

# Statistical Process Control (SPC)



HELP.QMQCSPC

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## Icons

Icon	Meaning
	Caution
	Example
	Note
	Recommendation
	Syntax

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## Statistical Process Control (SPC)

### Purpose

Statistical process control (SPC) is used to monitor, control, and improve processes.

### Features

The most important tool in statistical process control is the [control chart \[Page 6\]](#)

## Control Charts (QM-QC-AQC-CHT)

### Purpose

A **control chart** is a graphical tool used by quality technicians to control, analyze and document the processes involved in production and other quality-relevant areas.

Control charts are used to detect systematic deviations of a quality characteristic from a target value (signals) against the background of inevitable, random fluctuations in individual measured values (interference). Today, this form of control chart is the central element of **statistical process control** (SPC).

### Implementation Considerations

Control charts are primarily used in **inspections during production** to monitor and manage controlled production processes. A process is *controlled* or *under statistical control* if the observed process parameters only vary randomly from sample to sample. The control chart can be used to detect special influences on the process. You correct the disturbances by intervening in the process. You can use the control chart to determine whether the correction was successful.

The control chart is also a suitable medium for determining whether a process is or was in control or not, even if it is too late for corrective interventions. The control chart, therefore, can also be used for procurement and dispatch (for example, for incoming inspections based on a scheduling agreement with periodic release orders).

### Integration

You define how to run a control chart for an inspection characteristic during your **inspection planning** activities. You can run control charts within an inspection lot/production order or for several inspection lots/production orders.

You can display and update control charts during **results recording** or using a separate transaction. You can have the system calculate the action limits and warning limits (if necessary) in the control chart window. The algorithms required to do this are stored in the Customizing application and can be replaced if necessary.

You can use a control chart to **value the inspection results**.

If the relevant valuation rule is used, a sample is rejected if at least one of the action limits defined in the associated control chart was violated.

If action limits are violated, the **Workflow** can be triggered automatically, provided that you have defined a suitable defect code in the inspection plan characteristic and the system has been set accordingly.



You cannot value inspection results based on the action limits and link the Workflow for moving mean-value charts, EWMA charts, and moving range charts.

A [run-chart \[Ext.\]](#) is a graphic that is similar to a control chart. The run chart displays a chronological curve of the measured values or sample mean values for a characteristic. In contrast to control charts, a run chart does not contain action limits; instead, it contains limits for the tolerance range. As with [a histogram \[Ext.\]](#), you can call up a run chart during results recording and when making evaluations, without making any prior settings in the basic data.

## Features

In statistical process control, one or more **control variables** of the observed characteristic are selected and determined by taking samples from the process at set time intervals if possible. These statistics are entered in the chart in chronological order. The most important control variables are:

- Mean value  $\bar{x}$
- Standard deviation  $s$
- Median value
- Range
- Original value of a sample
- Number of nonconforming units
- Number of defects

Two control variables of a characteristic are often run in parallel as two **tracks** on a control chart (for example, the mean value and the standard deviation). In this example, the location and dispersion of the process can be observed at the same time.

Apart from the control variable, each track on the control chart also contains **control limits** for the process. You must intervene in the process if these limits are violated. In addition to these action limits, you can also define warning limits (only when using SAP Statistical Graphics) or a mean line for individual chart types.

The limits are generally determined from the current process data or the results of a preliminary run, using statistical methods. The limits are calculated using various algorithms that are based on different mathematical approaches.

The standard control charts are:

- Acceptance charts
- Shewhart charts

**Acceptance charts** are based on the specified tolerance and control the share of scrap in the process. With these charts, the limits are extended if a long-term reduction in the process dispersion can be achieved by means of technical or organizational changes.

With **Shewhart charts**, the limits contract in this case. These charts only take internal process parameters into account and not external tolerance specifications. In a constantly recurring statistical test, the hypothesis that the defined "in control" status of the process has not (yet) changed, is tested.

Other types of control chart are currently used in industry in addition to these standard types. These include charts with extended limits, pre-control charts, cusum charts and various moving-average charts.

The following control chart types are available in the *Quality Management* component for inspection characteristics:

- Mean value chart with tolerances (acceptance chart)
- Mean value chart without tolerances (Shewhart chart)
- Standard deviation chart (Shewhart chart)

**Control Charts (QM-QC-AQC-CHT)**

- Moving mean-value chart
- EWMA chart (for mean values with exponential weighting)
- Original value and moving range chart for sample size  $n = 1$
- NP-chart for the number of nonconforming units
- P-chart for the fraction of nonconforming units
- C-chart for the number of defects
- U-chart for the number of defects for each sample unit



## Planning Control Charts

### Purpose

If you want to manage a control chart for an inspection characteristic during inspection processing, you must take the appropriate steps when planning a quality inspection. You make the settings required for this in the **sampling procedure** and in the **task list characteristic**. If you are using master inspection characteristics, some of the preparations can be made in the **master inspection characteristic**.



You cannot run control charts for a characteristic referenced in a material specification.

### Process Flow

The following steps are necessary for planning control charts:

1. [Maintaining sampling procedure for control charts \[Page 10\]](#)
2. [Maintaining inspection characteristics for control charts \[Page 12\]](#)

## Maintaining Sampling Procedure for Control Charts

# Maintaining Sampling Procedure for Control Charts

## Use

Control charts can only be used for inspection characteristics with sampling procedures. You store the control chart type in the sampling procedure.

For information on how to maintain a sampling procedure, see [Changing a Sampling Procedure \[Ext.\]](#).

When maintaining sampling procedures for control charts, you should pay particular attention to the following guidelines.

## Creating a Sampling Procedure for Control Charts

When you create a **new sampling procedure**, you must maintain the following data specifically for using control charts:

- **Sampling Type**

You must choose **fixed sample**.

- **Valuation Mode**

You can select the valuation mode yourself. A special valuation mode **SPC inspection** is available, however, for valuating samples or characteristics using the action limits of the control chart. If an action limit is violated in this mode, the sample or characteristic is rejected. The system automatically switches to manual valuation if no action limits have been calculated (initial run).



For control charts with a memory (moving mean-average charts, EWMA charts and moving range charts), the control variable is not just based on the current sample.

The **SPC inspection** valuation mode is not supported for these control chart tracks.

- **Control Chart Type**

You can assign a **control chart type** to a sampling procedure. If you have selected the SPC inspection valuation mode, you must enter a control chart type. When a control chart type is assigned, the system checks whether inspection points or independent multiple samples have been planned in the sampling procedure. Control chart types with samples can only be assigned if this is the case. (Otherwise control chart types without samples are assigned.) The appropriate short text for the control chart type is displayed after you have assigned the control chart type.

- **Sample Size**

When selecting the sample size, you should take certain quality-relevant conditions into account.

If you want to use the sample size **n=1**, you should make sure that:

- The control chart does not contain an s track.
- While calculating the action limits, the process dispersion is determined using the total dispersion or the dispersion between samples and not using the internal dispersion.

### Maintaining Sampling Procedure for Control Charts

The reason for this is that the standard deviation of sample size  $n=1$  is always 0.

In the case of **SPC inspections with recording of measured values**, sample sizes between 4 and 20 are standard; the most frequently used value is **n=5**.

By choosing a larger sample size, you can use the central specification limit record for quantitative characteristics whose original values do not have a normal distribution. An approximate normal distribution of the mean values is then calculated according to this central specification limit record. Therefore, you can also use Shewhart charts for the mean value even if the population is not normally distributed. The sample size you select should be in accordance with the degree to which the distribution deviates from the standard distribution.

- **Inspection frequency** (for a sampling procedure with inspection points during production)

### Extending Existing Sampling Procedures for Control Charts

You can modify an existing sampling procedure with the sample type **fixed sample** in order to use a control chart. The above information must also be taken into consideration here.

Note that you must also extend the inspection plan characteristic in addition to the sampling procedure, if you want to create control charts.

**See also:**

[Valuating a Sample Using the Control Chart \[Page 24\]](#)

[Maintaining Inspection Characteristics for Control Charts \[Page 12\]](#)

## Maintaining Inspection Characteristics for Control Charts

### Use

If you plan to manage a control chart for an inspection characteristic, you can either use a suitable master inspection characteristic or define the characteristic in the plan directly.

**See also:**

[Maintaining Master Inspection Characteristics for Control Charts \[Page 13\]](#)

[Maintaining Task List Characteristics for Control Charts \[Page 15\]](#)

## Maintaining Master Inspection Characteristics for Control Charts

### Use

You must use master inspection characteristics to manage a control chart. A master inspection characteristic, however, must fulfill certain requirements if you want to use it **in the task list** with a control chart.

How to **create a master inspection characteristic** is described in [Processing Master Inspection Characteristics \[Ext.\]](#)

When you create master inspection characteristics for control charts, you must fulfill the following **special conditions**:

- You must set both the control indicators for the **sampling procedure** and the **SPC characteristic**.

When you assign the sampling procedure, the system checks whether the selected **control chart type** for the sampling procedure can be used for this characteristic. The following control indicators for the characteristic are then compared to the requirements profile of the control chart type:

- Measured values
- Upper specification limit
- Lower specification limit
- Confirmation of number of defects
- Single result
- Scope not fixed
- Fixed scope
- Smaller scope
- Larger scope



Suitable default values for the control indicators can be defined in Customizing to simplify this procedure and to avoid errors.

- If you want to document **action limit violations** automatically or report and process them using the SAP Workflow application, you must set the control indicator for **defects recording** and store defect codes if necessary.
- If you want to use the defects recording function, you can store up to three **defect codes**. The way in which these codes are used depends on the control chart tracks. For the mean value, the system uses the *At upper tolerance* and *At lower tolerance* codes, for the standard deviation it uses the *General* code. For the nonconforming units and number of defects, the codes *At upper tolerance* and *At lower tolerance* are used. If no code has been defined for *At upper tolerance* and *At lower tolerance*, the system uses the *General* code. If no codes have been defined, the system automatically displays a dialog box for recording defects during results recording if a sample or characteristic is rejected.

## Maintaining Master Inspection Characteristics for Control Charts



The defect class assigned to a defect code establishes the link to the Workflow function and activates the quality notification automatically. The appropriate settings for these functions are made in Customizing for the defect classes.

**See also:**

[Maintaining Control Indicators \[Ext.\]](#)

[Assigning Code Groups or Selected Sets to A Characteristic \[Ext.\]](#)

[Defects Recording \[Ext.\]](#)

## Changing a Master Inspection Characteristic for a Control Chart

You can modify an existing master inspection characteristic for a control chart in the following way:



You cannot change the control indicators if you have already used the master inspection characteristic. In this case, you must create a new version of the characteristic.

**See also:**

[Versions in QM \[Ext.\]](#)

## Maintaining Task List Characteristics for Control Charts

### Use

If you want to manage a control chart for a characteristic in the plan, you must pay attention to the following points when maintaining the inspection characteristic:

- Planning the control chart type
- Planning the number of control charts for an inspection characteristic

### Planning the Control Chart Type for an Inspection Characteristic

The basic prerequisite when maintaining a characteristic in the task list is that you set the two control indicators for the **sampling procedure** and the **SPC characteristic**.

You assign the **control chart type** to the characteristic, using the sampling procedure. When you assign the sampling procedure, the system checks whether the other control indicators for the characteristic are suitable for the control chart type. The following indicators are checked:

- Measured values
- Upper specification limit
  - Lower specification limit
- Confirmation of number of defects
- Single result
- Scope not fixed
  - Fixed scope
  - Smaller scope
  - Larger scope

This check may determine that you **cannot** assign a sampling procedure to a characteristic.



You have assigned the control chart type **mean-value acceptance chart** to a sampling procedure. The profile of this control chart, however, specifies that measured values as well as the upper and lower specification limits are required and that the sample size must be adhered to.

You can only assign this sampling procedure to the characteristic if you have set the corresponding control indicators. In this case, it is not important whether single original values, classed measured values or only the mean value and standard deviation are confirmed for this characteristic.



You can only use sampling procedures with a **c-chart** or **u-chart** (for the number of defects) for inspection characteristics, in which the control indicator *Confirmation of defects* is set.

## Maintaining Task List Characteristics for Control Charts

### Planning the Number of Control Charts for an Inspection Characteristic

You can use control charts to control or observe one or more processes. You use the task list characteristic to determine how these processes are combined or separated.

In the case of an SPC characteristic, you must enter an **SPC criterion** for this purpose. You can use this SPC criterion to plan the number of control charts for each planning characteristic:

- You use the SPC criterion to define which inspection lots refer to a collective control chart.  
There are two ways of doing this:
  - You can specify that a separate control chart is opened for **each new inspection lot**, that is also for each new production order.
  - You can specify that control charts are used **for all lots**.
- For the **various materials** inspected on the basis of the inspection plan, you can specify that:
  - **Separate control charts** be managed. This option is useful if the material number affects the determination of the quality. This is particularly significant if you are using material-specific target values and tolerances.
  - One control chart be managed **for all materials**.  
This is useful if the materials are very similar.

You can call up a list of the existing SPC criteria using the input help. The input is not checked to determine if it is useful from a quality and data point of view.



# Control Charts in Inspection Processing

## Purpose

This process explains how control charts are incorporated into the inspection processing function in the QM component. You can call the control charts in the functions for recording and displaying inspection results, or using a separate transaction.

## Process Flow

The information below explains how control charts are incorporated in the inspection processing function:

### 1. Assigning a control chart to the inspection lot

When the quality inspection is prepared, a control chart number is assigned **automatically** to all of the inspection characteristics that contain a control chart type and an SPC criterion as part of the sample calculation procedure.

If an incomplete control chart already exists for the objects specified in the SPC criterion, this chart is assigned. Otherwise, a new number is assigned internally and a new control chart is created.



Each control chart has a data record that contains the **number** and **type** of the control chart, as well as the **SPC criterion** and the information required for the criterion, such as the task list, characteristic and material number. Further selected information is taken from the task list characteristic. This includes the short text, target value, tolerance and the optional additional limits for the characteristic.

Every **track** on the control chart has an additional data record that contains the track number and the current control limits.

The inspection results and attributes of control variables, such as mean values or standard deviations, are not stored in the control chart itself. Instead, they are determined using a database index from the original inspection result tables. The number of the control chart is entered in the inspection results for this purpose.

### 2. Calling Up Control Charts in the Results Recording Function

You can call up the control chart in the results recording using a pushbutton or by choosing *Extras* → *Graphic* → *Call up control chart*.

A separate graphics window is opened for each track on the chart. The results from the current inspection and the completed results from other inspections assigned to this control chart are displayed in the chart.

You can **valuate the inspection results** using the control chart.

#### See also:

[Transactions for Control Charts \[Page 19\]](#)

[Calling Up a Control Chart \[Page 20\]](#)

**Control Charts in Inspection Processing**

[Valuating the Sample Using the Control Chart \[Page 24\]](#)

## Transactions for Control Charts

### Use

With the transactions

- QGC1 Control charts for inspection lots
- QGC2 Control charts for task list characteristics
- QGC3 Control charts for master inspection characteristics

You can display and process control charts independently of the functions for recording, changing and displaying inspection results.

You can access these transactions using the menu path

*Logistics* → *Quality management* → *Quality inspection* → *Work list* → *Quality control chart* →...

### Features

In these transactions, you obtain a configurable list of the selected control charts.

You can use the following functions in the list:

- Calling up a control chart
- Activating one or more control charts
- Closing one or more control charts
- Saving changes



For the selection screens and the configuration of lists, you can define general or user-specific selection or list variants in Customizing.

## Calling Up a Control Chart

# Calling Up a Control Chart

## Use

If a control chart is managed for an inspection characteristic, you can call it up in the functions for recording, changing and displaying the inspection results in the overview and individual screens. The graphic is displayed as an OCX graphic in OCX systems, if you have not set the indicator *modal graphic* in *Defining Control Chart Types* in Customizing. In non-OCX systems, the control chart is shown as SAP Statistical Graphics.



Only samples with the **valid attribute** are included in the control chart. Samples from other inspection lots or inspection points must be closed first.

When you display a control chart using SAP Statistical Graphics, a separate graphics window is opened for **each track** in the control chart. All of the graphics windows are active (for inputs); the recording or display windows of the inspection results remain in the background (inputs cannot be made here). In comparison, the OCX graphic is integrated in the screen.

## Prerequisites



The graphics windows contain certain functions for processing the control chart. Two modes are available: **display mode** and **change mode**. Changes to the control chart cannot be made in display mode. The change mode is activated automatically if the following **requirements** are fulfilled:

- You are in the record or change mode.
- The inspection characteristic is being processed or valuated but has not been closed.
- The control chart is not being processed by another user.
- You have SPC authorization.
- The authorization object checked by the system is **Q\_SPC**. SPC authorization can be assigned for one or more plants and one or more SPC criteria.







## Features

You can use the following functions to process control charts:


### Valid Functions for OCX and SAP Statistical Graphics

Function	Pushbutton (for OCX graphics)	What You Should Know
<a href="#">Calculating Control Limits for a Track [Page 27]</a>		
<a href="#">Calculating the Capability Indexes [Page 29]</a>		


Calling Up a Control Chart

Exporting to the <a href="#">QM-STI interface [Ext.]</a>		Using this function, you can transfer SPC data to the QM-STI interface for evaluation by an external statistics system.
Showing planned value and tolerance		Using this function, you can display the upper and lower limiting values, as well as the target value for the inspection characteristic, if this is allowed for the control chart track. For more information, see Customizing under Defining Control Chart Types.
Updating from the database		If several inspection lots are displayed in a control chart, you can use this function to query the database in order to check the current results status. If new results or changes were recorded for one or more inspection lots, the system automatically updates the control chart.
<a href="#">Activating the Control Chart [Page 25]</a>		
<a href="#">Closing the Control Chart [Page 26]</a>		
<a href="#">Manual Entry of the Control Limits [Page 28]</a>		
Printing graphics		You can use this standard function to output the graphic locally or on an SAP printer.  You can use the function in OCX graphics by clicking with the right mouse button.
<a href="#">Saving Changes [Page 30]</a>		

Only Valid when Using OCX Graphics

Function	Pushbutton (in OCX graphics)	What You Should Know
Closing the window and restoring the standard size		


**Calling Up a Control Chart**

Setting the save mode for graphic layout		You configure whether changes in the layout (for example, color settings) are merely <i>user-specific</i> or are <i>valid throughout the company</i> . You require the corresponding authorization if you want to save layout changes so that they are valid on a company-wide basis.
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**Only Valid when Using SAP Statistical Graphics**

Function	What You Should Know
Scrolling function for reference axis	For a reference axis with an object number, you can use pushbuttons to display areas outside of the specified interval size for the control chart. See <a href="#">Settings for Control Chart Types [Page 35]</a>
Positioning function for reference axis	For a time-based reference axis, you can use this function to mark the current time in a run-chart. See <a href="#">Settings for Control Chart Types [Page 35]</a>
Sending the graphic	This standard function of the SAP Graphics application allows you to send the graphic by mail.
Exiting the graphic	This function is used to close a graphics window. Once you have closed the last graphics window, you return to the transaction, from which you called the graphic.
<a href="#">Chart in Background [Page 31]</a>	

**Activities**

To call up a control chart, choose  *Control chart* in the [transactions for control charts \[Page 19\]](#) or in the results recording.

If the control chart does not yet contain any data

- a note to this effect appears for SAP Statistical Graphics
- the graphics window in OCX graphics remains empty

**See also:**

[OCX Chart Presentation Graphic \[Ext.\]](#)

[Valuating the Sample Using the Control Chart \[Page 24\]](#)

[Settings and Enhancements for Control Charts \[Page 32\]](#)

[Statistical Details \[Page 40\]](#)



## Valuating a Sample Using the Control Chart

# Valuating a Sample Using the Control Chart

## Use

You can use a control chart to **value** the inspection results. If the relevant valuation rule is used, a sample is rejected if at least one of the action limits defined in the associated control chart was violated.

## Prerequisites

To value samples using the action limits of a control chart, the following condition must be met:

- An appropriate **valuation rule** and a **valuation mode** must be defined in the Customizing application.

## Features

### Comparison with the Action Limits

If you value a characteristic or sample in the results recording function and a valuation using the action limits has been specified for the sampling procedure, the current control variables of the control chart are determined and compared to the action limits of the tracks.

Whether you have called the control chart beforehand or not is not important. If the control chart (still) does not contain any action limits, the system requests you to enter the valuation manually.



If you are managing an  $\bar{x}/s$  chart, the sample will be rejected if the mean value or the standard deviation of the sample is outside the associated action limits.

Warning limits and further SPC criteria, such as run or trend, are not included in the valuation.

For control charts with a memory (moving mean-average charts, EWMA charts and moving range charts), the control variable is not just based on the current sample. You cannot value these tracks on the basis of action limits. Since these tracks are combined with other tracks for which such a valuation is possible, the system does not display an error message in this case.



Incomplete inspection results or changes to the control chart settings in the Customizing application may render the valuation impossible. However, a user with the corresponding authorization, can initiate a **forced closure**.

### See also:

[Maintaining Sampling Procedure for Control Charts \[Page 10\]](#)

[Forced closure \[Ext.\]](#) of characteristics

[Settings and Enhancements for Control Charts \[Page 32\]](#)



## Activating the Control Chart

### Use

A newly created control chart has the initial status **new**.

You can use the function for activating the chart to change the status from new to **active**. The system displays the status in the control chart window. When you use SAP Statistical Graphics, this status change is shown when the background color changes from gray to dark blue. When you use OCX Graphics, status changes will be indicated as text. Other functions are not affected by this status change.

You can activate a control chart before or after the control limits are calculated.

In the transactions

- Control charts for inspection lots
- Control charts for inspection characteristics
- Control charts for master inspection characteristics

you can activate more than one control chart simultaneously

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**Closing a Control Chart**

## Closing a Control Chart

### Use

You use the function for closing the chart to change the status of the control chart from **active** to **closed**. When you use SAP Statistical Graphics, this change is shown in the control chart window and when the background color changes from blue-green to dark blue. When you use OCX Graphics, status changes will be indicated as text.

When you close a control chart, the chart is no longer used when samples are calculated for new inspection lots. As a result, a new control chart is created for the next inspection lot.

In [transactions \[Page 19\]](#)

- Control charts for inspection lots
- Control charts for planning characteristics
- Control charts for master inspection characteristics

you can close more than one control chart simultaneously

## Calculating the Control Limits

### Use

Depending on the type and setting, up to five of the following control limits can be included in each track on a control chart:

- Upper action limit
- Upper warning limit
- Center line
- Lower warning limit
- Lower action limit

A procedure for calculating these limits is stored for each track in the Customizing settings for the control charts.

When you call up the function for calculating the limits, the limits are determined and entered in the track.

The algorithms in the standard system are based on statistical methods and use all of the **valid inspection results** currently in the chart.

Therefore, you can only calculate the limits after you have recorded the first inspection results (preliminary test).



Not only the original values, but also the statistics derived from these values (such as the mean value or standard deviation) are required to calculate the limits.

The standard deviation is calculated automatically during results recording once a sample has been valuated. However, you can determine it before this is done by using the function for calculating the statistical moments.

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**Manual Entry of the Control Limits**

## Manual Entry of the Control Limits

### Use

In addition to the [automatic calculation of control limits \[Page 27\]](#), you can also enter and change the control limits manually. For each control limit, the system records whether the value was calculated or changed manually. You can also use this function to display the calculated values for the control limits.

### Prerequisites

To enter the control limits manually, you must make sure that the following conditions have been met:

- The indicator *Change control limits* must be set in Customizing for the control chart track.
- You have SPC authorization.
- The chart must be called up in the change mode.

### Activities

To access the function, choose *GoTo* → *Control limits*.

## Calculating the Capability Indexes

### Use

If a characteristic has single-sided or double-sided tolerance limits, you can calculate and display the capability indexes  $c_p$  and  $c_{pk}$  in the mean value tracks and the qualitative tracks.

### Information for Calculating the Capability Indexes

The process capability index  $c_p$  is a measurement of the smallest possible share of nonconforming units that results from the optimum distribution of characteristic values in the process (centered production). However, this value does not indicate, whether this is the case.

The process capability index  $c_{pk}$  is a measurement of the expected share of nonconforming units in the process. The larger this value is, the smaller the share of nonconforming units.

- The following formulas are used in the mean value tracks for the calculation:

$$c_p = (\text{USL} - \text{LSL}) / 6*s$$

$$c_{pk} = \min((\text{USL} - \bar{x}), (\bar{x} - \text{LSL})) / 3*s$$

Here, the **USL** and the **LSL** are the tolerance range limits; **x-bar** and **s** are estimated values for the expected value and the standard deviation of the original value distribution. **S** is calculated according to the process model of the control chart, either as the inner dispersion or total dispersion of the measured values. **X** is the overall mean value of the measured values.

- To calculate the process capability index  $c_{pk}$  in the qualitative tracks, the following formula is used:


$$c_{pk} = u(1 - p) / 3$$

Where **p** is the estimated share of nonconforming units and **u** is the quantile function of the normal distribution.

This formula typically produces the same value for  $c_{pk}$  as with a normally distributed characteristic with the same fraction of nonconforming units (single-sided).

### Activities

To calculate or display the capability indexes, choose

 when using OCX graphics.

*Goto* → *Statistical values* when using SAP Statistical Graphics.

Then the capability indexes are calculated and displayed in a dialog box.

---

**Saving Changes****Saving Changes**

When you save changes in the control chart status, mark the newly calculated control limits so that they are saved in the database.

Changes to the database only take effect, however, when the data is saved in the calling function.

## Chart in Background

### Use

If you use SAP Statistical Graphics and want to return to the function for recording, changing or displaying the test results, call up the **chart in background** function. The last recording or display window is then active (for an input) and the control chart remains visible on the screen.

When you call up the control chart again, the contents of the chart are updated and the graphic becomes active again (for inputs). This is a faster way of switching between the two functions than by closing the graphic and calling it up again. This also applies if you have selected a different characteristic and have to replace the chart.

The background graphics window of the control chart is closed automatically when you exit or cancel the transaction.

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**Settings and Enhancements for Control Charts**

## Settings and Enhancements for Control Charts

This section describes the control chart settings that can be made in the Customizing application and how to replace standard functions with your own programs.

The following data is set in the Customizing application:

- [SPC criteria \[Page 33\]](#)  
The SPC criterion defines whether individual or global control charts are to be managed for different orders, work centers, materials, manufacturers or customers.
- [Control Chart Type \[Page 35\]](#)  
The requirements regarding the control indicators of the inspection characteristic and the sampling procedure are specified for each control chart type.  
The control chart tracks are defined at the next level. The control variable and the algorithms used to calculate the warning and action limits are determined for each track. The available parameters can be used to match the statistical properties to the relevant company or national requirements.
- [Number Ranges \[Page 39\]](#)  
The number ranges used in the control charts must be defined.



## Settings for SPC criteria

The SPC criteria are defined in the Customizing application. Generally, they do not need to be modified.

Each SPC criterion has a three-character ID and is described by a short text in several languages.



Ascending numbers from 900 onward and characters from A to Z are reserved as identifiers for customer enhancements for the predefined control charts.

The criterion is also assigned a function module. This function module checks whether a suitable chart is already available before a new control chart is created. Information on the assigned function module is available using the system help functions.

The following function modules are implemented in the standard system:

- QRKS\_CHARACTERISTIC  
Control chart for a characteristic
- QRKS\_CHARACTERISTIC\_PM\_OBJECT  
Control chart for a characteristic and equipment/functional location
- QRKS\_INSPECTION\_LOT  
Control chart for a characteristic/inspection lot
- QRKS\_MASTER\_CHAR\_MATERIAL  
Control chart for a master inspection characteristic/material
- QRKS\_MASTER\_CHAR\_PM\_OBJECT  
Control chart for master inspection characteristic and equipment/technical location
- QRKS\_MASTER\_CHARACTERISTIC  
Control chart for a master inspection characteristic
- QRKS\_MATERIAL  
Control chart for a characteristic/material
- QRKS\_MATERIAL\_CUSTOMER  
Control chart for a characteristic/material/customer
- QRKS\_MATERIAL\_MANUFACTURER  
Control chart for a characteristic/material/manufacturer
- QRKS\_MATERIAL\_SOLD\_TO\_PARTY  
Control chart for a characteristic/material/sold-to-party
- QRKS\_MATERIAL\_VENDOR  
Control chart for characteristic/material/vendor
- QRKS\_MATERIAL\_WORK\_CENTER

**Settings for SPC criteria**

Control chart for characteristic/material/work center

- QRKS\_PURCHASING\_DOCUMENT

Control chart for a characteristic/purchasing document

- QRKS\_SALES\_ORDER

Control chart for a characteristic/sales order



You can copy these modules if you want to create additional function modules.  
These copies should be stored in a separate function group.

## Settings for Control Chart Types

### Control Chart Types

The control chart types are defined in the Customizing application as a two-level view. The first level is used for general settings for the control chart type. The second level is used for individual track settings.



Each control chart type has a three-character ID and is described by a short text in several languages. Ascending numbers from 900 onward and characters from A to Z are reserved as identifiers for customer enhancements for the predefined control charts.

### General Control Chart Settings

The following general control chart settings are defined in Customizing:

- **Requirements for the inspection characteristic**

The requirements that must be fulfilled by an inspection characteristic so that the control chart type can be used are stored for each control chart type. These include the following indicators for:

- Measured values
- Upper specification limit
- Lower specification limit
- Confirmation of number of defects
- Single result
- Independent multiple samples (or inspection points)
- Scope not fixed
- Fixed scope
- Smaller scope
- Larger scope

The indicator for **independent multiple samples** defines whether individual sample records of an inspection characteristic are to be included in the control chart. These sample records can result from sampling procedures with independent multiple samples or inspection points. The indicator must match the sampling procedure exactly.

The other indicators simply define minimum requirements for the inspection characteristic. The tolerance or single results are not required for an  $\bar{x}$ -Shewhart chart for example. These indicators, therefore, are not set in the requirements profile. This control chart, however, can also be used for characteristics with a tolerance range limited on one side or on both sides or with single values.

- **Setting parameters for the reference axis**

## Settings for Control Chart Types

This parameter defines how the x-axis of the control chart is displayed. The following four options are available:

- Object number (inspection lot, sample, inspection point)
- Creation time (of data record)
- Time of last change (to data record)
- Inspection time

The reference axis is valid for all tracks in a control chart. The entries for reference axes with a time reference are not equidistant but refer to the actual time intervals. If all of the time values refer to the same day, a finer time grid is selected than if they are distributed over more than one day.

For reference axes with object numbers, you can also specify the number of samples to be displayed simultaneously in the graphic.

- **Number range**

Entering the number range defines the number range from which the numbers for new control charts are taken. The number range 1 should be used if you do not want to differentiate between the control charts.

- **Function module for calling up the control chart**

The name of a function module is stored for calling up the control chart. The **QRKG\_STANDARD\_CHART** module is entered in the standard system for all control charts. This module is used to display a one or two-track control chart with horizontal control limits. The control chart is created using the *OCX Graphics* function. If you want a graphical representation using the *SAP Statistics Graphics* function, select the *Modal Graphics* function.

If you want to modify the graphical representation or the functions available in the graphic, you can enter the name of a customer-specific module here. It is advisable to make a copy of the standard module for this purpose.

You can use the **test call** function to check whether the modification was successful. A simulation of the call function is then performed using example data; you do not have to create an inspection plan or inspection lots.

Information on the assigned function module is available using the system help functions.

## Track Settings

A one-digit number is used to differentiate between the tracks of a control chart type. In theory, therefore, up to nine tracks can be defined for each chart. The standard system contains settings for one and two-track control charts. The track type is described by means of a short text in several languages.

The track is assigned a function module. The information for selecting or defining the control variable and the algorithms for calculating the control limits are programmed in this module.

The following modules are implemented in the standard system:

- QRKT\_C\_SHEWHART  
C-chart for the number of defects with sigma limits
- QRKT\_EWMA\_2

## Settings for Control Chart Types

- EWMA chart with total dispersion
- QRKT\_MEAN\_VALUE\_ACCEPTANCE  
Acceptance chart for  $\bar{x}$  with internal dispersion
- QRKT\_MEAN\_VALUE\_ACCEPTANCE\_2  
Acceptance chart for  $\bar{x}$  with total dispersion
- QRKT\_MEAN\_VALUE\_SHEWHART  
Shewhart chart for  $\bar{x}$  with internal dispersion
- QRKT\_MEAN\_VALUE\_SHEWHART\_2  
Shewhart chart for  $\bar{x}$  with total dispersion
- QRKT\_MEAN\_VALUE\_SHEWHART\_R2  
Shewhart chart for  $\bar{x}$  with dispersion over the moving range
- QRKT\_MOVING\_AVERAGE\_2  
Moving average chart with total dispersion
- QRKT\_MOVING\_RANGE\_SHEWHART\_K  
Moving range chart for sample size  $n = 1$
- QRKT\_NP\_SHEWHART  
NP chart for the number of nonconforming units with sigma limits
- QRKT\_P\_SHEWHART  
P chart for the number of nonconforming units with sigma limits
- QRKT\_STD\_DEVIATION\_SHEWHART  
Shewhart chart for  $s$  with internal dispersion
- QRKT\_STD\_DEVIATION\_SHEWHART\_2  
Shewhart chart for  $s$  with total dispersion
- QRKT\_U\_SHEWHART  
U-chart for the number of defects for each sample unit with sigma limits

You can replace these modules with customer-specific modules if necessary.

The function modules have six possible parameters that can be set in the details screen for the track. In this way, you can influence the statistical levels when the control limits are calculated. The way in which the parameters are used can vary from module to module.



The action limits of an  $\bar{x}$  Shewhart chart can be calculated in such a way that 99% or 99.73% (  $3\sigma$ - rule) of the mean values are within the limits, if the process is not in control.

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Settings for Control Chart Types

## Setting the Number Ranges

The control chart is a separate number-range object. If you want to manage control charts, a minimum of one number range must be defined. The numbers are always assigned internally. The number range, from which a new number is taken, is defined in the control chart. The number range 1 is used in the standard system.

## Statistical Details

## Statistical Details

This section contains the formulas that are used to calculate the control limits for the various control charts. A knowledge of statistical principles is required to understand the information in this section, as these are not described in detail here.

### Estimating the Process Location Parameter and Process Dispersion

The parameters of suitable probability distributions are required to calculate the control limits of the control charts. Since these parameters are not known, they are estimated using the sample results that are available when the calculation is made.

#### Designations

$i = 1 \dots k$     Number of samples

$n_i$     Scope of sample  $i$

$j = 1 \dots n_i$     Number of original value  $j$   
in sample  $i$

#### Process Location Parameter

The **total mean value** of all samples is used to estimate the process location parameter.

Total mean value

$$\hat{\mu} = \bar{x}_{ges} = \frac{\sum_{i=1}^k \sum_{j=1}^{n_i} x_{ij}}{\sum_{i=1}^k n_i}$$

If the size of all of the samples is identical, the total mean value is also the mean value of the sample mean values.



### Process Dispersion

You can choose whether the **internal dispersion** or the **total dispersion** of the original values is used to estimate the process dispersion.

Internal dispersion

$$\hat{\sigma} = \sqrt{\frac{\sum_{i=1}^k \sum_{j=1}^{n_i} (x_{ij} - \bar{x}_{i\bullet})^2}{\sum_{i=1}^k (n_i - 1)}}$$

Total dispersion

$$\hat{\sigma} = \sqrt{\frac{\sum_{i=1}^k \sum_{j=1}^{n_i} (x_{ij} - \bar{x}_{ges})^2}{\sum_{i=1}^k (n_i - 1)}}$$

The internal dispersion is used most frequently. You can use the total dispersion for a short-term evaluation or if the size of the individual samples is **n=1**.

You can also estimate the dispersion of mean values using the differences of successive mean values (moving range). You can also use this process for sample size **n = 1** and for the mean value track of the IR chart.

## Statistical Details

## Moving Range

$$\hat{\sigma}_x = \frac{1}{m-1} \sum_{i=2}^m \frac{|\bar{x}_i - \bar{x}_{i-1}|}{d_2}$$

Where,  $m$  is the number of samples used in the calculation and  $d_2 = 1,1283791671$ .

Control Limits for the  $\bar{x}$  - Acceptance Chart

The action limits of the  $\bar{x}$  acceptance chart are defined by points on the operation characteristic. In other words, at specified proportions  $p$  above the tolerance or  $q$  below the tolerance, an intervention is not to be made in the process with the specified probabilities  $P$  and  $Q$ . The original values must be distributed normally.

## Upper Action Limit

$$UAL = USL - \sigma \left( u_{1-p} + \frac{u_{1-p}}{\sqrt{n}} \right)$$

## Center Line

$$\bar{x}_{ges}$$

## Lower Action Limit

$$LAL = LSL - \sigma \left( u_{1-q} + \frac{u_{1-q}}{\sqrt{n}} \right)$$

Where  $u_\alpha$  is the  $\alpha$  quantile of the standard normal distribution and  $n$  is the size of the sample to be entered.

Warning limits are not included in the  $\bar{x}$  acceptance chart. The four  $p, P, q, Q$  parameters can be specified in the Customizing application.

Control Limits for the  $\bar{x}$  - Shewhart Chart

The action and warning limits of the  $\bar{x}$  Shewhart chart are selected in such a way that the limits are not exceeded with predefined probabilities  $p_1, p_2, p_3, p_4$  if the process is in control. The sample mean values must be distributed normally.

Upper action limit	$UAL = \bar{x}_{ges} + u_{p1} \cdot \frac{\hat{\sigma}}{\sqrt{n}}$
Upper warning limit	$UWL = \bar{x}_{ges} + u_{p2} \cdot \frac{\hat{\sigma}}{\sqrt{n}}$
Center line	$\bar{x}_{ges}$
Lower warning limit	$LWL = \bar{x}_{ges} - u_{p3} \cdot \frac{\hat{\sigma}}{\sqrt{n}}$
Lower action limit	$LAL = \bar{x}_{ges} - u_{p4} \cdot \frac{\hat{\sigma}}{\sqrt{n}}$

For the estimation of the mean values using the moving-range method,  $\hat{\sigma}/\sqrt{n}$  must be replaced by  $\hat{\sigma}_{\bar{x}}$  in these formulas.

Where  $u_{\alpha}$  is the  $\alpha$  quantile of the standard normal distribution and  $n$  is the size of the sample to be entered. You can define the  $p_1, p_2, p_3, p_4$  parameters in the Customizing application. If you enter 0 for a parameter, the corresponding limit is suppressed.

### Control Limits for the S Shewhart Chart

The action and warning limits of the s Shewhart chart are selected in such a way that the limits are not exceeded with the specified probabilities  $p_1, p_2, p_3, p_4$  if the process is in control. The original values of the samples must be distributed normally. The mean line is entered at the height of the estimated expected value of the sample standard deviation  $s$ .

## Statistical Details

Upper action limit	$UAL = \hat{\sigma} \cdot \sqrt{\frac{\chi_{n-1; p1}^2}{n-1}}$
Upper warning limit	$UWL = \hat{\sigma} \cdot \sqrt{\frac{\chi_{n-1; p2}^2}{n-1}}$
Center line	$\hat{\sigma} \cdot \sqrt{\frac{2}{n-1}} \cdot \frac{\Gamma\left(\frac{n}{2}\right)}{\Gamma\left(\frac{n-1}{2}\right)}$
Lower warning limit	$LWL = \hat{\sigma} \cdot \sqrt{\frac{\chi_{n-1; p3}^2}{n-1}}$
Lower action limit	$LAL = \hat{\sigma} \cdot \sqrt{\frac{\chi_{n-1; p4}^2}{n-1}}$

Where  $n$  is the size of the samples to be entered and  $\chi_{n-1; \alpha}^2$  the  $\alpha$  quantile of the  $\chi^2$  distribution. You can define the  $p_1, p_2, p_3, p_4$  parameters in the Customizing application. If you enter 0 for a parameter, the corresponding limit is suppressed.

### Control Limits for the Moving Average Chart

The action limits, warning limits, and mean line for moving-range charts are calculated using the same formulas as with the  $\bar{x}$  Shewhart chart. In place of sample size  $n$ , the fictitious sample size  $mn$  is used in the formulas. Where  $m$  is the number of combined samples (group size). For purposes of simplification, these formulas are also used for the control chart's starting area, where the moving average cannot be fully used.

### Control Limits for the EWMA Moving-Average Chart

The action limits, warning limits, and mean line for EWMA-charts are calculated using the same formulas as with the  $\bar{x}$  Shewhart chart. In place of the mean value dispersion  $\hat{\sigma}/\sqrt{n}$ , the asymptomatic dispersion of the control variable is used:

$$\hat{\sigma} = \frac{p \cdot s^2}{n \cdot (2 - p)}$$

$p = \text{factor\_sample} / (\text{factor\_sample} + \text{factor\_previous value})$

### Control Limits for the Moving R Chart with Group Size 2

The action limits and warning limits for the Moving R Chart with group size 2 are defined with the help of k-factors.

Upper action limit

$$UAL = \bar{r} + k_1 \cdot d3 \cdot \hat{\sigma}_x$$

Upper warning limit

$$UWG = \bar{r} + k_2 \cdot d3 \cdot \hat{\sigma}_x$$

Center line

$$\bar{r} = \frac{1}{m-1} \sum_{i=2}^m |\bar{x}_i - \bar{x}_{i-1}|$$

Lower warning limit

$$LWL = \bar{r} - k_3 \cdot d3 \cdot \hat{\sigma}_x$$

Lower action limit

$$LAL = \bar{r} - k_4 \cdot d3 \cdot \hat{\sigma}_x$$

### Statistical Details

In this case,  $m$  is the number of samples  $\hat{\sigma}_x = \bar{r} / d2$  used for the calculation;  $d2 = 1.1283791671$  and  $d3 = 0.8525024664$ .

If a negative value is obtained in the calculation of one of the two lower limits, the value for the limit is corrected to 0.

### Control Limits for the np-Shewhart Chart

The action limits and warning limits for the np Shewhart chart are defined with the help of k-factors. The standard deviation needed for the calculation is estimated on the basis of the mean share of nonconforming units  $p$ , using the formulas for a binomial distribution.

Standard deviation	$\hat{\sigma}_{np} = \sqrt{n \cdot \bar{p} \cdot (1 - \bar{p})}$
Upper action limit	$UAL = n \cdot \bar{p} + k_1 \cdot \hat{\sigma}_{np}$
Upper warning limit	$UWL = n \cdot \bar{p} + k_2 \cdot \hat{\sigma}_{np}$
Center line	$n \cdot \bar{p}$
Lower warning limit	$LWL = n \cdot \bar{p} - k_3 \cdot \hat{\sigma}_{np}$
Lower action limit	$LAL = n \cdot \bar{p} - k_4 \cdot \hat{\sigma}_{np}$

In this case,  $n$  is the sample size to be entered.

If a negative value is obtained in the calculation of one of the two lower limits, the value for the limit is corrected to 0.

### Control Limits for the P Shewhart Chart

The action limits and warning limits for the P Shewhart chart are defined with the help of k-factors. The standard deviation needed for the calculation is estimated on the basis of the mean share of nonconforming units  $p$ , using the formulas for a binomial distribution.

Standard deviation	$\hat{\sigma}_p = \sqrt{\frac{\bar{p} \cdot (1 - \bar{p})}{n}}$
Upper action limit	$UAL = \bar{p} + k_1 \cdot \hat{\sigma}_p$
Upper warning limit	$UWL = \bar{p} + k_2 \cdot \hat{\sigma}_p$
Center line	$\bar{p}$
Lower warning limit	$LWL = \bar{p} - k_3 \cdot \hat{\sigma}_p$
Lower action limit	$LAL = \bar{p} - k_4 \cdot \hat{\sigma}_p$

In this case,  $n$  is the sample size to be entered.

If a negative value is obtained in the calculation of one of the two lower limits, the value for the limit is corrected to 0.

### Control Limits for the C Shewhart Chart

The action limits and warning limits for the C Shewhart chart are defined with the help of k-factors. The standard deviation needed for the calculation is estimated on the basis of the cumulated number of defects  $C$ , the cumulated sample size  $N$ , and the current sample size  $n$  using the formulas for a Poisson distribution.

## Statistical Details

Center line	$\hat{\mu} = \frac{n \cdot C}{N}$
Standard deviation	$\hat{\sigma}_c = \sqrt{\hat{\mu}}$
Upper action limit	$UAL = \hat{\mu} + k_1 \cdot \hat{\sigma}_c$
Upper warning limit	$UWL = \hat{\mu} + k_2 \cdot \hat{\sigma}_c$
Lower warning limit	$LWL = \hat{\mu} - k_3 \cdot \hat{\sigma}_c$
Lower action limit	$LAL = \hat{\mu} - k_4 \cdot \hat{\sigma}_c$

If a negative value is obtained in the calculation of one of the two lower limits, the value for the limit is corrected to 0.

**Control Limits for the U Shewhart Chart**

The action limits and warning limits for the u Shewhart chart are defined with the help of k-factors. The standard deviation needed for the calculation is estimated on the basis of the cumulated number of defects  $C$ , the cumulated sample size  $N$ , and the current sample size  $n$  using the formulas for a Poisson distribution.



Center line	$\hat{\mu} = \frac{C}{N}$
Standard deviation	$\hat{\sigma}_u = \sqrt{\frac{u}{n}}$
Upper action limit	$UAL = \bar{u} + k_1 \cdot \hat{\sigma}_u$
Upper warning limit	$UWL = \bar{u} + k_2 \cdot \hat{\sigma}_u$
Lower warning limit	$LWL = \bar{u} - k_3 \cdot \hat{\sigma}_u$
Lower action limit	$LAL = \bar{u} - k_4 \cdot \hat{\sigma}_u$

If a negative value is obtained in the calculation of one of the two lower limits, the value for the limit is corrected to 0.

### Numerical Procedures

The higher mathematical functions listed above are calculated using the following function modules:

QF00_LOG_GAMMA	Natural logarithm of the gamma function
QF10_IDF_CHI2	Quantile of the chi square distribution
QF10_IDF_NORMAL	Quantile of the normal distribution

Details and sources of the algorithms used are provided in the documentation for these function modules.