Control Charts

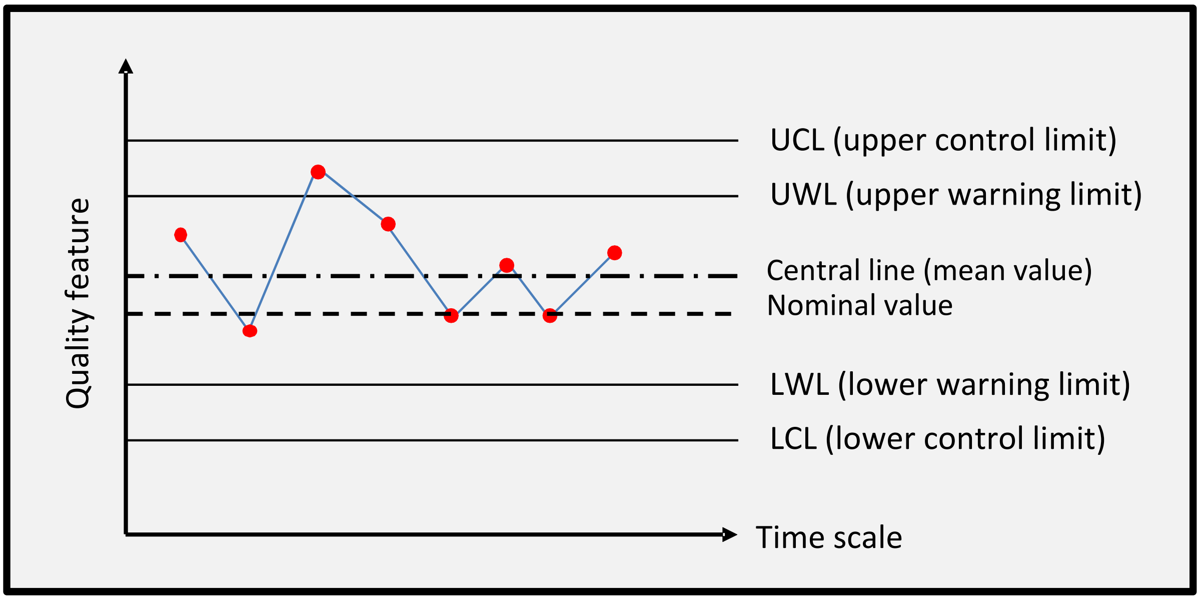
Introduction

A Control Chart shows the time course of a process characteristic. For this purpose, data can be taken continuously or in periodic samples. The prerequisite is that the process capability has previously been confirmed. The Control Chart is also well known as Statistical Process Control SPC.
There are control charts for continuing quantitative measurands and for attributive characteristics (test with counts). The sole representation of a continuing measurand is defined as an single measurement chart.

Continuing measurements	Attributive characteristics
Single measurement chart (only measurand on its own)	p-chart proportion of defective units
$\bar{x}/s$ - control chart (additionally with scatter distribution)	np-chart number of defective units
$\bar{x}/R$ - control chart (additionally with distribution of range)	u-chart Number of errors per unit for multiple possible errors

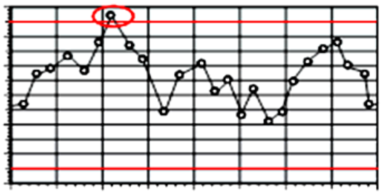
Purpose and benefit:

The quality control chart helps in recognizing systematic influences of a process, as well as disturbance variables and environmental influences. In the SPC, warning and control limits calculated statistically from the process data are determined and entered. An intervention is only required if the control limits are exceeded, leading to a more stable process (see illustration):

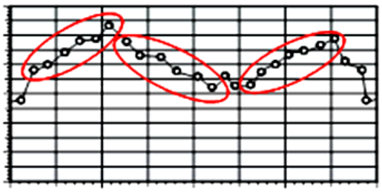


If one or more values of a random sample is/are outside the control limits, this defect must be identified and rectified as quickly as possible before the process exceeds the tolerance limits. Note: The tolerance is normally not shown in the control chart.

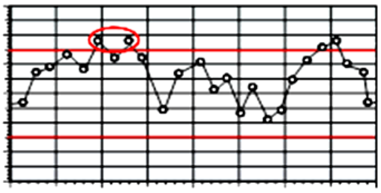
Further interventions must be made if the following conditions are met:



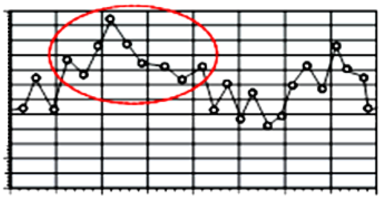
One point outside ± 3s



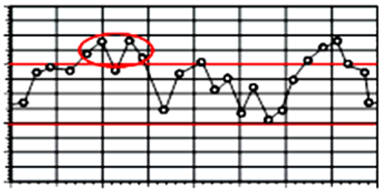
6 points in succession rising or falling



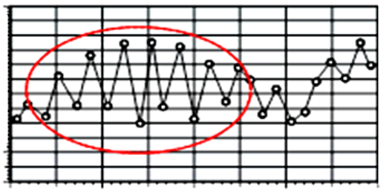
2 out of 3 points in succession



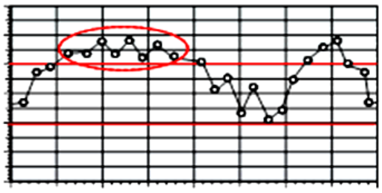
9 points in succession on the same side



4 out of 5 points in succession



14 points in succession alternating above and below the midline



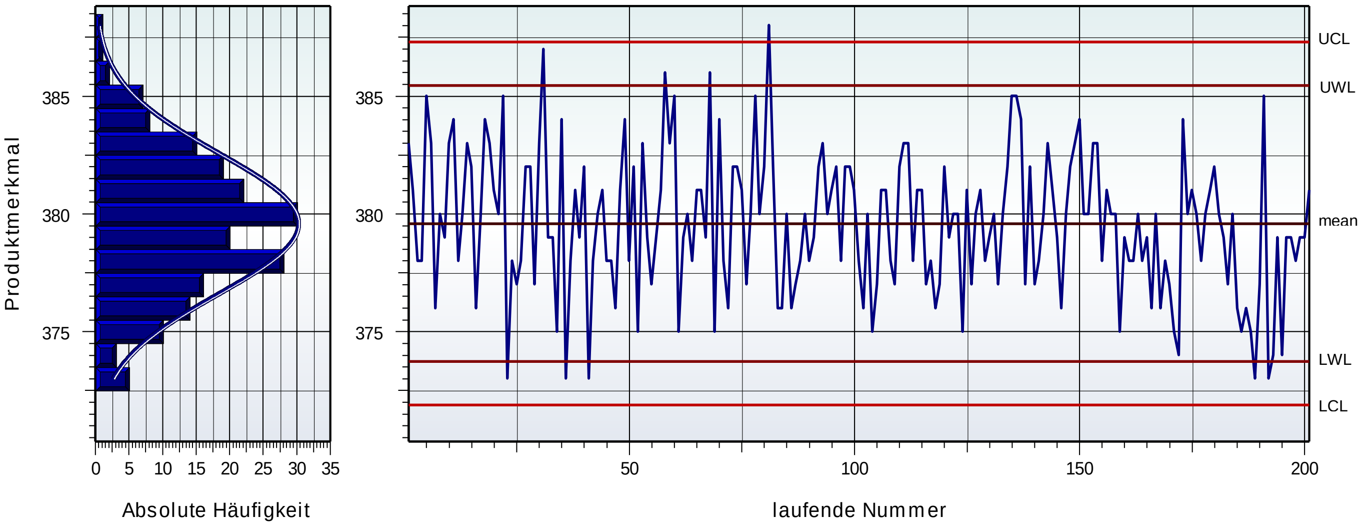
8 points in succession outside ± 1s

An expansion to 8 rules is also referred to the so called "Western Electric Rules". The causes of these deviations must be ascertained. Measures carried out in a corresponding way are noted on the SPC. The production quantity since the last random sample was taken must be traced.

Basics and examples

$\overline{x}$ - Quality control chart

In the following illustration, the length of a transverse member was monitored using the SPC:



What are referred to as the lower/upper warning limits LWL/UWL and control limits LCL/UCL are shown on the right.

LWL - UWL	95.45 %	Average value ±2·s‘
LCL - UCL	99.73 %	Average value ±3·s‘

The areas ±2 s‘ and ±3s‘ correspond to a probability range of 95.45% and 99.73%. (Note: In sources from the German literature, warning and control limits above 95% and 99% probability are often defined).
These limits do not reflect the tolerance range, but rather only the observed frequency distribution (histogram on the left in the previous illustration) of the particular random sample parameter that is being monitored. The tolerance limits are never specified on the process control chart. The collected process data does however form the basis for the process capability investigation in relation to the tolerance (see Cp/Cpk).
The warning and control limits are calculated periodically based on the most recent process data. Intervention of correction of the process only takes place once the control limits have been undershot or exceeded.

$\bar{x}$/s - Quality control chart

In the $\bar{\mathbf{x}}/\mathbf{s}$ - quality control chart acc. to Shewhart, the data is subdivided into random samples. Within these random samples, it is possible to create a standard deviation for each, the profile of which is represented alongside the average value. The warning and control limits for the average values are brought into relation with a subdivided sample size n‘ here (standard group size n‘ = 5):

LWL - UWL	95.45 %	Average value $\pm 2 s' / \sqrt{n'}$
LCL - UCL	99.73 %	Average value $\pm 3 s' / \sqrt{n'}$

Warning and control limits for the standard deviation are calculated here using the χ^2-distribution:

$$LWL = s\sqrt{\frac{\chi^2_{0,02275,\,n'-1}}{n'-1}} \qquad UWL = s\sqrt{\frac{\chi^2_{0,97725,\,n'-1}}{n'-1}}$$

$$LCL = s\sqrt{\frac{\chi^2_{0,00135,\,n'-1}}{n'-1}} \qquad UCL = s\sqrt{\frac{\chi^2_{0,99865,\,n'-1}}{n'-1}}$$

The standard deviation should always be as small as possible, so the LWL and LCL are not used as a rule.

Quality control charts for qualitative features

Qualitative features are understood to be events such as faulty/good, yes/no or missing/not missing, etc. In this case, large sample ranges are required so that defects can be detected. If there are very low defect probabilities, consequently, the samples must be taken over a long period and this can be a disadvantage. The following differentiation is made:

p-card	The proportion of faulty units in the sample is entered here
u-card	Here, the number of defects per unit in the sample is entered

p-card

The sample ranges do not have to be constant, although a fluctuation of more than 25% is not recommended. The relative proportion of faulty units is:

$$p = \frac{n^*}{n'} = \frac{n' p}{n'}$$

p : relative defect proportion
n^* : number of faulty units
n' : sample range (faulty and intact units)

Depending on whether the relative defect proportion (p-card) or the absolute defects are noted on the control chart, there is also what is referred to as the np-card for the latter case. In the np-card, the random sample range is constant.

The average defect proportion in several random samples is then:

$$\bar{p} = \frac{1}{n_{tot}} \sum_{i=1}^{m} n_i^*$$

n_i^* : number of defects per random sample
m : number of random samples
n_{tot} : number of total units

The control limits are calculated by way of approximation to the normal distribution where:

$$LCL = \bar{u} - 3\sqrt{\frac{\bar{u}}{\bar{n}}} \qquad UCL = \bar{u} + 3\sqrt{\frac{\bar{u}}{\bar{n}}}$$

$\bar{u}$: Mean sample size

Here too, LCL is generally not required, particularly since negative values are mathematically possible.

u-card

In the u-card, the random samples must consist of units with several components or defect possibilities. The sample size can be different, but should not fluctuate by more than 25%. The number of defects per unit is:

$$u = \frac{c}{n'}$$

c : number of defects in the random sample
n' : sample range

Analogously to the u-card, there is also the c-card, in which the absolute number of defects is shown here. The random sample range is constant.
In the u-card, the average number of defects is:

$$\bar{u} = \frac{1}{n_{tot}} \sum_{i=1}^{m} c_i$$

c_i : number of defects per random sample
m : number of random samples
n_{tot} : number of total units

The control limits are calculated as follows:

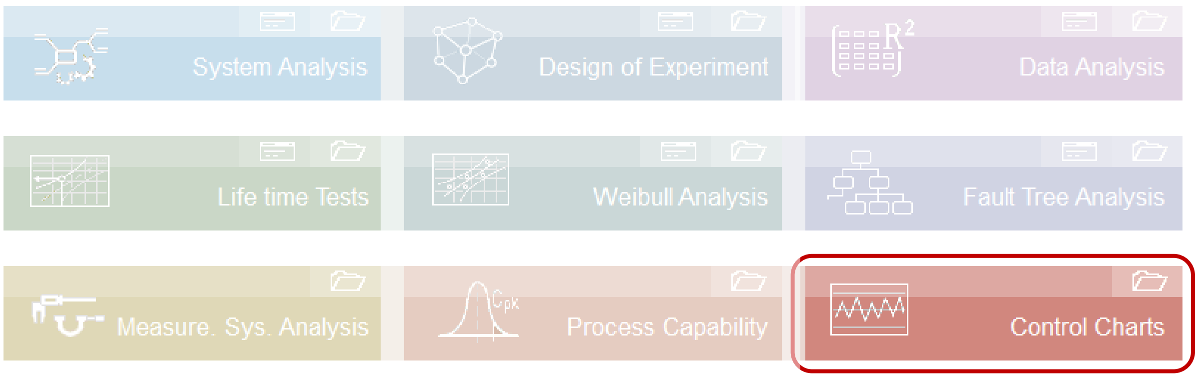
$$UEG = \bar{u} - 3\sqrt{\frac{\bar{u}}{\bar{n}}} \qquad OEG = \bar{u} + 3\sqrt{\frac{\bar{u}}{\bar{n}}}$$

$\bar{n}$: Mean sample size

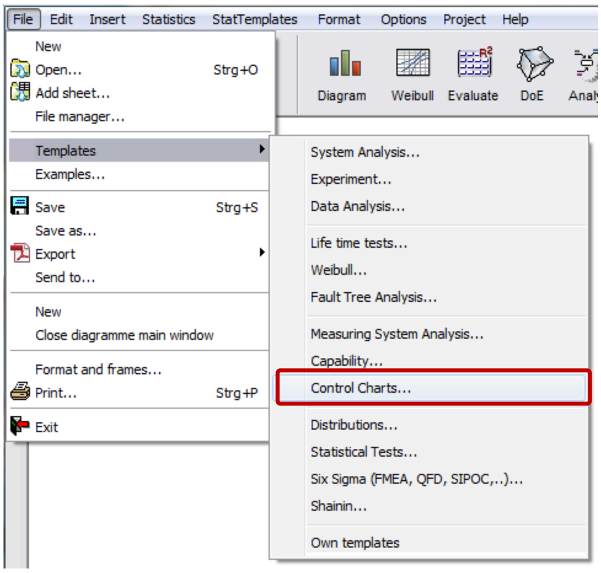
LCL, however, is usually not used and can also be negative.

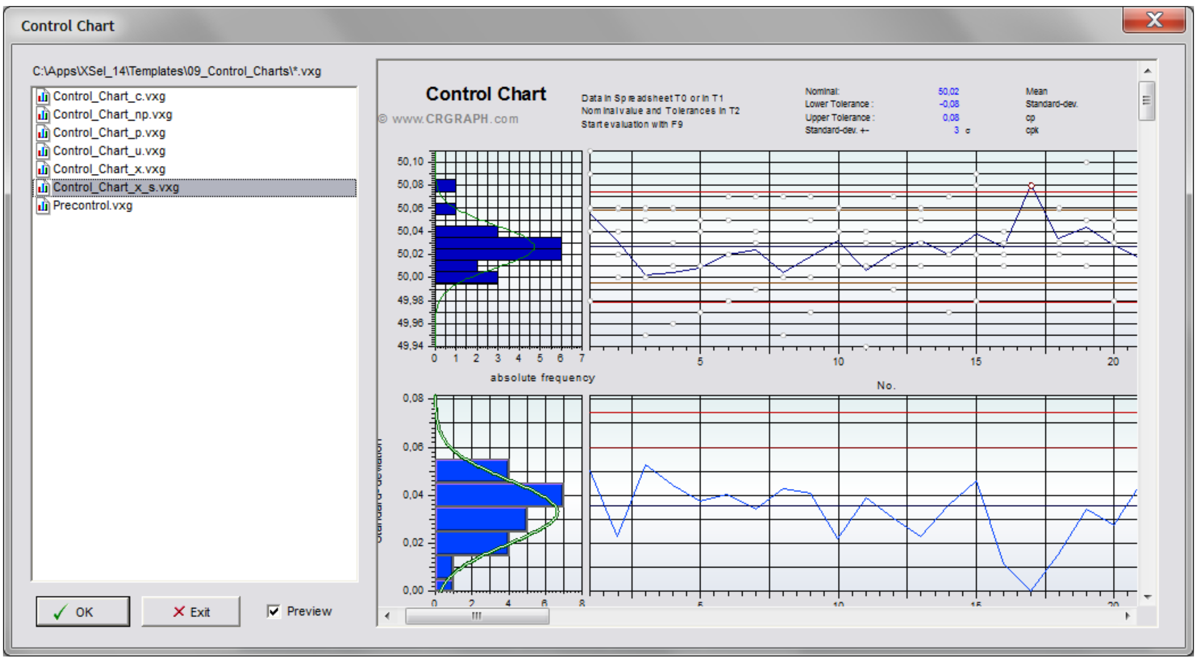
Using Visual-XSel

All control charts are available as templates. Click to the icon in the main guide…



or use menu ***File / Templates***…

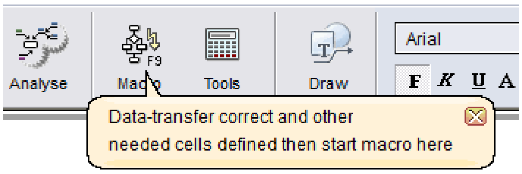


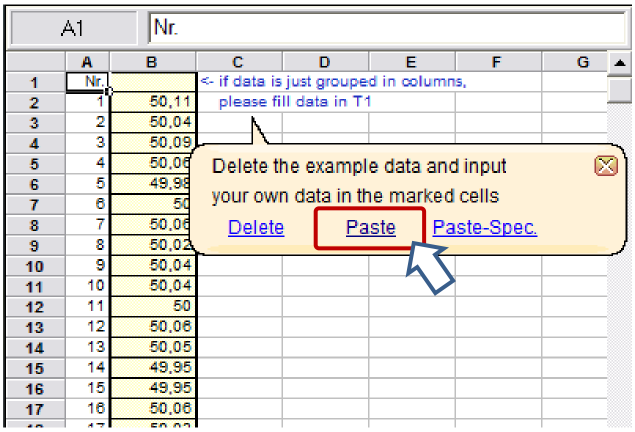


Control Charts

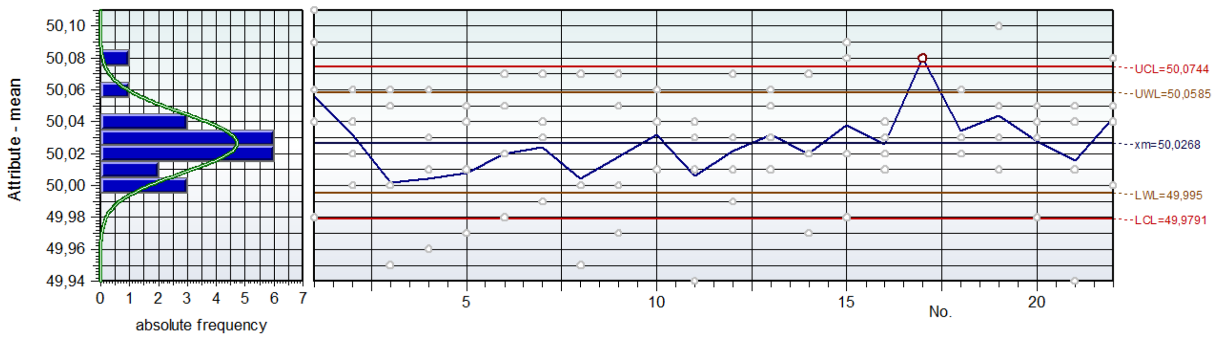
Use the ***Paste*** – link for your data in the clipboard, which has to be copied before (e.g. from Excel).

After data transfere start the macro





Then the charts on the right main window has update with the new data



In case of the Control_Chart_x_s.vxg on the 2nd page the "Western Electric Rules" will be shown, if relevant conditions where met here.

The example has at point 17 one point is outside ± 3s