

## Chapter 246

# s Charts

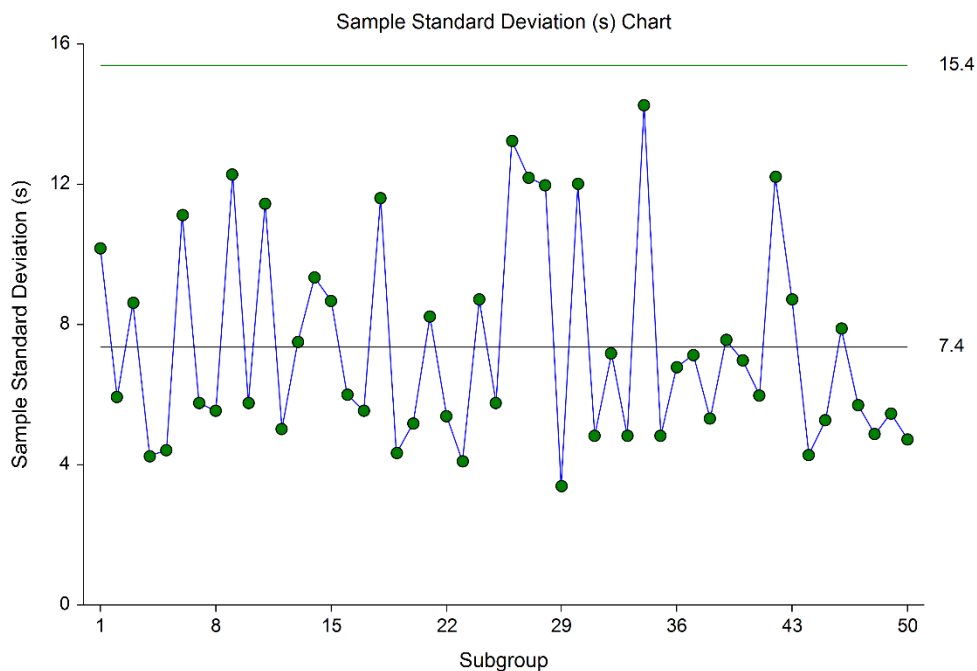
### Introduction

This procedure generates s control charts for variables. The format of the control charts is fully customizable. The data for the subgroups can be in a single column or in multiple columns. This procedure permits the defining of stages. Sigma may be estimated from the data or a standard sigma value may be entered. A list of out-of-control points can be produced in the output, if desired, and standard deviations may be stored to the spreadsheet.

### s Control Charts

The s chart is used to monitor the variation of a process based on samples taken from the process at given times (hours, shifts, days, weeks, months, etc.). The measurements of the samples at a given time constitute a subgroup. Typically, an initial series of subgroups is used to estimate the standard deviation of a process. The standard deviation is then used to produce control limits for the range of each subgroup. During this initial phase, the process should be in control. If points are out-of-control during the initial (estimation) phase, the assignable cause should be determined and the subgroup should be removed from estimation. Determining the process capability (see R & R Study and Capability Analysis procedures) may also be useful at this phase.

Once the control limits have been established for the s chart, these limits may be used to monitor the variation of the process going forward. When a point is outside these established control limits, it indicates that the variation of the process is out-of-control. An assignable cause is suspected whenever the control chart indicates an out-of-control process.



## Other Control Charts for the Variation of a Process

A very similar chart to the s chart is the R chart. The R chart uses the range of the subgroups rather than the standard deviation for estimating the standard deviation ( $\sigma$ ). The s chart is generally recommended over the R chart when the subgroup sample size is moderately large ( $n > 10$ ), or when the sample size is variable from subgroup to subgroup (Montgomery, 2013).

When only a single response is available at each time point, then the individuals and moving range (I-MR) control charts can be used for early phase monitoring of the mean and variation.

## Control Chart Formulas

Suppose we have  $k$  subgroups, each of size  $n$ . Let  $x_{ij}$  represent the measurement in the  $j^{\text{th}}$  sample of the  $i^{\text{th}}$  subgroup.

### Formulas for the Points on the Chart

The  $i^{\text{th}}$  subgroup standard deviation is calculated using

$$s_i = \sqrt{\frac{\sum_{j=1}^n (x_{ij} - \bar{x}_i)^2}{n-1}}$$

### Estimating Sigma – Mean of Standard Deviations

The true standard deviation ( $\sigma$ ) may be input directly, or it may be estimated from the standard deviations by

$$\hat{\sigma} = \frac{\bar{s}}{c_4}$$

where

$$\bar{s} = \frac{\sum_{i=1}^k s_i}{k}$$

$$c_4 = \frac{E(s)}{\sigma} = \frac{\mu_s}{\sigma}$$

The calculation of  $E(s)$  requires the knowledge of the underlying distribution of the  $x_{ij}$ 's. Making the assumption that the  $x_{ij}$ 's follow the normal distribution with constant mean and variance, the values for  $c_4$  are obtained from

$$c_4 = \sqrt{\frac{2}{n-1}} \frac{\Gamma\left(\frac{n}{2}\right)}{\Gamma\left(\frac{n-1}{2}\right)}$$

## Estimating Sigma – Weighted Approach

When the sample size is variable across subgroups, a weighted approach is recommended for estimating sigma (Montgomery, 2013):

$$\hat{\sigma} = \bar{s} = \left[ \frac{\sum_{i=1}^k (n_i - 1) s_i^2}{\sum_{i=1}^k n_i - k} \right]^{1/2}$$

## Estimating the s Chart Center Line

If a standard sigma (standard deviation) value is entered by the user, the s Chart center line is computed using

$$\bar{s} = c_4 \sigma$$

If the standard deviation is estimated from a series of subgroups, the s chart center line is given by  $\bar{s}$ , whether computed by the mean of standard deviations approach, or by the weighted approach.

## s Chart Limits

The lower and upper control limits for the s chart are calculated using the formula

$$LCL = \bar{s} - m \hat{\sigma} \sqrt{1 - c_4^2}$$

$$UCL = \bar{s} + m \hat{\sigma} \sqrt{1 - c_4^2}$$

where  $m$  is a multiplier (usually set to 3) chosen to control the likelihood of false alarms, and  $c_4$  is defined above, and is based on the assumption of normality.

## Runs Tests

The strength of the s control chart comes from its ability to detect sudden changes in a process that result from the presence of assignable causes. Unfortunately, this chart is poor at detecting drifts (gradual trends) or small shifts in the process. For example, there might be a positive trend in the last ten subgroups, but until a range goes above the upper control limit, the chart gives no indication that a change has taken place in the process.

Runs tests can be used to check control charts for unnatural patterns that are most likely caused by assignable causes. Runs tests are sometimes called “pattern tests”, “out-of-control” tests, or “zones rules”.

In order to perform the runs tests, the control chart is divided into six equal zones (three on each side of the centerline). Since the control limit is three sigma limits (three standard deviations of the mean) in width, each zone is one sigma wide and is labeled A, B, or C, with the C zone being the closest to the centerline. There is a lower zone A and an upper zone A. The same is true for B and C. The runs tests look at the pattern in which points fall in these zones.

The runs tests used in this procedure are described below.

### Test 1: Any Single Point Beyond Zone A

This runs test simply indicates a single point is beyond one of the two three-sigma limits.

## s Charts

### Test 2: Two of Three Successive Points in Zone A or Beyond

This usually indicates a shift in the process average. Note that the two points have to be in the same Zone A, upper or lower. They cannot be on both sides of the centerline. The third point can be anywhere.

### Test 3: Four of Five Successive Points in Zone B or Beyond

This usually indicates a shift in the process average. Note that the odd point can be anywhere.

### Test 4: Eight Successive Points in Zone C or Beyond

All eight points must be on one side of the centerline. This is another indication of a shift in the process average.

### Test 5: Fifteen Successive Points Fall in Zone C on Either Side of the Centerline

Although this pattern might make you think that the variation in your process has suddenly decreased, this is usually not the case. It is usually an indication of stratification in the sample. This happens when the samples come from two distinct distributions having different means. Perhaps there are two machines that are set differently. Try to isolate the two processes and check each one separately.

### Test 6: Eight of Eight Successive Points Outside of Zone C

This usually indicates a mixture of processes. This can happen when two supposedly identical production lines feed a single production or assembly process. You must separate the processes to find and correct the assignable cause.

There are, of course, many other sets of runs tests that have been developed. You should watch your data for trends, zig-zags, and other nonrandom patterns. Any of these conditions could be an indication of an assignable cause and would warrant further investigation.

---

## Issues in Using Control Charts

There are several additional considerations surrounding the use of control charts that will not be addressed here. Some important questions are presented below without discussion. For a full treatment of these issues you should consider a statistical quality control text such as Ryan (2011) or Montgomery (2013).

### Subgroup Size

How many items should be sampled for each subgroup? Some common values are 5, 10, and 20. How does the subgroup size affect my use of control charts? What about unequal subgroup sizes?

### Dealing with Out-of-Control Points

How do you deal with out-of-control points once they have been detected? Should they be included or excluded in the process average and standard deviation?

### Control Limit Multiplier

Three-sigma limits are very common. When should one consider a value other than three?

### Startup Time

How many subgroups should be used to establish control for my process?

## Normality Assumption

How important is the assumption of normality? How do I check this? Should I consider a transformation? (See also the Box-Cox Transformation and Capability Analysis procedures in NCSS.)

---

## Data Structure

In this procedure, the data may be in either of two formats. The first data structure option is to have the data in several columns, with one subgroup per row.

### Example dataset

S1	S2	S3	S4	S5
2	6	3	8	5
8	8	7	7	9
6	2	2	4	3
5	6	7	6	10
48	2	6	5	0
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.

The second data structure option uses one column for the response data, and either a subgroup size or a second column defining the subgroups.

### Alternative example dataset

Response	Subgroup
2	1
6	1
3	1
8	1
5	1
8	2
8	2
7	2
7	2
9	2
6	3
2	3
.	.
.	.
.	.

In the alternative example dataset, the Subgroup column is not needed if every subgroup is of size 5 and the user specifies 5 as the subgroup size. If there are missing values, the Subgroup column should be used, or the structure of the first example dataset.

## Procedure Options

This section describes the options available in this procedure. To find out more about using a procedure, go to the Procedures chapter.

### Variables Tab

This panel specifies the variables that will be used in the analysis.

#### Input Type

Specify whether the data is in a single response column or in multiple columns with one subgroup per row.

- Response Column and Subgroup Column or Subgroup Size**

Response	Subgroup
5	1
6	1
4	1
3	2
7	2
6	2
4	3
5	3
8	3
.	.
.	.
.	.

- Multiple Columns with One Subgroup Per Row**

X1	X2	X3
5	6	4
3	7	6
4	5	8
.	.	.
.	.	.
.	.	.

### Variables – Response Column

#### Response Variable

Specify the column with the data values. The data values are separated into subgroups below using the Subgroup Specification options.

#### Subgroup Specification

Specify whether subgroups are defined by a Subgroup ID variable, or by a subgroup size. If the subgroup size is 3, then subgroups are formed by going down the response column in groups of 3. The first subgroup would be 5, 6, 4; the second would be 3, 7, 6; and so on.

## s Charts

**Subgroup ID Variable**

Specify the column containing the subgroup identifiers.

Response	ID Variable
5	1
6	1
4	1
3	2
7	2
6	2
4	3
5	3
8	3
.	.
.	.
.	.

A new subgroup is created for each change in the Subgroup ID Variable, going down.

**Subgroup Size**

Specify the number of individuals in each subgroup.

Response
5
6
4
3
7
6
4
5
8
.
.
.

If the subgroup size is 3, then subgroups are formed by going down the response column in groups of 3. The first subgroup would be 5, 6, 4; the second would be 3, 7, 6; and so on.

---

**Variables – Multiple Columns****Data Variables**

Specify the columns containing the sample responses. Each row represents a subgroup.

X1	X2	X3
5	6	4
3	7	6
4	5	8
.	.	.
.	.	.
.	.	.

## s Charts

If only one variable is specified, NCSS automatically generates an individuals chart with a moving-range of size 2.

### Stages

#### Number of Stages

Specify whether the analyses and charts are to be produced based on a single set of subgroups, or a series of sets of subgroups. Typically a single stage is used unless you wish to have separate estimation for various segments of the subgroups. When using multiple stages, the software requires that there be at least one subgroup in every stage specified.

#### Stage Specification

Specify whether the various stages will be defined using a variable (column) with a unique value for each stage, or by entering a range of rows for each stage.

- **Stage Variable**

X1	X2	X3	Stage
5	6	4	1
3	7	6	1
4	5	7	1
6	5	4	1
3	7	6	1
5	8	3	2
2	6	4	2
3	6	5	2
4	5	8	2
.	.	.	.
.	.	.	.
.	.	.	.

- **Enter a range for each stage**

1-50, 51-100, 101-150

This would produce three stages. The first stage would be made up of rows 1 to 50, the second stage would be rows 51 to 100, and the third stage would be rows 101 to 150.

#### Stage Variable

Specify the variable (column) that contains the identifiers for each stage.

X1	X2	X3	Stage Variable
5	6	4	1
3	7	6	1
4	5	7	1
6	5	4	1
3	7	6	1
5	8	3	2
2	6	4	2
3	6	5	2
4	5	8	2
.	.	.	.
.	.	.	.
.	.	.	.

A new stage is created for each change in the Stage Variable, going down.



## s Charts

### Stage Ranges

Enter a range for each stage using a dash. Separate each stage with a comma.

**Example:** 1-50, 51-100, 101-150

This would produce three stages. The first stage would be made up of rows 1 to 50, the second stage would be rows 51 to 100, and the third stage would be rows 101 to 150.

---

### Specify Rows in Calculations

#### Specification Method

Select which method will be used to specify the rows of the data to be used to form subgroups.

- **All Rows**  
All rows in the response column(s) will be used.
- **Enter First Row and Last Row**  
Specify the first row and the last row of the data for use in calculations.
- **First N Rows (Enter N)**  
The data beginning at Row 1 and ending at Row N will be used in calculations.
- **Last N Rows (Enter N)**  
Subgroups will be formed from the last N rows of the dataset.
- **Keep Rows Variable**  
Specify a variable and a value in that variable column that will be used to determine which rows are used to form the subgroups.
- **Remove Rows Variable**  
Specify a variable and a value in that variable column that will be used to determine which rows will not be used to form the subgroups.

#### First Row

Specify the beginning row to be used for the first subgroup.

#### Last Row

Specify the last row to be used for the last subgroup.

#### N

Enter the number of rows to be used in forming subgroups.

#### Keep Rows Variable

This variable (column) is used to specify which rows of the data will be used to form the subgroups for the calculations.

#### Keep Rows Value

This value determines which rows of the Keep Rows Variable will be used in the calculation portion of the analysis.

## s Charts

### Remove Rows Variable

This variable (column) is used to specify which rows of the data will not be used to form the subgroups for the calculations.

### Remove Rows Value

This value determines which rows of the Remove Rows Variable will not be used in the calculation portion of the analysis.

---

## Specify Rows in Charts

### Specification Method

Select which method will be used to specify the rows of the data to be used to form subgroups for the charts.

- **All Rows**  
All rows in the response column(s) will be used.
- **Enter First Row and Last Row**  
Specify the first row and the last row of the data for use in the plots.
- **First N Rows (Enter N)**  
The data beginning at Row 1 and ending at Row N will be used in the plots.
- **Last N Rows (Enter N)**  
Subgroups will be formed from the last N rows of the dataset.
- **Keep Rows Variable**  
Specify a variable and a value in that variable column that will be used to determine which rows are used to form the subgroups.
- **Remove Rows Variable**  
Specify a variable and a value in that variable column that will be used to determine which rows will not be used to form the subgroups.

### First Row

Specify the beginning row to be used for the first subgroup.

### Last Row

Specify the last row to be used for the last subgroup.

### N

Enter the number of rows to be used in forming subgroups.

### Keep Rows Variable

This variable (column) is used to specify which rows of the data will be used to form the subgroups for the plots.

### Keep Rows Value

This value determines which rows of the Keep Rows Variable will be used in the plots.

### Remove Rows Variable

This variable (column) is used to specify which rows of the data will not be used to form the subgroups for the plots.

## Remove Rows Value

This value determines which rows of the Remove Rows Variable will not be used in the plots.

---

## Labels (Optional)

### Subgroup Label Variable

Specify a variable (column) that contains the desired x axis (subgroup) labels for plots. If left blank, the plot will use the subgroup number. The format of the labels is controlled on the x axis tab of the plot format window.

### Point Label Variable

Specify a variable (column) that contains the desired individual point labels for plots. If left blank, no point labels are shown. The format of the labels is controlled on the main chart tab of the plot format window.

---

## Sigma & Limits Tab

The options on the Sigma & Limits tab are used to specify the limit multipliers and the method by which sigma is estimated.

---

## Sigma Estimation Options

### Sigma Specification

Specify the method by which Sigma will be estimated for use in the charts.

- **From Data – s-bar Estimate**

Estimate sigma based on the average of the standard deviations. Only the subgroups specified for use in calculations will be used.

- **From Data – Weighted Approach Estimate**

This method estimates s-bar using a special formula that is recommended when the subgroup size varies across subgroups. Only the subgroups specified for use in calculations will be used.

- **Enter Standard Sigma Value(s)**

In this case the sigma value is entered directly. The corresponding s-bar value for plots is back-calculated from this value. If multiple stages are used, separate the sigma values for each stage by spaces.

- **Use a Variable with Standard Sigma Value(s)**

Specify a column containing the standard sigma value in row 1. The corresponding s-bar value for plots is back-calculated from this value. If multiple stages are used, a sigma value should be entered in a separate cell for each stage, beginning with row 1 for the first stage.

### Sigma Value(s)

Enter the value to be used for the standard sigma. If multiple stages are used, separate the sigma values for each stage by spaces.

### Sigma Variable

Specify a column containing the standard sigma value in row 1. The corresponding R-bar or s-bar value for plots is back-calculated from this value. If multiple stages are used, a sigma value should be entered in a separate cell for each stage, beginning with row 1 for the first stage.

---

## Limit Multipliers

### Primary Limit Multiplier

This option specifies the multiplier of sigma for the primary control limits. For the well-known 3-sigma limits, the multiplier is set to 3.

### Secondary Limit Multiplier

This option specifies the multiplier of sigma for the optional, secondary control limits. The secondary limits may be shown on the plot by checking the 'Secondary Limit' option on the plot format window.

---

## Reports Tab

The following options control the format of the reports.

---

### Specify Reports

#### Chart Summary (Control Limits and Estimation) Section

This report gives the numeric values of the center lines and limits, as well as the sigma estimation section.

#### Out-of-Control List Section

This report shows the out-of-control points and the corresponding reason (runs test or outside control limit).

---

### Report Options

#### Precision

Specify the precision of numbers in the report. A single-precision number will show seven-place accuracy, while a double-precision number will show thirteen-place accuracy. Note that the reports are formatted for single precision. If you select double precision, some numbers may run into others. Also note that all calculations are performed in double precision regardless of which option you select here. This is for reporting purposes only.

#### Variable Names

This option lets you select whether to display variable names, variable labels, or both.

#### Page Title

This option specifies a title to appear at the top of each page.

#### Plot Subtitle

This option specifies a subtitle to appear at the top of each plot.

---

## s Chart Tab

This panel sets the options used to define the appearance of the s chart.

---

### Select Plots

#### s (standard deviation) Chart

This chart is controlled by three form objects:

1. A checkbox to indicate whether the chart is displayed.
2. A format button used to call up the plot format window (see Quality Control Chart Format Options below for more formatting details).

s Charts

- A second checkbox used to indicate whether the chart can be edited during the run.

## Storage Tab

The options on this panel control the automatic storage of the standard deviations on the current dataset.

### Storage Columns

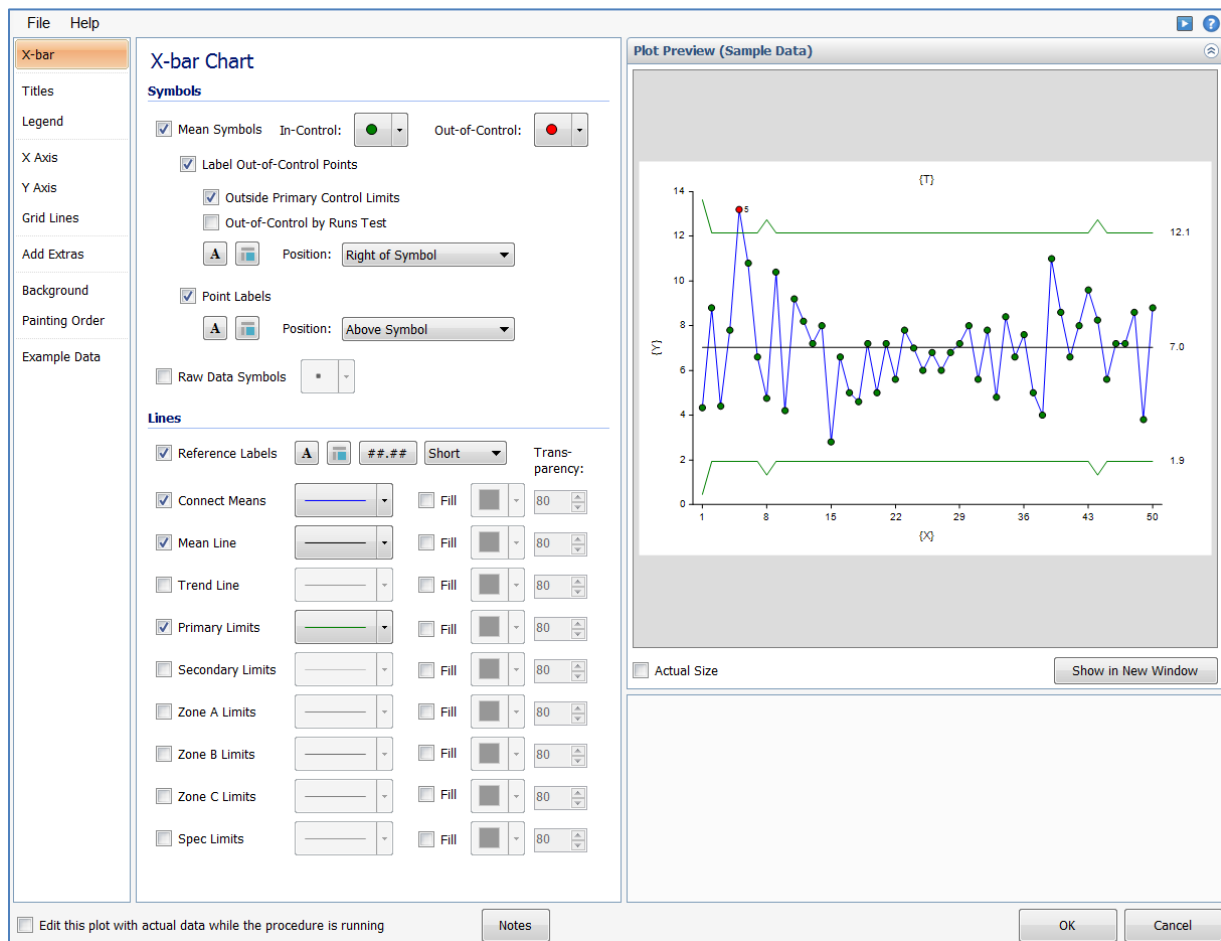
#### Store Standard Deviation in Column

You can automatically store the standard deviation of each subgroup into the column specified here.

Warning: Any data already in this column is replaced. Be careful not to specify columns that contain important data.

## Quality Control Chart Format Window Options

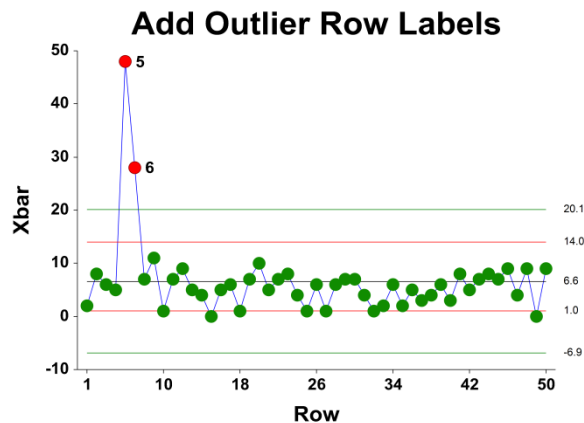
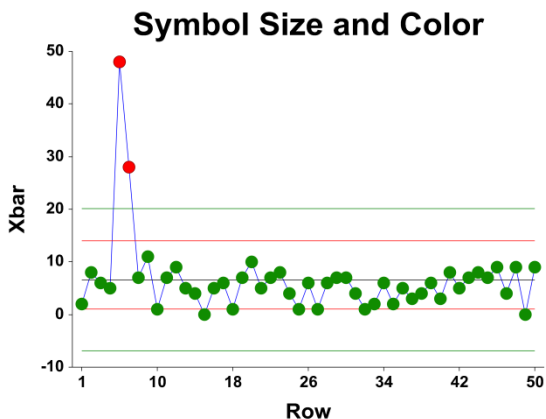
This section describes a few of the specific options available on the first tab of the control chart format window, which is displayed when a quality control chart format button is pressed. Common options, such as axes, labels, legends, and titles are documented in the Graphics Components chapter.



## [Xbar] / [Range] Chart Tab

### Symbols Section

You can modify the attributes of the symbols using the options in this section.

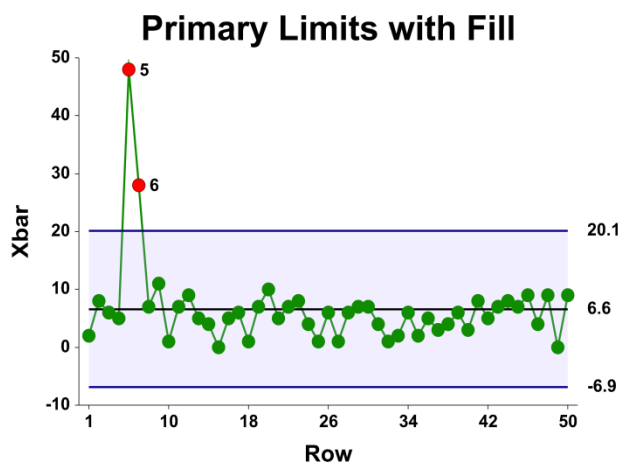
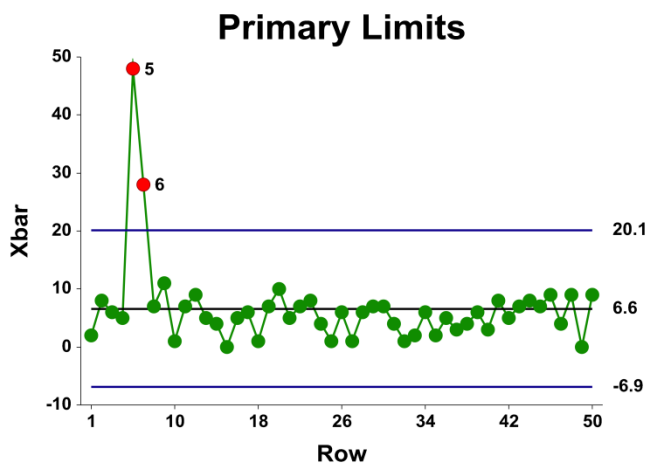


A wide variety of sizes, shapes, and colors are available for the symbols. The symbols for in-control and out-of-control points are specified independently. There are additional options to label out-of-control points. The label for points outside the primary control limits is the subgroup number. The label for points that are out-of-control based on the runs test is the number of the first runs test that is signaled by this point.

The user may also specify a column of point labels on the procedure variables tab, to be used to label all or some of the points of the chart. The raw data may also be shown, based on customizable raw data symbols.

### Lines Section

You can specify the format of the various lines using the options in this section. Note that when shading is desired, the fill will be to the bottom for single lines (such as the mean line), and between the lines for pairs of lines (such as primary limits).



Lines for the zones, secondary limits, and specification limits are also specified here.

---

## Titles, Legend, Numeric Axis, Group Axis, Grid Lines, and Background Tabs

Details on setting the options in these tabs are given in the Graphics Components chapter. The legend does not show by default, but can easily be included by going to the Legend tab and clicking the Show Legend checkbox.

---

### Example 1 – s Chart Analysis (Phase I)

This section presents an example of how to run an initial s Chart analysis to establish control limits. The data represent 50 subgroups of size 5. The data used are in the QC dataset. We will analyze the variables D1 through D5 of this dataset.

You may follow along here by making the appropriate entries or load the completed template **Example 1** by clicking on Open Example Template from the File menu of the s Charts window.

#### 1 Open the QC dataset.

- From the File menu of the NCSS Data window, select **Open Example Data**.
- Click on the file **QC.NCSS**.
- Click **Open**.

#### 2 Open the s Charts window.

- Using the Analysis or Graphics menu or the Procedure Navigator, find and select the **s Charts** procedure.
- On the menus, select **File**, then **New Template**. This will fill the procedure with the default template.

#### 3 Specify the variables.

- On the s Charts window, select the **Variables tab**.
- Double-click in the **Data Variables** text box. This will bring up the variable selection window.
- Select **D1** through **D5** from the list of variables and then click **Ok**. “D1-D5” will appear in the Data Variables box.

#### 4 Run the procedure.

- From the Run menu, select **Run Procedure**. Alternatively, just click the green Run button.

---

## Center Line Section

### Center Line Section for Subgroups 1 to 50

Number of Subgroups 50

Center Line	Estimate
s-bar	7.365443

This section displays the center line values that are to be used in the s chart.

### s-bar

This is the average of the standard deviations.

## Primary Control Limit Section

### Primary Control Limit Section for Subgroups 1 to 50

These limits are based on a subgroup of size 5.

Chart Type	Primary Control Limits	
	Lower	Upper
s	0	15.3864

This report gives the lower and upper limits for the chart, corresponding to a specific subgroup size.

### s Lower and Upper Primary Control Limits

These limits are the primary control limits of the s chart, as defined in the sub-section s Chart Limits of the Control Chart Formulas section toward the beginning of this chapter. Since the lower limit for the s chart is less than 0, it has been reset to 0.

## Sigma Estimation Section

### Sigma Estimation Section for Subgroups 1 to 50

Estimation Type	Estimated Value	Estimated Sigma
Ranges (R-bar)	18.14	7.798796
Standard Deviations (s-bar)*	7.365443	7.835698
Weighted Approach (s-bar)	7.902911	7.902911

\* Indicates the estimation type used in this report.

This report gives the estimation of the population standard deviation (sigma) based on three estimation techniques. The estimation technique used for the plots in this procedure is based on the ranges.

### Estimation Type

The formula for estimating sigma based on the ranges is shown earlier in this chapter in the Control Chart Formulas section. The formulas for the Standard Deviations method and Weighted Approach method are shown in the X-bar and s Charts chapter.

### Estimated Value

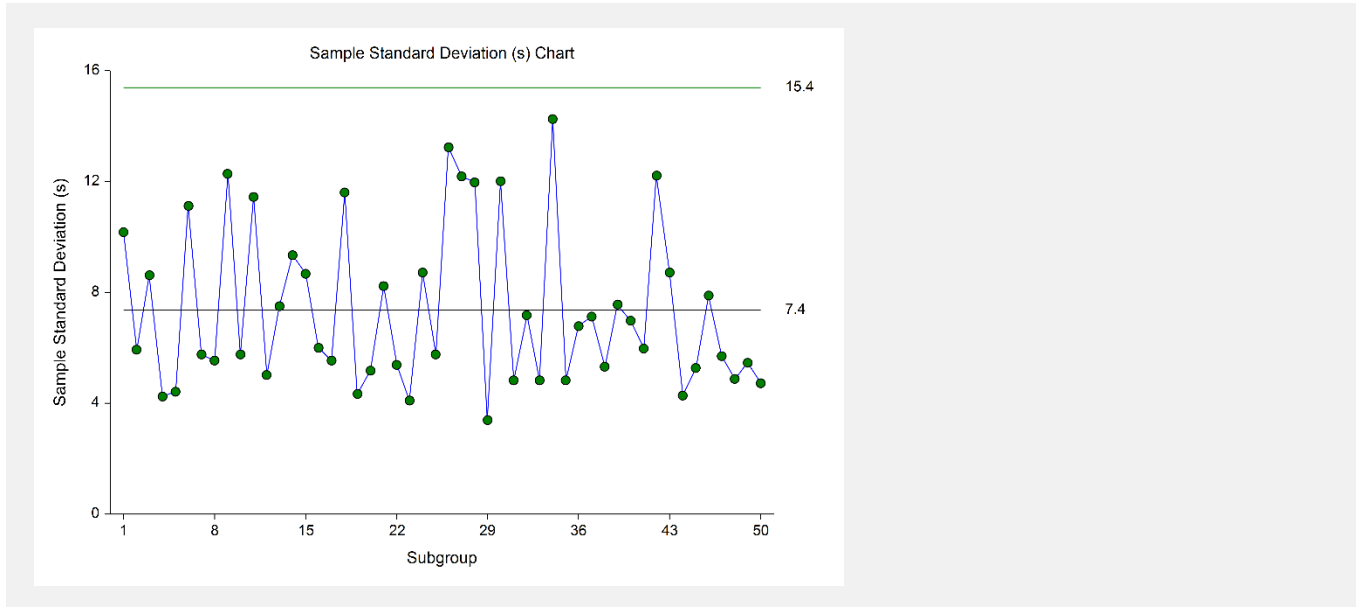
This column gives the R-bar and s-bar estimates based on the corresponding formulas.

### Estimated Sigma

This column gives estimates of the population standard deviation (sigma) based on the corresponding estimation type.



## s Charts



This plot shows the standard deviations for each subgroup, as well as the corresponding centerline and limits. The s chart seems to indicate the variation is in control.

## Out-of-Control List

**Out-of-Control List for Subgroups 1 to 50**

Subgroup	Mean	s	Subgroup Label	Reason
30	70.4	12.01249	30	s: 4 of 5 in zone B or beyond

This report provides a list of the subgroups that failed one of the runs tests (including points outside the control limits). The report shows that subgroup 30 is the final point of 4 out of 5 points in Zone B. This run does not appear to indicate a clear shift in the process variation.

## Example 2 – s Charts Analysis (Phase II)

This section presents a continuation of the previous example. In this example the limits are based on the first 50 observations, but the ranges are monitored for an additional 100 subgroups. The data are given in the columns D1ext – D5ext of the QC dataset.

You may follow along here by making the appropriate entries or load the completed template **Example 2** by clicking on Open Example Template from the File menu of the s Charts window.

### 1 Open the QC dataset.

- From the File menu of the NCSS Data window, select **Open Example Data**.
- Click on the file **QC.NCSS**.
- Click **Open**.

### 2 Open the R Charts window.

- Using the Analysis or Graphics menu or the Procedure Navigator, find and select the **s Charts** procedure.
- On the menus, select **File**, then **New Template**. This will fill the procedure with the default template.

### 3 Specify the variables.

- On the s Charts window, select the **Variables tab**.
- Double-click in the **Data Variables** text box. This will bring up the variable selection window.
- Select **D1ext** through **D5ext** from the list of variables and then click **Ok**. “D1ext-D5ext” will appear in the Data Variables box.

### 4 Specify the Rows in Calculations.

- Under Specify Rows in Calculations, set the **Specification Method** to **First N rows (Enter N)**.
- Set **N** to **50**.

### 5 Run the procedure.

- From the Run menu, select **Run Procedure**. Alternatively, just click the green Run button.

## Center Line, Control Limits, and Estimation Sections

### Center Line Section for Subgroups 1 to 50

Number of Subgroups 50

Center Line	Estimate
s-bar	7.365443

### Primary Control Limit Section for Subgroups 1 to 50

These limits are based on a subgroup of size 5.

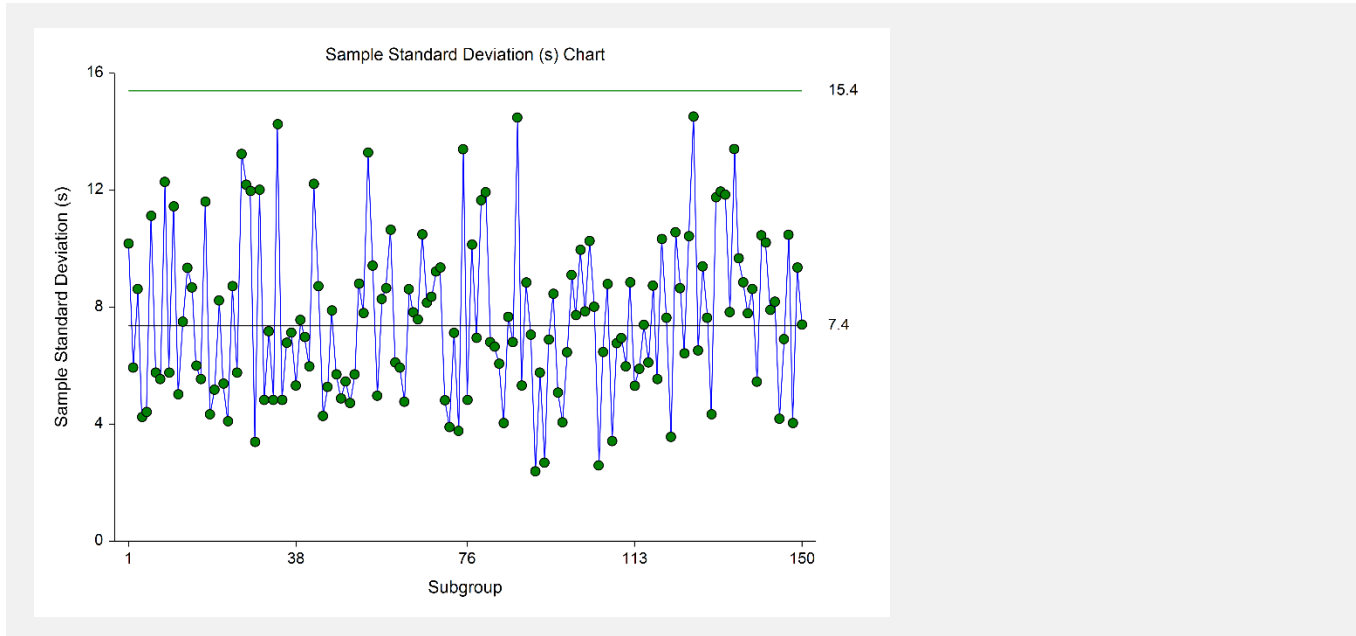
Chart Type	Primary Control Limits	
	Lower	Upper
s	0	15.3864

### Sigma Estimation Section for Subgroups 1 to 50

Estimation Type	Estimated Value	Estimated Sigma
Ranges (R-bar)*	18.14	7.798796
Standard Deviations (s-bar)	7.365443	7.835698
Weighted Approach (s-bar)	7.902911	7.902911

Since the first 50 subgroups are the same as those of Example 1, and since only the first 50 subgroups are used in the calculations for this run, the results for these sections are the same as those of Example 1.

## s Chart



This plot has the same limits as those of Example 1. There does not appear to be an obvious change in the standard deviations.

## Out-of-Control List

**Out-of-Control List for Subgroups 1 to 150**

Subgroup	Mean	Subgroup Range	Label	Reason
30	70.4	12.01249	30	s: 4 of 5 in zone B or beyond
70	69	9.354143	70	s: 8 in zone C or beyond
135	61.2	13.40522	135	s: 4 of 5 in zone B or beyond
138	68.8	7.79102	138	s: 8 in zone C or beyond
139	73.4	8.619744	139	s: 8 in zone C or beyond

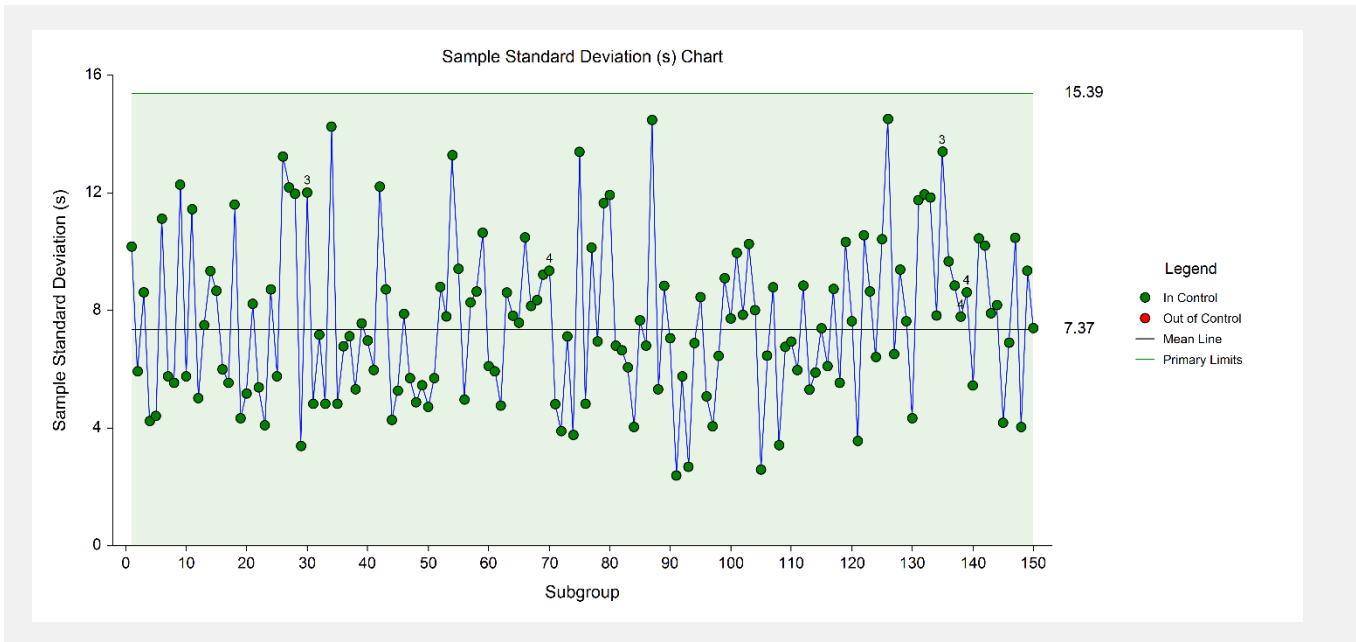
This list indicates a handful of out-of-control signals by Runs tests. There may be a signal for subgroups in the 130s.

## Example 3 – s Chart with Additional Formatting

This example uses the same setup as Example 2, except that a variety of improvements are made in the plot format. These improvements are made by clicking the s Chart format button on the s Chart tab.

You can load the completed template **Example 3** by clicking on Open Example Template from the File menu of the s Charts window.

### s Chart



As shown here, a variety of enhancements can be made to the formatting of the control charts to make the chart as easy to read as possible. The numbers above the points represent the number of the first runs test that is signaled by that point.