number of defects

c-Chart - Also known as the Number of Defects or Number of Non-Conformities Chart

For a sample subgroup, the number of times a defect occurs is measured and plotted as a simple count. Statistically, in order to compare number of defects for one subgroup with the other subgroups, this type of chart requires that the subgroup sample size is fixed across all subgroups.



The c-chart displays the number of total defects per sample interval.

Number of Defects Control Chart – Also known as Number Nonconformities or c-chart

UCL	=	c	+	3 * Sqrt (c)
Center line	=	c		
LCL	=	c	-	3 * Sqrt (c)

u-Chart – Also known as the Number of Defects per Unit or Number of Non-Conformities per Unit Chart

For a sample subgroup, the number of times a defect occurs is measured and plotted as either a percentage of the total subgroup sample size, or a fraction of the total subgroup sample size. Since the plotted value is a fraction or percent of the sample subgroup size, the size of the sample group can vary without rendering the chart useless. Even though the output of the chart shows a y-axis which is scaled to a fraction or a percentage, the input to the sample interval section is still the total number of defects, as a whole number.

The u-chart displays the number of defects normalized (divided by) the number of samples per sample interval.

Number of Defects per Unit Control Chart – Also known as Number Nonconformities per Unit or u-chart

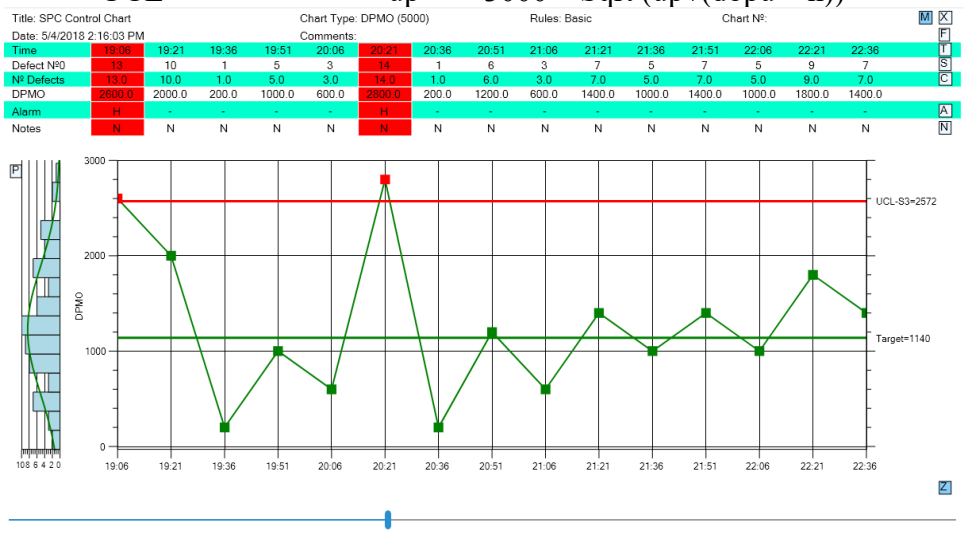
UCL	=	u	+	3 * Sqrt (u / n)
Center line	=	u		
LCL	=	u	-	3 * Sqrt (u / n)

DPMO Chart – Also known as the Number of Defects per Million Chart

For a sample subgroup, the number of times a defect occurs is measured and plotted as a value normalized to defects per million. Since the plotted value is normalized to a fixed sample subgroup size, the size of the sample group can vary without rendering the chart useless.

Number Defects Per Million – Also known as DPMO

$$UCL = up + 3000 * Sqrt(up /(dopu * n))$$



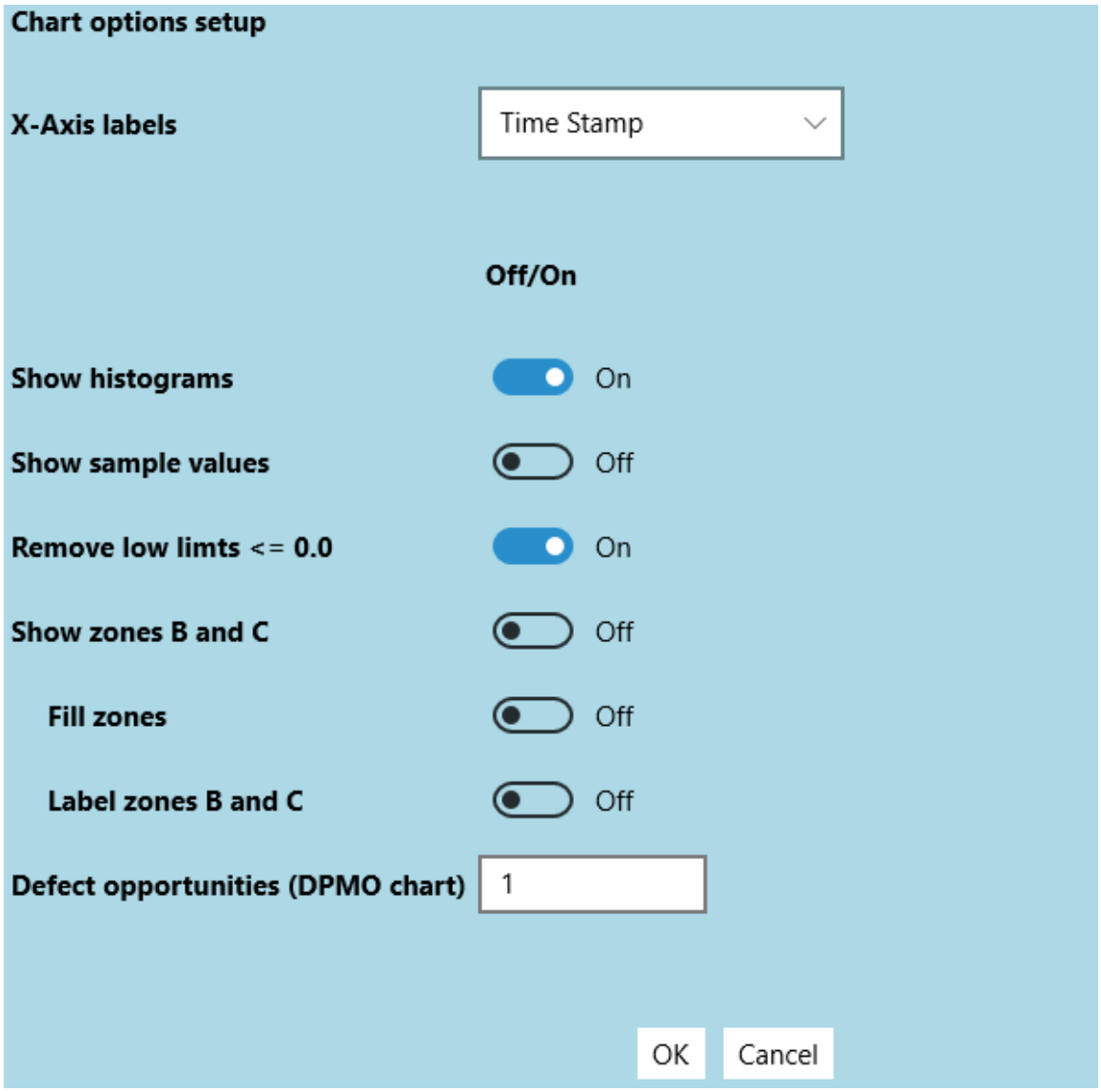
The DPMO-chart displays the number of defects normalized (divided by) one million.

$$Center\ line = up$$

$$LCL = up - 3000 * Sqrt(up/(dopu * n))$$

Special Note for DPMO Charts

DPMO charts use an important parameter known is the *defect opportunites per unit*. The default value for the parameter is 1. So if you are using 1 as the the value of *defect opportunites per unit* in your chart, you don't need to do anything. If your value is greater than 1, you need to specify that using the Defect opportunites per unit (DPMO) property in the Chart Options dialog.



If your DPMO chart uses a defect opportunities value other than 1, you will need to set that in the Chart Options setup form.

4. Control Rule Sets

Western Electric (WECO) Rules

The normal SPC control limit rules display at the 3-sigma level, both high and low. In this case, a simple threshold test determines if a process is in, or out of control. Once a process is brought under control using the simple 3-sigma level tests, quality engineers often want to increase the sensitivity of the control chart, detecting and correcting problems before the 3-sigma control limits are reached. Other, more complex tests rely on more complicated decision-making criteria. These rules utilize historical data and look for a non-random pattern that can signify that the process is out of control, before reaching the normal ±3 sigma limits. The most popular of these are the Western Electric Rules, also know as the WECO Rules, or WE Runtime Rules. First implemented by the Western Electric Co. in the 1920's, these quality control guidelines were codified in the 1950's and form the basis for all of the other rule sets. Different industries across the globe have have developed their own variants on the WECO Rules. Other sets of rules, common enough to have an identifying name, i.e. *named rules*, are listed below.

WECO Runtime and Supplemental Rules – Western Electric Co. - Western Electric Company (1956), *Statistical Quality Control handbook.* (1 ed.), Indianapolis, Indiana: Western Electric Co., p. v, OCLC 33858387. Sometimes the Supplemental Rules are referred to as the Montgomery Rules, after the statistical quality control expert Douglas Mongtomery. *Introduction to Statistical Quality Control* (5 ed.), Hoboken, New Jersey: John Wiley & Sons, ISBN 9780471656319

There are other, commonly used named rule sets which are not included in the free version of the software, but are found in the Standard version, which if not already out, will be out in July 2018.

Nelson Rules – The Nelson rules were first published in the October 1984 issue of the Journal of Quality Technology in an article by Lloyd S Nelson.

AIAG Rules– The (AIAG) Automotive Industry Action Group control rules are published in the their industry group "Statistical Process Control Handbook".

Juran Rules - Joseph M. Juran was an international expert in quality control and defined these rules in his "Juran's Quality Handbook", McGraw-Hill Professional; 6 edition (May 19, 2010), **ISBN-10:** 0071629734

Hughes Rules – The only sources we could find for the Hughes rules were all second hand. If anyone can direct is to an original source for the Hughes Rules, please send an e-mail to support@quinn-curtis.com.

Duncan Rules – Acheson Johnston Duncan was an international expert in quality control and published his rules in the text book "Quality control and industrial statistics" (fifth edition). Irwin, 1986.

Gitlow Rules - Dr. Howard S. Gitlow is an international expert in Sigma Six, TQM and SPC. His rules are found in his book "Tools and Methods for the Improvement of Quality", 1989, **ISBN-10: 0256056803** .

Westgard Rules – The Westgard rules are based on the work of James Westgard, a leading expert in laboratory quality management . They are considered "Laboratory quality control rules". You can find more information about the Westgard Rules, and James Westgard at the web site: http://www.westgard.com

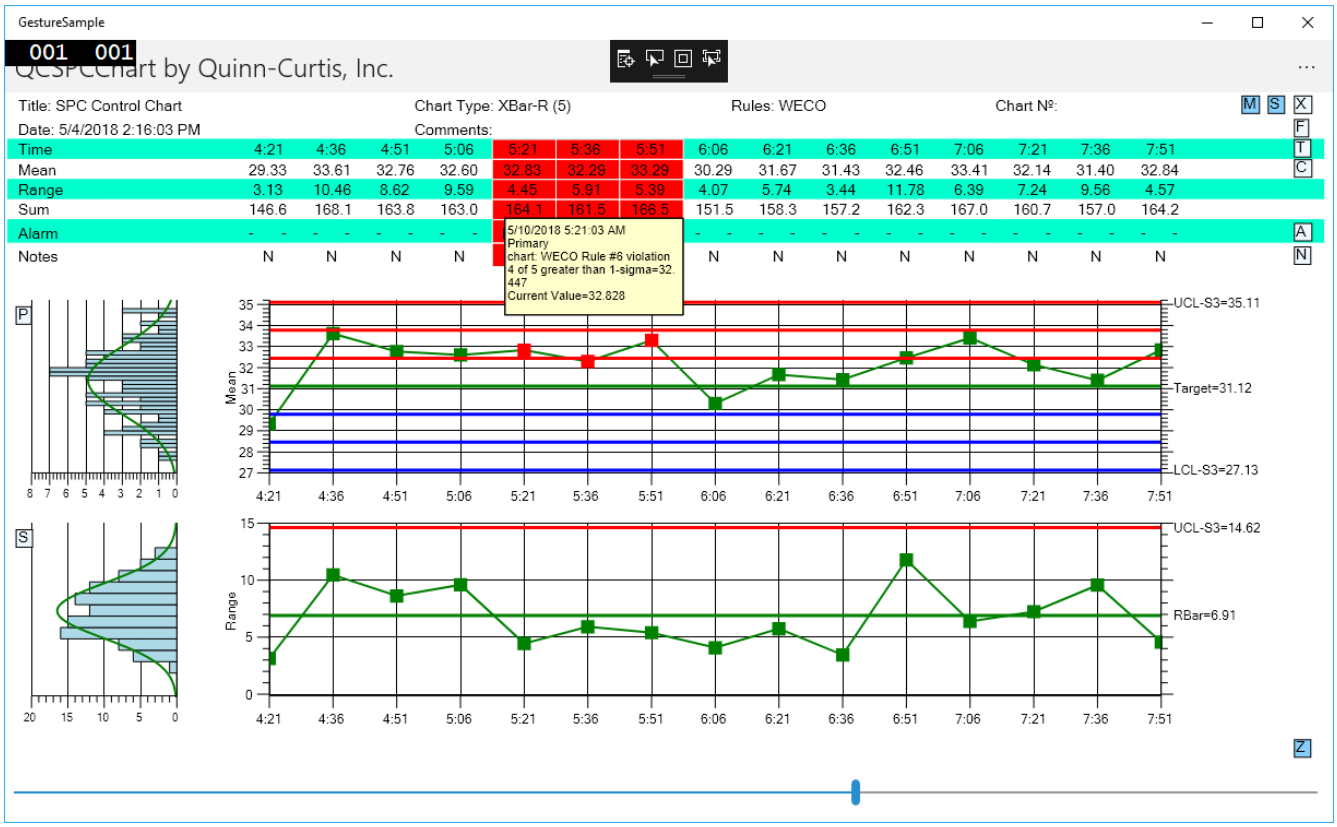
The rules sets have many individual rules in common. In particular, the WECO rules and the Nelson rules, have 7 out of 8 rules in common, and only differ in the fourth rule.

Basic Rules

The Basic Rules are the default rules for all of the SPC charts. They correspond to the ±3-sigma rules used by almost every industry standard SPC chart implementation.

1. One of one point is outside of ±3-sigma control limits

Western Electric (WECO) Rules



The Western Electric Rules adds many additional tests to the Basic +-3 sigma rules, looking for early signs that a process is out-of-control.

In the Western Electric Rules A process is considered out of control if any of the following criteria are met:

1. **The most recent point plots outside one of the 3-sigma control limits.** If a point lies outside either of these limits, there is only a 0.3% chance that this was caused by the normal process.

2. **Two of the three most recent points plot outside and on the same side as one of the 2-sigma control limits.** The probability that any point will fall outside the warning limit is only 5%. The chances that two out of three points in a row fall outside the warning limit is only about 1%.

3. **Four of the five most recent points plot outside and on the same side as one of the 1-sigma control limits.** In normal processing, 68% of points fall within one sigma of the mean, and 32% fall outside it. The probability that 4 of 5 points fall outside of one sigma is only about 3%.

4. **Eight out of the last eight points plot on the same side of the center line, or target value.** Sometimes you see this as 9 out of 9, or 7 out of 7. There is an equal chance that any given point will fall above or below the mean. The chances that a point falls on the same side of the mean as the one before it is one in two. The odds that the next point will also fall on the same side of the mean is one in four. The probability of getting eight points on the same side of the mean is only around 1%.

These rules apply to both sides of the center line at a time. Therefore, there are eight actual alarm conditions: four for the above center line sigma levels and four for the below center line sigma levels.

There are also additional WE Rules for trending. These are often referred to as **WE Supplemental Rules**. Don't rely on the rule number, often these are listed in a different order.

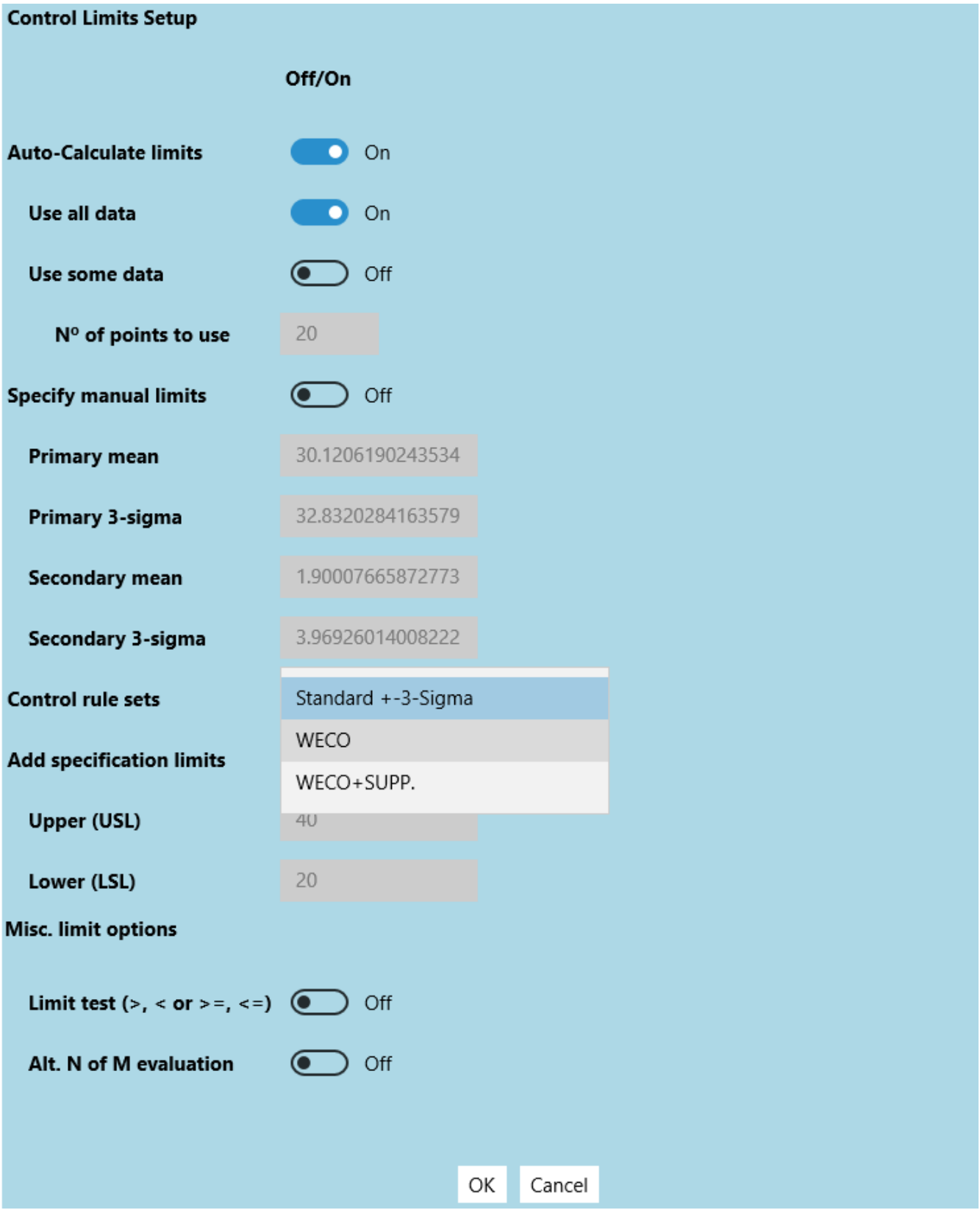
5. **Six points in a row increasing or decreasing.** The same logic is used here as for rule 4 above. Sometimes this rule is changed to seven points rising or falling.

6. **Fifteen points in a row within one sigma.** In normal operation, 68% of points will fall within one sigma of the mean. The probability that 15 points in a row will do so, is less than 1%.

7. **Fourteen points in a row alternating direction.** The chances that the second point is always higher than (or always lower than) the preceding point, for all seven pairs is only about 1%.

8. **Eight points in a row outside one sigma.** Since 68% of points lie within one sigma of the mean, the probability that eight points in a row fall outside of the one-sigma line is less than 1%.

Select which rule set (Standard +- 3-Sigma, WECO or WECO+Supplemental) you want to use by setting the *Control rule sets* property of the Control Limits menu item.



Use the Control Limits setup form to set the Control rule set you want to use.

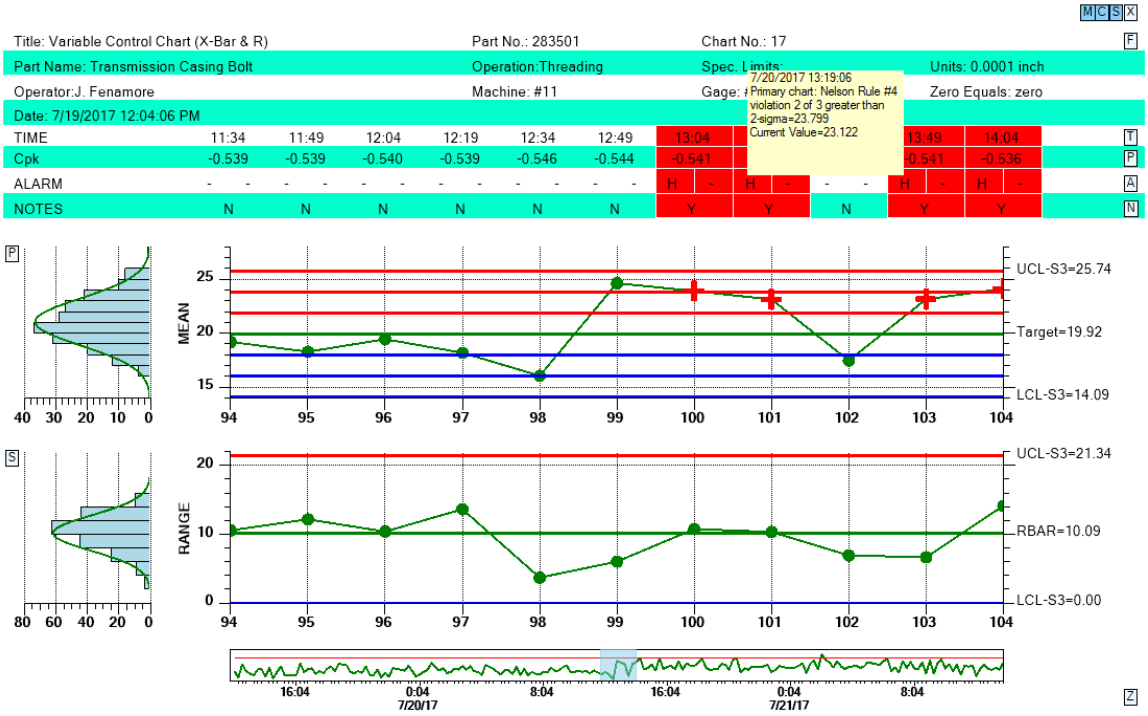
N of M testing when the most recent point entering the test is within limits

Our default mode takes a strict approach to N of M testing. Regardless of the value of the most recent point to enter the calculation (even if it is within the test limits), if N of M values are outside of limits we consider the sample interval to be in alarm. But some customers challenged this interpretation and presented us with published examples which show that if the most recent point is within limits and the previous N points out of limits, the sample interval should NOT be considered in alarm. The logic for those using the alternative evaluation scheme is that after the the first N values were found to fail the N of M test, a correction was made to the process. And therefore the next sample interval is within limits and should not be in alarm, even though it fails the strict N of M test, since it still picks up the N out of limit values before the process was corrected. We researched the issue and found no agreement. It is implemented in the published literature both ways, going back 50 years. So a simple global flag has been added you can use to choose one evaluation method or the other, with the default being our original method. If you want to change the N of M evaluation scheme from the default (strict N of M testing), to the alternative method, go to the Control Limits setup page and set the Alternative N of M test property to On.

Misc. Control Limit Options

Alt N of M test **[Off]**

In the picture below, the default method of N of M valuation produces an alarm at sample interval 101. While sample 101 is within 2-sigma, the previous two samples were greater than 2-sigma, so the 2 out of 3 > 2-sigma test fails for sample interval 101.



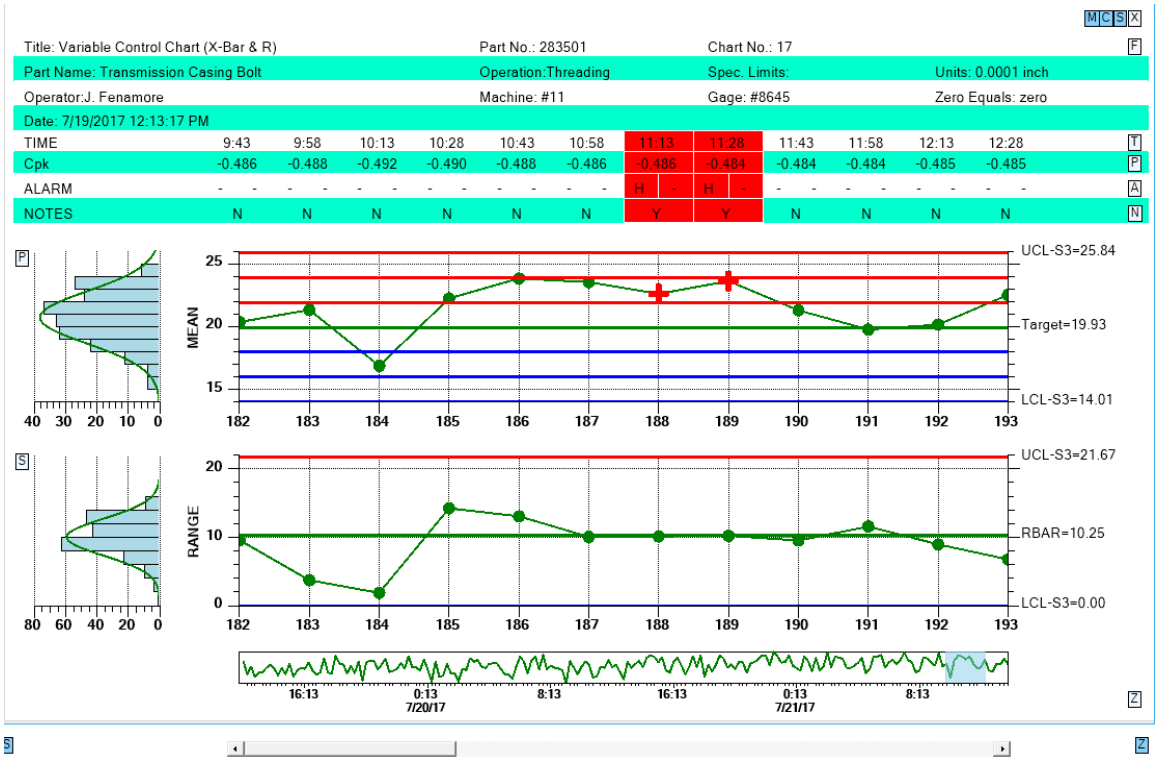
Using the default N of M testing, the sample interval 101 fails the 2 out of 3 > 2-sigma test of the WECO and Nelson rules.

If the **Alt N of M test** property is set to On:

Alt N of M test [On]

sample 101 would NOT be in alarm, even though the previous two samples were > 2-sigma.

In the picture below, DefaultAltNofMRule property has been set On. Using the regular, default rules, the sample interval at 190 would be considered in alarm because 4 out of 5 samples intervals were greater than 1-sigma. But since the alternative evaluation method for N of M rules is enabled, it is shown as NOT being in alarm, because it is within 1-sigma.



Using the Alternative N of M evaluation method, sample interval 190 does not show an alarm for the 4 out of 5 > 1-sigma test, because it is within 1-sigma.

Appendix

Sample	Xbar-R Charts				Xbar-Sigma		
Size	A2	d2	D3	D4	A3	B3	B4
2	1.88	1.128	0	3.268	2.659	0	3.267
3	1.023	1.693	0	2.574	1.954	0	2.568
4	0.729	2.059	0	2.282	1.628	0	2.266
5	0.577	2.326	0	2.114	1.427	0	2.089
6	0.483	2.534	0	2.004	1.287	0.03	1.97}
7	0.419	2.704	0.076	1.924	1.182	0.118	1.882
8	0.373	2.847	0.136	1.864	1.099	0.185	1.815
9	0.337	2.97	0.184	1.816	1.032	0.239	1.761
10	0.308	3.078	0.223	1.777	0.975	0.284	1.716
11	0.285	3.173	0.256	1.744	0.927	0.321	1.679
12	0.266	3.258	0.283	1.717	0.886	0.354	1.646
13	0.249	3.336	0.307	1.693	0.85	0.382	1.618
14	0.235	3.407	0.328	1.672	0.817	0.406	1.594
15	0.223	3.472	0.347	1.653	0.789	0.428	1.572
16	0.212	3.532	0.363	1.637	0.763	0.448	1.552
17	0.203	3.588	0.378	1.622	0.739	0.466	1.534
18	0.194	3.64	0.391	1.608	0.718	0.482	1.518
19	0.187	3.689	0.403	1.597	0.698	0.497	1.503
20	0.18	3.735	0.415	1.585	0.68	0.51	1.49
21	0.173	3.778	0.425	1.575	0.663	0.523	1.477
22	0.167	3.819	0.434	1.566	0.647	0.534	1.466
23	0.162	3.858	0.443	1.557	0.638	0.545	1.455
24	0.157	3.895	0.451	1.548	0.619	0.555	1.445
25	0.153	3.931	0.459	1.541	0.606	0.565	1.435

Sample	I-R Chart		Median-Range	
Size	E2	D4	A3	D3
1	2.66	3.268		
2			2.22	0.0
3			1.26	0.0
4			0.83	0.0
5			0.71	0.0

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