

## Chapter 247

# Cumulative Sum (CUSUM) Charts

## Introduction

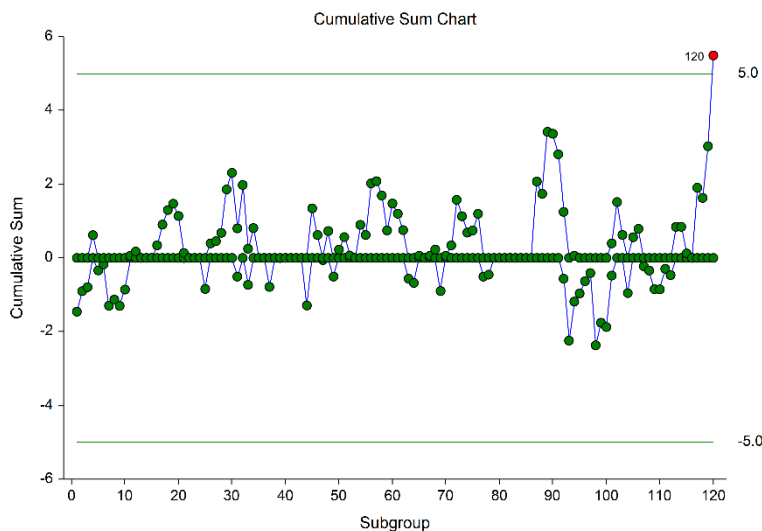
This procedure generates cumulative sum (CUSUM) control charts for. The format of the control chart is fully customizable. The data for the subgroups can be in a single column or in multiple columns. This procedure permits the defining of stages. The target value and sigma may be estimated from the data (or a subset of the data), or a target value and sigma may be entered directly. The CUSUM chart may be used for subgroup data, or for single observations at each time point. A fast initial response (head start) may be employed by the CUSUM chart, if desired.

## Cumulative Sum (CUSUM) Control Charts

The CUSUM chart is used to monitor the mean 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. Rather than examining the mean of each subgroup independently, the CUSUM chart shows the accumulation of information of current and previous samples. For this reason the CUSUM chart is generally better than the X-bar chart for detecting small shifts in the mean of a process.

The CUSUM chart relies on the specification of a target value and a known or reliable estimate of the standard deviation. For this reason, the CUSUM chart is better used after process control has been established.

The CUSUM chart typically signals an out-of-control process by an upward or downward drift of the cumulative sum until it crosses the boundary. An assignable cause is suspected whenever the CUSUM chart indicates an out-of-control process.



## Other Control Charts for the Mean of a Process

The X-bar chart is the most common control chart for monitoring the process mean. The X-bar chart is usually used in Phase I monitoring, when process control is being established. The X-bar chart is useful for detecting large changes in the process mean. The CUSUM chart is based on an established target mean and a reliable value for sigma. The CUSUM chart is useful for quickly detecting small shifts in the process mean.

An alternative to the CUSUM chart is the exponentially weighted moving average (EWMA) chart. The EWMA chart has similar properties to the CUSUM chart, and is also useful for detecting smaller shifts in the process mean.

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. CUSUM and EWMA charts may also be used for single responses, and are useful when small changes in the mean need to be detected.

## 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.

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

$$\bar{x}_i = \frac{\sum_{j=1}^n x_{ij}}{n}$$

## Estimating the Target Value

In the CUSUM procedure, the target value may be input directly, or it may be estimated from a series of subgroups. If it is estimated from the subgroups the formula for the grand average is

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

If the subgroups are of equal size, the above equation for the grand mean reduces to

$$\bar{\bar{x}} = \frac{\sum_{i=1}^k \bar{x}_i}{k} = \frac{\bar{x}_1 + \bar{x}_2 + \cdots + \bar{x}_k}{k}$$

## Cumulative Sum (CUSUM) Charts

**Estimating Sigma – Sample Ranges**

Either the range or the standard deviation of the subgroups may be used to estimate sigma, or a known (standard) sigma value may be entered directly. If the standard deviation (sigma) is to be estimated from the ranges, it is estimated as

$$\hat{\sigma} = \frac{\bar{R}}{d_2}$$

where

$$\bar{R} = \frac{\sum_{i=1}^k R_i}{k}$$

$$d_2 = \frac{E(R)}{\sigma} = \frac{\mu_R}{\sigma}$$

The calculation of  $E(R)$  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  $d_2$  are derived through the use of numerical integration. It is important to note that the normality assumption is used and that the accuracy of this estimate requires that this assumption be valid.

When  $n$  is one, we cannot calculate  $R_i$  since it requires at least two measurements. The procedure in this case is to use the ranges of successive pairs of observations. Hence, the range of the first and second observation is computed, the range of the second and third is computed, and so on. The average of these approximate ranges is used to estimate  $\sigma$ .

**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

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

## Cumulative Sum (CUSUM) Charts

## Estimating Sigma – Weighted Approach

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

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

## CUSUM Charts

Following the CUSUM procedure presented by Ryan (2011), the steps for creating a CUSUM chart may be summarized as follows:

1. Calculate the  $z_i$  using the formula

$$z_i = \frac{\bar{x}_i - \bar{\bar{x}}}{\hat{\sigma}_{\bar{x}}}$$

2. Calculate the lower and upper cumulative sums as follows

$$S_{Li} = -\max[0, (-z_i - k) + S_{Li-1}]$$

$$S_{Hi} = \max[0, (z_i - k) + S_{Hi-1}]$$

3. Plot  $S_{Hi}$  and  $S_{Li}$  on a control chart. The control limits are chosen as plus or minus  $h$ . The usual choice for  $k$  is 0.5 (for detecting one-sigma shifts in the mean) and  $h$  is typically set to 5.
4. When an out-of-control situation is detected, the corresponding sum may be left as it is, or reset to an appropriate starting value. In NCSS, the re-starting value may be set to zero or the fast initial restart (FIR) value of  $h/2$ .

## 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
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.

## Cumulative Sum (CUSUM) Charts

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
.	.
.	.
.	.

## Cumulative Sum (CUSUM) Charts

- 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.

**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.

## Cumulative Sum (CUSUM) Charts

### 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
.	.	.
.	.	.
.	.	.

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.

## Cumulative Sum (CUSUM) Charts

### 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.

### 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.



## Cumulative Sum (CUSUM) Charts

---

### Specify Rows in Target Value and/or Sigma 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.

#### 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.

## Cumulative Sum (CUSUM) Charts

---

### 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.

## Cumulative Sum (CUSUM) Charts

### 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.

---

## Target & Sigma Tab

The options on the Target & Sigma tab are used to specify the target value and sigma.

---

### Target Value Options

#### Target Value Specification

Specify whether the target value is estimated from the data, or whether it will be specified directly.

- **From Rows in Calculations Data**  
Estimate the target value from the subgroups specified for calculations.
- **Enter Target Value(s)**  
Specify the target value directly. If multiple stages are used, separate the target value for each stage by spaces.
- **Use a Variable with Target Value(s)**  
Specify a column containing the target value in row 1. If multiple stages are used, a target value should be entered in a separate cell for each stage, beginning with row 1 for the first stage.

#### Target Value(s)

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

#### Target Value(s) Variable

Specify a column containing the target value in row 1. If multiple stages are used, a target value should be entered in a separate cell for each stage, beginning with row 1 for the first stage.

---

### Sigma Estimation Options

#### Sigma Specification

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

- **From Rows in Calculations Data - R-bar or s-bar Estimate**  
Estimate sigma based on the average of the ranges or standard deviations (whichever is specified under R-bar or s-bar Estimation). Only the subgroups specified for use in calculations will be used.
- **From Rows in Calculations 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 Sigma Value(s)**  
In this case the sigma value is entered directly. If multiple stages are used, separate the sigma values for each stage by spaces.
- **Use a Variable with Sigma Value(s)**  
Specify a column containing the sigma value in row 1. 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.

## Cumulative Sum (CUSUM) Charts

### Sigma Value(s)

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

### Sigma Variable

Specify a column containing the sigma value in row 1. 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.

---

## Reports Tab

The following options control the format of the reports.

---

### Specify Reports

#### Target Value and Sigma Summary Section

This report gives the numeric values of the target value and sigma, as well as the sigma estimation.

---

### 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.

---

## CUSUM Chart Tab

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

---

### Select Plots

#### CUSUM 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).
3. A second checkbox used to indicate whether the chart can be edited during the run.

## Cumulative Sum (CUSUM) Charts

### Threshold Limit (h)

This value and the corresponding negative value constitute the out-of-control limit for the CUSUM chart. The threshold value is sometimes called the decision interval. It is typically set to five.

### Reference Value (k)

The reference value (k) is the mean-shift detection constant for the CUSUM chart. It is sometimes called the allowance, or slack value. It is typically set to 0.5.

### Start Method

The start method specifies whether the cumulative sum starting value is zero, or whether a fast initial response value (FIR) is used.

- **Zero**  
Prior to the first cumulative sum of the chart, the cumulative sum is set to zero.
- **Fast Initial Response (FIR)**  
Prior to the first cumulative sum of the chart, the cumulative sum is set to  $h/2$ .

### Restart Method

After an out-of-control signal is encountered, the restart method specifies whether the cumulative sum is set to zero, a restarting fast initial response (FIR) value, or is left as is.

- **Zero**  
After an out-of-control signal, and before the next cumulative sum, the cumulative sum is set to zero.
- **Fast Initial Response (FIR)**  
After an out-of-control signal, and before the next cumulative sum, the cumulative sum is set to  $h/2$ .
- **None**  
After an out-of-control signal, no adjustment is made to the cumulative sum value.

---

## Storage Tab

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

---

### Storage Columns

#### Store Means in Column

You can automatically store the mean 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

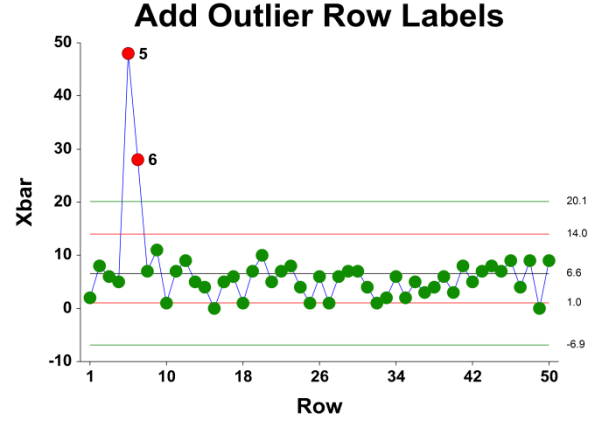
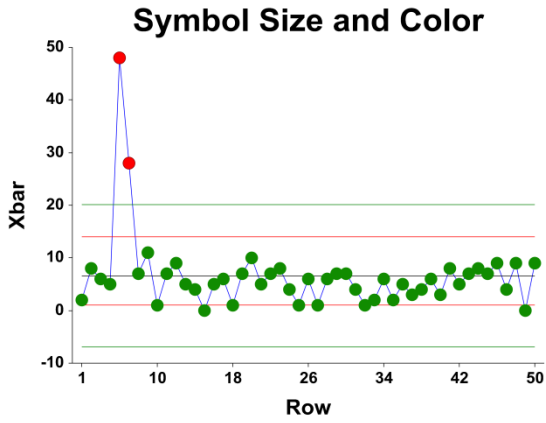
This section describes a few of the specific options available on the first tab of the control chart format window, which is displayed when a quality control chart format button is pressed. Common options, such as axes, labels, legends, and titles are documented in the Graphics Components chapter.

The screenshot shows the 'X-bar Chart' format window. On the left is a sidebar with options like 'Titles', 'Legend', 'X Axis', 'Y Axis', 'Grid Lines', 'Add Extras', 'Background', 'Painting Order', and 'Example Data'. The main area is divided into 'Symbols' and 'Lines' sections. The 'Symbols' section includes checkboxes for 'Mean Symbols', 'Label Out-of-Control Points', 'Outside Primary Control Limits', 'Out-of-Control by Runs Test', and 'Point Labels'. The 'Lines' section includes checkboxes for 'Reference Labels', 'Connect Means', 'Mean Line', 'Trend Line', 'Primary Limits', 'Secondary Limits', 'Zone A Limits', 'Zone B Limits', 'Zone C Limits', and 'Spec Limits'. Each line option has a color and fill selection. A 'Plot Preview (Sample Data)' window is open, showing a line graph with data points and control limits. The plot has a mean line at 7.0 and primary limits at 1.9 and 12.1. A single point at x=5 is highlighted in red and labeled '5'. The plot preview window has 'Actual Size' checked and a 'Show in New Window' button. At the bottom of the main window, there is an 'Edit this plot with actual data while the procedure is running' checkbox, a 'Notes' button, and 'OK' and 'Cancel' buttons.

## [Xbar] / [Range] Chart Tab

### Symbols Section

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

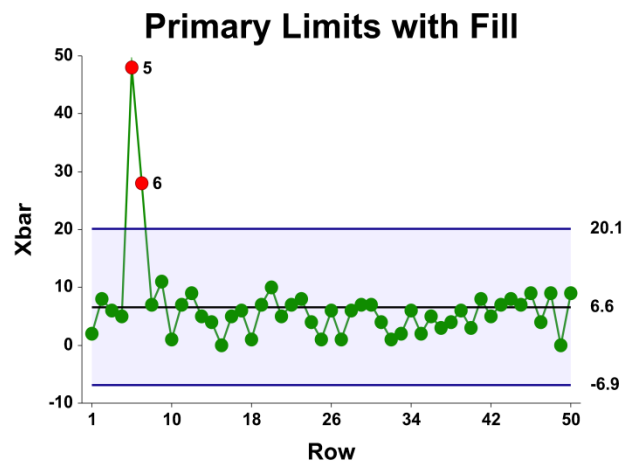
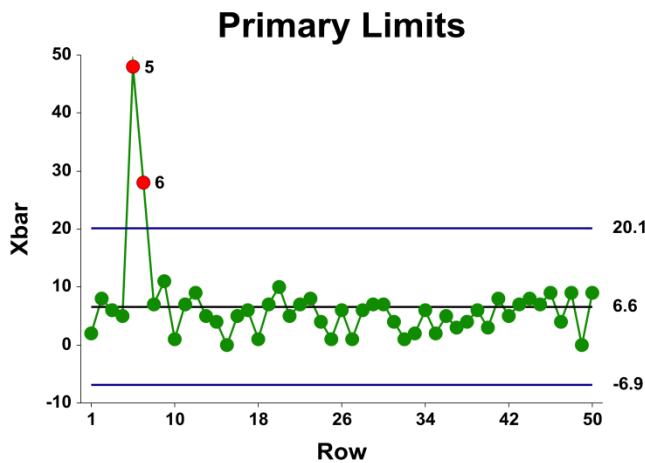


A wide variety of sizes, shapes, and colors are available for the symbols. The symbols for in-control and out-of-control points are specified independently. There are additional options to label out-of-control points. The label for points outside the primary control limits is the subgroup number. The 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.

## Cumulative Sum (CUSUM) Charts

---

## 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 – In-Control CUSUM Chart

This section presents an example of how to produce a CUSUM chart. 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. The target value is to be set to 67 and the sigma value is 8.

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 CUSUM 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 CUSUM Charts window.

- Using the Analysis or Graphics menu or the Procedure Navigator, find and select the **CUSUM 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 CUSUM 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 Specify the target value and sigma.

- On the CUSUM Charts window, select the **Target & Sigma tab**.
- Set **Target Value Specification** to **Enter Target Value(s)**. Set the **Target Value** to **67**.
- Set **Sigma Specification** to **Enter Sigma Value(s)**. Set the **Sigma Value** to **8**.

#### 5 Run the procedure.

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

---

## Target Value Section

### Target Value Section for Subgroups 1 to 50

Number of Subgroups 50

Target Value Specification	Value
User-Specified Target Value	67

This section displays the target value that is used in the CUSUM chart.

### Target Value Specification

This is the method by which the target value is obtained.



## Cumulative Sum (CUSUM) Charts

### Target Value

This is value of the target value used to create the CUSUM chart.

---

## Sigma Specification Section

### Sigma Specification Section for Subgroups 1 to 50

<b>Sigma Specification</b> User-Specified	<b>User-Specified Sigma Value</b> 8
--	--

This section shows the specification of the standard deviation used in the CUSUM chart.

### Sigma Specification

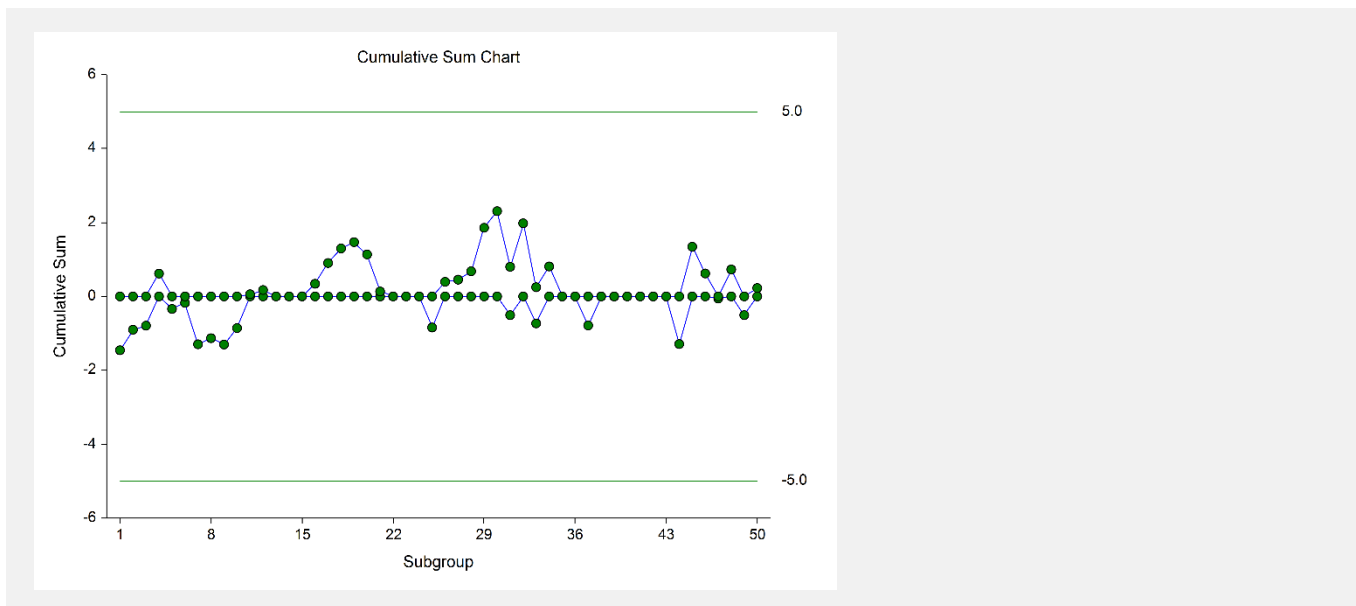
This is the method by which the sigma value is obtained.

### User-Specified Sigma Value

This is value of the sigma entered by the user, and is the value used to create the CUSUM chart.

---

## CUSUM Chart



This CUSUM plot shows the progress of the cumulative sum across the 50 subgroups. There does not appear to be an indication of a change in the process mean.

## Example 2 – CUSUM Chart with a Change in Process Mean

This section presents a continuation of the previous example. In this example the means are monitored for an additional 100 subgroups. The data are given in the columns D1ext – D5ext of the QC dataset. In this dataset, the mean of the process changed from 67 to 70 somewhere between subgroup 110 and 120.

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 CUSUM 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 CUSUM Charts window.

- Using the Analysis or Graphics menu or the Procedure Navigator, find and select the **CUSUM 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 target value and sigma.

- On the CUSUM Charts window, select the **Target & Sigma tab**.
- Set **Target Value Specification** to **Enter Target Value(s)**. Set the **Target Value** to **67**.
- Set **Sigma Specification** to **Enter Sigma Value(s)**. Set the **Sigma Value** to **8**.

### 5 Specify the restart method.

- On the CUSUM Charts window, select the **CUSUM Chart tab**.
- Set **Restart Method** to **None**.

### 6 Run the procedure.

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

## Target Value and Sigma Specification Sections

### Target Value Section for Subgroups 1 to 50

Number of Subgroups 50

Target Value Specification	Value
User-Specified Target Value	67

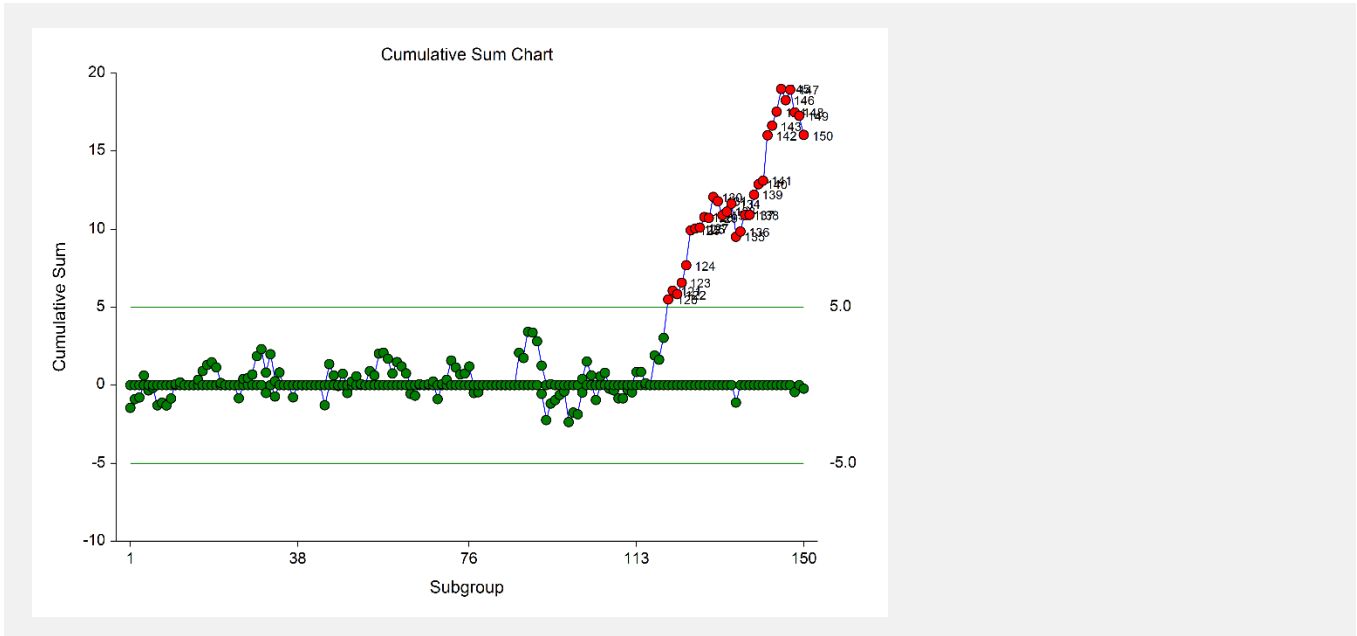
### Sigma Specification Section for Subgroups 1 to 50

Sigma Specification	User-Specified Sigma Value
User-Specified	8

Since the target value and sigma value specified are the same as those of Example 1, the results for these sections are the same as those of Example 1.

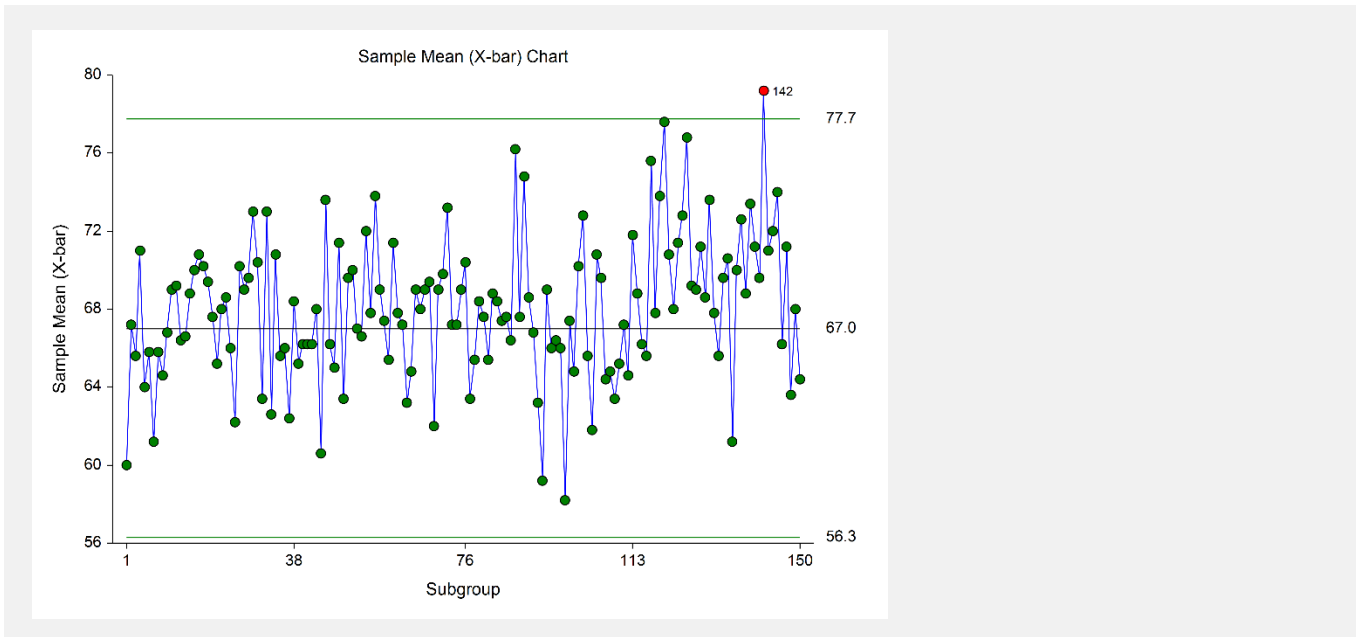
Cumulative Sum (CUSUM) Charts

CUSUM Chart



This plot gives a clear indication of a change in the process mean somewhere shortly before subgroup 120.

Corresponding X-bar Chart



Based on the X-bar chart of the same subgroups, the change in process mean is much less apparent.

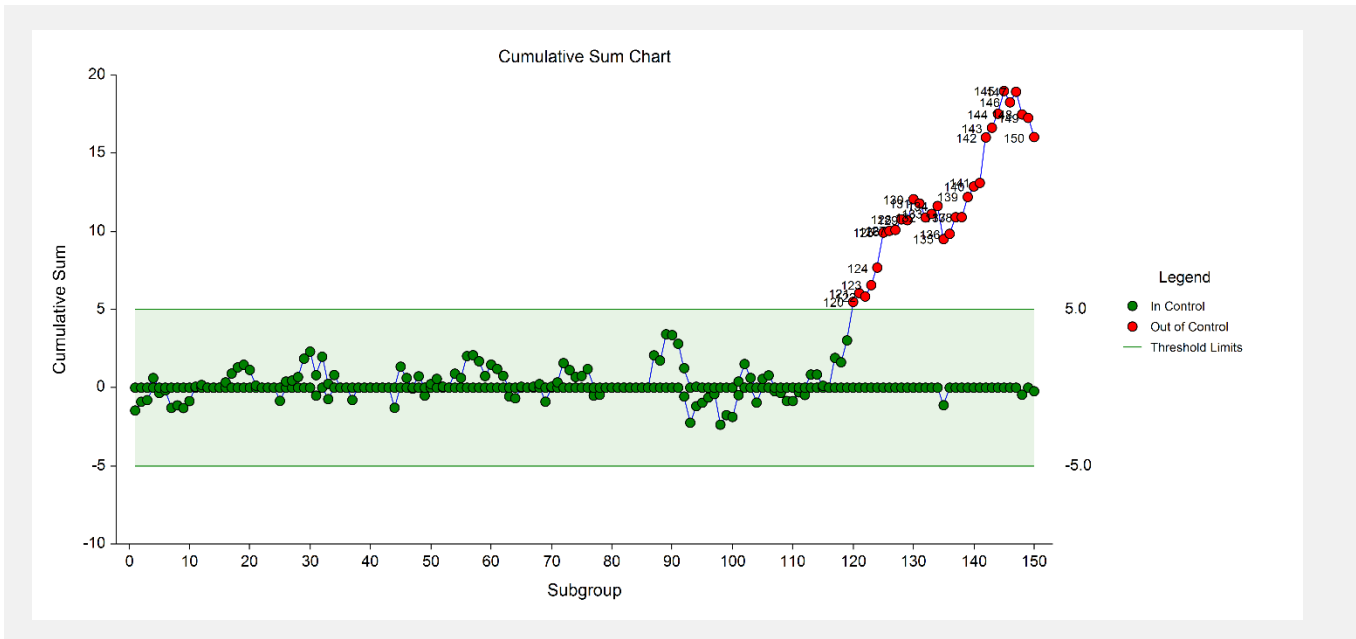
Cumulative Sum (CUSUM) Charts

### Example 3 – CUSUM 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 CUSUM Chart format button on the CUSUM Chart tab.

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

### CUSUM 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 subgroup number.