# JEDEC STANDARD

## Statistical Process Control Systems

## JESD557C

(Revision of EIA-557B, January 2006)

**APRIL 2015**

**JEDEC SOLID STATE TECHNOLOGY ASSOCIATION**

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# STATISTICAL PROCESS CONTROL SYSTEMS

## Contents

## Introduction

Continuous quality improvement and the achievement of operational and manufacturing excellence are the essence of the total quality philosophy. One of the major vehicles used for achieving the excellence objective is the application of Statistical Process Control (SPC) techniques.

SPC embraces a management philosophy of continuous process improvement that has a primary focus on prevention of outliers or maverick products to be shipped to customers. After a process has been characterized using statistical techniques (i.e., design of experiments (DOE), capability studies), SPC is a tool that can be applied to control and optimize the process and reduce variability. An acceptable approach toward an SPC system involves the use of "end-of-process" data to control the process through the application of SPC techniques. However, the intent of this standard is to emphasize the use of in-process data in order to better control and forecast product quality. This proactive use of SPC in conjunction with other techniques and the appropriate responsiveness to out-of-control situations serves to make SPC techniques critical in continuous process improvement and achieving excellence.

It is well recognized that the implementation of an effective and measurable continuous improvement program, which includes SPC, is an ongoing process. In order for techniques such as SPC to be firmly established throughout all facets of an organization, a strong management commitment must exist. In addition, personnel must be trained, involved, and held accountable in this statistical analysis, control and improvement process. The exact nature and sophistication of these techniques may vary from manufacturer to manufacturer, depending on the management concepts involved. In recognition of this tendency, this standard provides the general requirements of SPC, including definitions and terminology to promote standardization of best practices.

# STATISTICAL PROCESS CONTROL SYSTEMS

(From JEDEC Board ballot JCB-15-09, formulated under the cognizance of the JC-14 Committee on Quality and Reliability of Solid State Products.)

## 1 Scope

This standard specifies the general requirements of a statistical process control (SPC) system.

## 2 References

The following normative documents contain provisions that, through reference in this text, constitute provisions for this standard. For undated references, the latest edition of the normative document referred to applies.

JEDEC JEP132, *Process Characterization Guideline*
IS0 10012, *Measurement Management Systems - Requirements for Measurement Processes and Measuring Equipment*

## 3 Terms and definitions

EIA-557-B defined many terms used in the field of SPC. Many were not actually used in EIA-557-B. In this standard, JESD557C, the terms necessary to understand the text are defined in 3.1, other terms are defined in Annex F.

### 3.1 Terms and definitions used in this document

**audit**: The periodic review of procedures and observation of performed activities to evaluate compliance with requirements.

**average:** The sum of the sample values divided by the number of sample values. A measure of location used to estimate the population mean.

**capability**: The ability to meet a specification.

**capability index**: A measure of the relationship between the specification limits and the capability.

**characteristic:** A distinguishing feature of a process or its output on which variables or attributes data can be collected.

**characterization:** A description of the characteristics of a product or process by mathematical modeling, design of experiments, or statistical data evaluation.

NOTE Methods of statistical data evaluation are described in JESD557 and JEP132.

### 3.1 Terms and definitions used in this document (cont'd)

**common cause:** A source of natural variation that affects all the individual values of the process output being studied.

NOTE In control chart analysis common causes appear as part of the random process variation.

**control chart:** A graphic representation of a process characteristic showing plotted values of some statistic gathered from that characteristic, a central line and one or two statistically derived control limits.

**control limits:** The maximum allowable variation of a process characteristic due to common causes alone.

NOTE 1 Variation beyond a control limit may be evidence that special causes are affecting the process.

NOTE 2 Control limits are calculated from process data and are usually represented as a line (or lines) on a control chart. They are not to be confused with engineering specification limits.

**Cpk:** See "process capability index (Cpk)".

**critical (process) node:** A node in the process flow whose output has a significant impact on the process.

**data point:** A value that is either observed or calculated.

**individual:** A single unit or a single measurement of a characteristic.

**mean:** The sum of the population values divided by the number of values in the population—a measure of location (central tendency) equal to the center of gravity of the population.

**median:** The middle value in a group of measurements when arranged from lowest to highest—a measure of location.

NOTE When the number of measurements is an even number, the average of the two middle values is used as the median.

**node:** A definable point in the process at which form, fit, or function of the product or service is altered.

**normal distribution; Gaussian distribution:** A continuous, symmetrical, bell-shaped frequency distribution for variables data.

NOTE When measurements have a normal distribution, about 68.26% of all individuals lie within plus or minus one standard deviation unit of the mean; about 95.44% lie within plus or minus two standard deviation units of the mean; and about 99.73% of all individuals lie within plus or minus three standard deviation units of the mean.*

**out-of-control:** A set of data with the mean value or sigma of a sample violating the control limit

**out-of-spec:** A set of data with at least one value violating the spec limit.

**parameter:** A measurable characteristic.

### 3.1 Terms and definitions used in this document (cont'd)

**population:** The collection of all possible values of a given characteristic.

**probability:** The relative frequency with which an outcome takes place over a very large number of trials in each of which the outcome could have occurred.

**process:** (1) A combination of people, procedures, methods, machines, materials, measurement equipment, and/or environment for specific work activities to produce a given product or service.

(2) A repeatable sequence of activities with measurable inputs and outputs.

**process capability**: The capability of a process to meet its specification.

**process capability index (Cpk):** A measure of the relationship between the process specification limits and its capability.

**process capability study:** A study that quantifies natural process variability.

**run:** A number of consecutive points, usually seven or eight, above or below the centerline.

**sample:** A set of individuals taken from a population.

**special cause; assignable cause:** A source of variation that is intermittent, unpredictable, or unstable and affects only some of the individual values of the process output being studied.

**specification limits:** The boundaries for judging acceptability of a particular characteristic.

**standard deviation:** A measure of the spread or variation in a probability distribution (population standard deviation) or in a sample of values measured on the output from a process (sample standard deviation).

**statistic:** A value calculated from or based upon sample data used to make inferences about a parameter of the population from which the sample came.

**statistical control:** The conditions describing a process from which all special causes of variation have been eliminated and only common causes remain.

**statistical process control (SPC):** A method of quality control that uses statistical methods in order to monitor and control a process.

**statistical quality control (SQC):** Statistical methods and procedures used to document and ensure compliance with requirements.

**target:** The desired value for a statistic of a characteristic or parameter of a process node.

**trend:** The movement of a process in a consistently increasing or decreasing direction.

**variation:** The difference among individual outputs of a process.

NOTE The sources of variation can be grouped into two major classes: common causes and special causes.

### 3.2 Other terms related to SPC/SQC

For other terms and definitions related to SPC but not used in the text, see Annex F.

## 4 General SPC System Requirements

The general requirements of an SPC system are provided in the following paragraphs, however, the paragraphs are not provided in any prescribed order. The general requirements of an SPC system shall encompass, but are not limited to, the following elements:

a) Overall quality system
b) Management commitment
c) SPC system documentation
d) Critical process nodes
e) Gage characterization and capability
f) Process characterization and capability
g) Control system documentation
h) On-line/off-line control
i) Training
j) Supplier SPC systems
k) Calibration
l) Preventive maintenance
m) Self audit

### 4.1 Overall Quality System

A prerequisite to the effective implementation of SPC is the existence and adequate application of the basic elements of an overall quality system. A quality system shall be documented and capable of being audited. The basic elements are described in various documents such as ANSI/ISO/TS16949ff.

The quality system shall comply with the applicable standard requirements.

### 4.2 Management Commitment

Management shall:

- empower personnel with responsibility, authority, and provide sufficient resources to implement and maintain an SPC system, and
- periodically review and document the status of the SPC system.

### 4.3 SPC System Set Up

The manufacturer shall document and implement a plan for an SPC system.

The implementation plan shall contain regulations for the following topics:

- scope: delineate areas of the company to which the SPC system applies,
- definition of the organizational unit being responsible for the SPC system ( in this standard called SPC Steering Committee (SSC),
- task and responsibilities of the SSC,
- training matrix for all user of SPC,
- description of the SPC process,
- System documentation requirements, and
- Review and Audit of the SPC system.

## 5 Performing SPC

For information how to apply SPC for process characterization refer to JEP132. All process chosen to be characterized by SPC shall be documented. Documentation shall contain:

- Process description, and
- Control plan containing all measurement systems needed for SPC.

### 5.1 Measurement Equipment Gage Characterization and Capability

All equipment used for SPC shall be in calibration. Characterization and capability studies of test equipment and gages shall be performed to show variance, limitations and repeatability of the measurement equipment. All studies shall be documented and substantiated by data.

#### 5.1.1 Measurement system analysis (MSA)

Statistical studies shall be conducted to analyze the variation present in the results of each type of measuring and test equipment system. This requirement shall apply to measurement systems referenced in the control plan. The analytical methods and acceptance criteria used shall conform to those in customer reference manuals on measurement systems analysis. Other analytical methods and acceptance criteria may be used if approved by the customer.

#### 5.1.2 Calibration/verification records

Records of the calibration/verification activity for all gages (measurement systems), measuring and test equipment, needed to provide evidence of conformity of product to determined requirements, shall include:

- equipment identification, including the measurement standard against which the equipment is calibrated,
- revisions following engineering changes,
- any out-of-specification readings as received for calibration/verification,
- an assessment of the impact of out-of-specification condition, and
- statements of conformity to specification after calibration/verification.

### 5.2 Characterize and classify SPC parameters

The manufacturer determines appropriate characteristics (SPC parameters) to be measured for each process. Target values for each SPC parameter chosen shall be determined, with variability about that value to be identified, quantified, and reduced if appropriate. These steps may involve the use of various techniques (e.g., DOE, off-line data analysis, process mapping, customer request, etc.).

Process characterization and capability studies shall describe the process limitations with respect to the critical characteristics.

Process/product parameters for each process flow may change as process techniques, equipment, or other pertinent factors change. In this case, another process capability study may be required.

Parameters should be classified with respect to their criticality. For each class it should be defined:

– how to react on out-of-control situations
– how to react on out-of spec situations
– how control limits are calculated
– Cpk-Target values
– how to report (internally and externally)

Data are documented in control charts. Different types of control charts are:

- Mean Value Chart
- Variation Value Chart
- Charts for individual values (1 data point per sample)

Basic uses are to determine whether a process has been operating in statistical control and to aid in maintaining statistical control. For details see NIST/SEMATECH Engineering Statistics Handbook (section 6.3) or AEC Q003.

Elements of a control chart are:

1) Time series
   Typically, the process characteristics (e.g., sample mean, variance) are plotted
2) Center Line: CeL
   The center line represents the mean or the median of the process distribution.
3) Control Limits
   Upper Control Limit: UCL
   Lower Control Limit: LCL

Control limits are calculated from process data and are usually represented as a line (or lines) on a control chart. They are not to be confused with engineering specification limits. Variation beyond a control limit may be evidence that special causes are affecting the process.

## 5.2 Characterize and classify SPC parameters (cont'd)

The following section describes how to setup control limits for normal data for a mean value chart and for a standard deviation chart:

Set up the first data base. The initial run has k samples (typically k=25) and in each sample there are n data points measured. So for each sample the mean values M1,…,Mk and standard deviations S1,..,Sk and their squares, the variances, $S1^2$,…,$Sk^2$ can be derived. Finally the following process parameters can be calculated: MM the mean of mean values, SM the standard deviation of the sample mean values, S the average variation within the sample and ST the total variation of all individual data:

| | | |
|---|---|---|
| MM | = | (M1+…+Mk)/k |
| SM | = | standard deviation(M1,…,Mk) |
| S | = | square root( ($S1^2$+…+$Sk^2$)/k ) |
| ST | = | standard deviation (raw data) |

NOTE (M) the value of lot mean values is equal to the mean value of raw data values if the sample size per lot is identical.

The respective parameters for the two types of control charts are:

1) For the mean values chart
   LCL=MM – 3*SM
   CeL=MM
   UCL=MM+3*SM

2) For the standard deviation chart
   LCL=TL*S
   CeL=S
   UCL=TU*S

3) In case of small between-subgroup variance valid alternative control charts as described in Annex C could be used.

TL and TU: See Annex A

The mean chart formula can be applied also in the special case n=1 individual values. An example of a control chart calculation is given in Annex B.

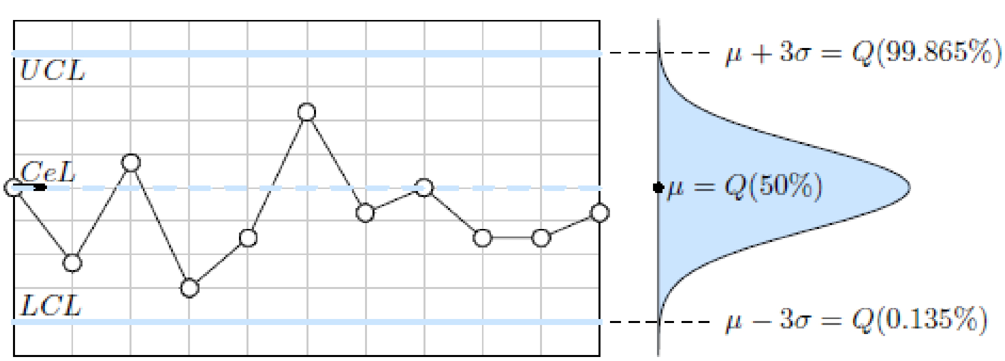


Figure 1 — Example of control chart

## 5.2 Characterize and classify SPC parameters (cont'd)

It should be kept in mind that all formulas and definitions given in this section are based on the assumption that the distributions are normal distributions. For skewed data other types of charts like Pearson X-chart or Robust X-chart should be taken into account.

## 5.3 Process Capability

For each parameter the Cpk value shall be calculated. Different calculation methods shall be applied depending on the data:

- Normal data Cpk for normal data
- Log-normal data Cpk for log-normal data
- quantile Cpk for other data
-

In 5.3.1 the JEDEC definition of Cpk is given. In case other definitions (e.g., ISO/TS16949) are used it should be specified when reporting.

### 5.3.1 Normal or log-normal data Cpk

For two sided specification limits (see also EIA 738)

(1) $C_p$ = (USL – LSL) / 6ST
(2) $C_{pl}$ = (MM – LSL) / 3ST
(3) $C_{pu}$ = (USL - MM) / 3ST
(4) $C_{pk}$ = min ($C_{pu}$ , $C_{pl}$ )

With

USL upper specification limit, use log values for log-normal data
LSL lower specification limit, use log values for log-normal data
This formula assumes a symmetric specification interval, which means, that Cpk is optimal if MM is equal to (USL + LSL)/2.

In case the target value is not identical with (USL + LSL)/2 use $C_{pm}$ values:

(5) Cpm = (USL – LSL) / 6SMm
(6) SMm= square-root ($ST^2$+$(MM\text{-}target)^2$)

### 5.3.2 Quantile Cpk

If data are not normal or log-normal, then a Cpk method based on the empirical quantiles can be used.

(7) Cpl = ($Q_{50\%}$ – LSL) / ($Q_{50\%}$ - $Q_{0.135\%}$ )
(8) $C_{pu}$ = (USL - $Q_{50\%}$) / ($Q_{99.865\%}$ - $Q_{50\%}$ )
(9) $C_{pk}$ = min ($C_{pu}$ , $C_{pl}$ )

with $Q_{n\%}$ being the n% empirical quantile.

NOTE This method is stable only if samples are big enough (typ n > 1000)

### 5.3.3 Control limits

In addition to the specification limits, control limits should be used to define when measures or reactions are needed. The control limits shall be reviewed periodically.

## 5.4 Setup per SPC Parameter

A system of statistical control procedures shall be implemented for each SPC parameter. As a minimum, the control system documentation shall include:

- The control techniques used for each characteristic: Depending on the classification online or offline techniques should be applied. Care should be taken to ensure that appropriate control techniques are used for normal and nonnormal distributions.
- Control chart design covering data to be plotted (e.g., sample mean, variance, center line, upper and lower control limits)
- A definition of out-of-control conditions (for example of rules, see Western Electric Rules).

  The out-of-control definition shall address the following situations:

  a. Data points that lie outside the statistical control limits,

  b. Data points that show significant changes, runs, trends or patterns within the statistical control limits.

  NOTE Decisions on which out-of-control signals to use in this case are determined by the manufacturer and may be based on criteria such as process capability, false alarm rates versus the cost of running out-of-control.
- The procedures for recording pertinent facts.

  Out-of-control situations shall be documented.
- The procedures (e.g., out of control corrective action plan) to search for assignable causes, implement corrective actions and conduct failure analysis including appropriate actions to be taken by inspectors, operators, supervisors, and engineers.

  Out-of-control situations should be investigated and the root causes identified, documented, and corrective actions implemented as warranted. Corrective actions should be evaluated for timeliness and effectiveness in order to prevent out-of-control conditions from recurring.
- The procedures for establishing and adjusting statistical control limits, sample size and frequency.

  Statistical control limits should be adjusted when the process has been changed and not routinely as a result of shifts/trends without assignable causes. The objective is to use online/real-time techniques to verify that the process is in control.

The appropriate control methods shall be identified according to the criticality classification (see 5.2)

## 5.5 Training

There shall be adequate and appropriate training to support the SPC system. Training shall be tailored to individual functions and responsibilities within the organization and shall include all techniques utilized. For example, the training program shall provide necessary training to management, engineering/technical personnel, production supervisors/operators, and support personnel.

## 5.6 Supplier SPC Systems

The SPC methods that suppliers are encouraged to use should be consistent with this standard. The system may vary based on the complexity of the supplier's materials and components, criticality to the manufacturer's processes, and resources of the supplier.

## 5.7 Calibration

Any instrument used to monitor critical characteristics shall be calibrated in accordance with military standards, industry standards, or equivalent international standards (e.g., ANSUASQ M1, IS0 10012, etc.).

## 5.8 Self-Audit

The manufacturer shall establish an independent, self-audit program to assess the effectiveness of the SPC system. Any deficiencies identified by the audit shall be directed to the appropriate individual(s), assigned the functional responsibility for the specific corrective action(s). All deficiencies shall be documented and a follow-up procedure used to ensure the corrective actions are implemented in a timely manner.

A self audit of the SPC system shall be conducted once a year, at a minimum. The audit can be done as part of a first-party audit of the Quality Management System.

## Annex A (informative) Control chart constants TL and TU as a function of sample size n

| n | TL | TU |
|---|---|---|
| 2 | 0.002 | 3.205 |
| 3 | 0.037 | 2.571 |
| 4 | 0.100 | 2.283 |
| 5 | 0.163 | 2.110 |
| 6 | 0.218 | 1.991 |
| 7 | 0.266 | 1.903 |
| 8 | 0.306 | 1.835 |
| 9 | 0.341 | 1.780 |
| 10 | 0.371 | 1.735 |
| 11 | 0.398 | 1.697 |
| 12 | 0.422 | 1.664 |
| 13 | 0.443 | 1.635 |
| 14 | 0.461 | 1.609 |
| 15 | 0.479 | 1.587 |
| 16 | 0.494 | 1.566 |
| 17 | 0.508 | 1.548 |
| 18 | 0.522 | 1.531 |
| 19 | 0.534 | 1.516 |
| 20 | 0.545 | 1.502 |
| 30 | 0.625 | 1.405 |
| 40 | 0.674 | 1.348 |
| 50 | 0.708 | 1.310 |
| 60 | 0.732 | 1.282 |
| 70 | 0.752 | 1.260 |
| 80 | 0.768 | 1.243 |
| 90 | 0.781 | 1.229 |
| 100 | 0.792 | 1.217 |
| 500 | 0.906 | 1.096 |
| 1000 | 0.933 | 1.068 |

## Annex B (informative) SPC Example

A hypothetical example is given with 25 lots (sample i) of 5 data points each.

The mean value and standard deviation is given in the last two columns.

| sample i | Data | | | | | Mi | Si |
|---|---|---|---|---|---|---|---|
| 1 | 20.10 | 20.37 | 20.34 | 20.88 | 20.73 | 20.48 | 0.32 |
| 2 | 19.57 | 19.86 | 20.23 | 20.22 | 19.83 | 19.94 | 0.28 |
| 3 | 20.25 | 20.26 | 20.17 | 19.93 | 20.53 | 20.23 | 0.21 |
| 4 | 19.42 | 19.24 | 19.55 | 19.37 | 19.19 | 19.35 | 0.14 |
| 5 | 19.64 | 19.91 | 19.70 | 19.87 | 19.77 | 19.78 | 0.11 |
| 6 | 20.48 | 19.97 | 19.95 | 20.30 | 19.66 | 20.07 | 0.32 |
| 7 | 20.45 | 20.76 | 21.28 | 20.73 | 20.50 | 20.74 | 0.33 |
| 8 | 20.45 | 20.16 | 20.02 | 20.58 | 20.56 | 20.36 | 0.25 |
| 9 | 20.36 | 19.69 | 20.00 | 19.96 | 19.87 | 19.97 | 0.24 |
| 10 | 20.67 | 20.43 | 20.20 | 20.32 | 19.87 | 20.30 | 0.30 |
| 11 | 20.12 | 20.21 | 20.32 | 20.40 | 20.47 | 20.30 | 0.14 |
| 12 | 20.41 | 20.14 | 19.97 | 20.22 | 19.99 | 20.15 | 0.18 |
| 13 | 20.31 | 20.12 | 20.32 | 19.91 | 20.61 | 20.25 | 0.26 |
| 14 | 20.03 | 20.28 | 20.42 | 20.36 | 20.33 | 20.28 | 0.15 |
| 15 | 19.76 | 20.53 | 20.17 | 19.93 | 19.50 | 19.98 | 0.40 |
| 16 | 19.49 | 19.63 | 19.29 | 19.83 | 19.92 | 19.63 | 0.25 |
| 17 | 20.70 | 20.47 | 20.22 | 20.97 | 21.02 | 20.68 | 0.34 |
| 18 | 20.33 | 19.70 | 19.94 | 20.04 | 19.71 | 19.94 | 0.26 |
| 19 | 19.45 | 19.82 | 19.38 | 18.78 | 19.16 | 19.32 | 0.39 |
| 20 | 20.24 | 19.90 | 19.80 | 19.65 | 20.07 | 19.93 | 0.23 |
| 21 | 20.08 | 20.09 | 20.17 | 20.36 | 20.45 | 20.23 | 0.17 |
| 22 | 19.22 | 19.58 | 19.75 | 19.40 | 19.57 | 19.51 | 0.20 |
| 23 | 19.36 | 19.22 | 19.57 | 19.81 | 19.48 | 19.49 | 0.22 |
| 24 | 20.27 | 20.40 | 20.43 | 20.33 | 20.56 | 20.40 | 0.11 |
| 25 | 19.89 | 20.11 | 20.38 | 20.07 | 20.33 | 20.16 | 0.20 |

Mi: Mean of sample i
Si: Sigma of sample i

**Annex B (informative) SPC Example (cont'd)**

Using the formulas of section 5.2 the following parameters have been calculated:

| | | |
|---|---|---|
| **Statistics** | | |
| MM = | 20.06 | Mean of mean values |
| SM= | 0.38 | Standard deviation of sample mean values |
| S= | 0.25 | Average variation within samples |
| ST= | 0.44 | Total variation of all data points |
| | | |
| **Mean values chart** | | |
| LCL= | 18.91 | Lower control limit |
| CeL= | 20.06 | Center line |
| UCL= | 21.21 | Upper control limit |
| | | |
| **Standard deviation chart** | | |
| LCL | 0.04 | Lower control limit |
| CeL | 0.25 | Center line |
| UCL | 0.53 | Upper control limit |
| | | |
| Process | capability | according formulas in section 5.3.1 |
| **Capability** | | |
| LSL= | 18.00 | Lower specification limit |
| USL= | 22.00 | Upper specification limit |
| Cp= | 1.52 | Process capability |
| Cpl= | 1.56 | Process capability wrt. lower specification limit |
| Cpu= | 0.87 | Process capability wrt. upper specification limit |
| Cpk= | 0.87 | Process capability index |

## Annex C (informative) Alternative Control Charts

1) The X-bar Chart control limit formula that uses a sample standard deviation of X-bar's; i.e., 'SM = standard deviation (M1, ... , Mk)' in section 5.2, instead of the estimated within-subgroup process standard deviation; i.e., s-bar/c4 for X-bar s Chart, is preferred because it also covers the between-subgroup variance. For small between-subgroup variance a valid alternative method is to use:

   s-bar= (S1+…+Sk)/k

   c4: correction factor (see NIST Handbook of Statistical Methods, 6.3.2)

   Example based on the data of Annex B:

**Mean values chart according to Annex C 1)**

| | |
|---|---|
| Sbar | 0.24 |
| LCL= | 19.72 |
| CeL= | 20.06 |
| UCL= | 20.40 |

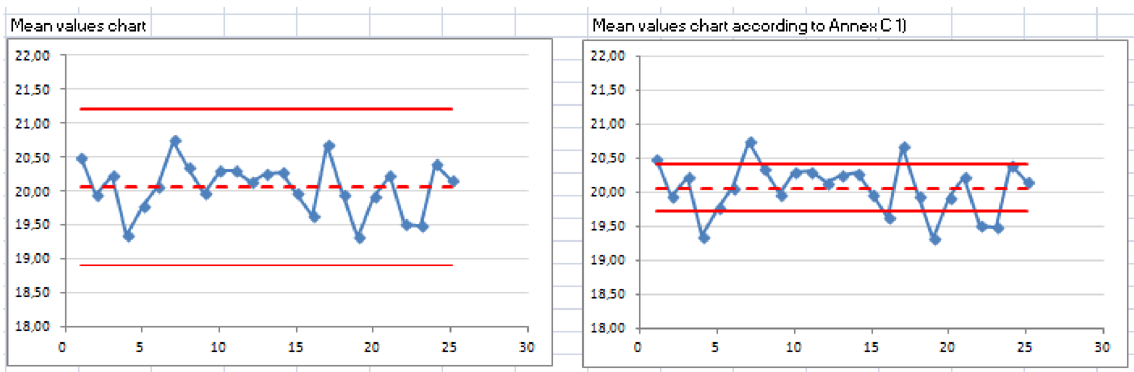


**Figure C.1 — Mean value chart calculated with formulas in 5.2 (left) and C1 (right).**

2) The s Chart control chart limits, TL and TU, and the centerline are calculated with a square root of within-subgroup variance average as in 'S = square root $((S1^2 + ... + Sk^2)/k)$. Alternatively they could also be calculated using s-bar with above definition and corresponding correction factor.

Example based on the data of Annex B:

**Standard deviation chart according to Annex C 2)**

| | |
|---|---|
| LCL | 0.00 |
| CeL | 0.24 |
| UCL | 0.50 |

**Annex C (informative) Alternative Control Charts (cont'd)**

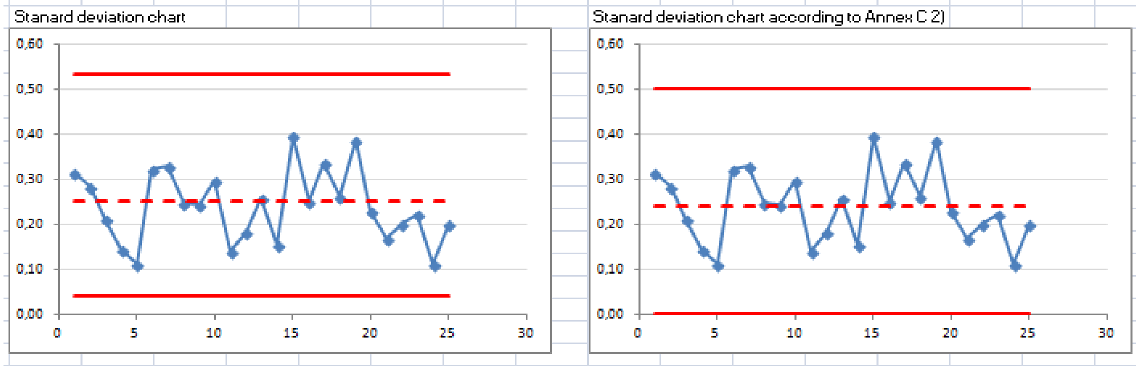


**Figure C.2 — Standard deviation chart calculated with formulas in 5.2 (left) and C2 (right).**

3) Another control Chart for mean values is the X-bar R Chart using the within-subgroup process standard deviation: R-bar/d2

R-bar= (R1+…+Rk)/k

d2: correction factor (see NIST Handbook of Statistical Methods, 6.3.2)

However this also does not cover the between-subgroup variance.

## Annex D (informative) Alternative for Quantile Cpk

1) $C_{pl} = (Q_{50\%} – LSL) / ( Q_{50\%} - Q_{0.5\%} )•3/2.58$
2) $C_{pu} = (USL - Q_{50\%}) / ((Q_{99.5\%} - Q_{50\%} )•3/2.58$

with $Q_{n\%}$ being the n% empirical quantil.

The proposed method uses the 0:5%, 50% and 99:5% quantiles. Under the normal distribution an interval of ±2.58σ is generated. To obtain an interval of ±3σ, insert a correction factor (3/2.58) to extrapolate along the normal distribution.

## Annex E (informative) Related books

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## Annex F (informative) Related guidelines and standards

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|---|---|
| EIA-738 | Guideline on the Use and Application of Cpk |
| IPC-9191 | General Guidelines for Implementation of Statistical Process Control (SPC) |
| NIST/SEMATECH Engineering Statistics Handbook | |
| AEC Q003 | Guidelines for Characterizing the Electrical Performance of Integrated Circuit Products |
| WER | Western Electric Company (1956), Statistical Quality Control handbook |
| ISO/TS 16949 | Particular requirements for the application of ISO 9001:2008 for automotive production and relevant service part organizations |
| MIL-HDBK-683 | Statistical Process Control (SPC) Implementation and Evaluation Aid |

## Annex G (informative) Other terms and definitions related to SPC

**accuracy:** The difference between the sample estimate and the population parameter being estimated.

**attribute data**: Data that result from counting items or classifying items into distinct nonoverlapping categories.

**binomial distribution; Bernoulli distribution:** A specific discrete probability distribution for attributes data.

**cause-and-effect diagram**: A tool for individual or group problem-solving that uses a graphic description of the various process elements to analyze potential sources of process variation.

NOTE This tool is also called a “fishbone diagram” (after its appearance) or “Ishikawa diagram” (after its developer).

**centerline:** A reference line on a control chart about which the chart points are expected to cluster in the absence of a special cause.

NOTE A centerline is usually set at the average, median, or mode of the points being plotted or (for a tunable process) at an achievable target value (to detect deviations from the value thought most desirable).

**checklist**: A simplified listing of the specified criteria that may be checked off during an audit or inspection.

**check sheet**: A form for data collection.

**control loop:** A corrective action system based on a feedback procedure.

**cusum chart:** A statistical process control (SPC) chart in which cumulative deviation from a target is plotted.

**discrepant material:** Material that does not conform to specifications.

NOTE See also “nonconforming unit”.

**exponential distribution; Poisson distribution:** A specific discrete probability distribution often applied to attributes data.

**exponentially weighted moving average (EWMA) chart:** A statistical process control (SPC) chart based on weights assigned to past observations.

**Annex G (informative) Other terms and definitions related to SPC (cont'd)**

**failure mode and effect analysis (FMEA):** A systematized group of activities intended to recognize, evaluate, and prioritize the potential failure modes of a product or process and the effects of a failure, and then to identify actions that could reduce the probability of occurrence of each failure mode, listed in the order of seriousness of a potential failure in the customer's application.

NOTE 1 The FMEA provides a structured analysis in order to assess the probability of occurrence of a failure from the failure mode as well as the effect of the failure.

NOTE 2 A fully developed FMEA is continuously maintained and updated to reflect the latest actions and changes to the design or process.

**histogram:** A graph obtained by dividing the range of the data set into equal intervals and plotting the number of data points in each interval against the interval number.

**inspection:** The assessment of a characteristic and its comparison to a standard.

NOTE Examples of inspections include low-temperature electrical tests, room-temperature tests, and visual inspection.

**location:** The typical value or central tendency of a distribution.

**long-term capability:** The process capability under normal operating conditions over an extended period of time.

**mode:** The most frequently occurring value in a group of measurements—a measure of location.

**nonconforming:** Not conforming to specification(s), procedures, or requirements.

**nonconforming unit:** A unit that does not conform to a specification.

NOTE See also "discrepant material".

**nonconformity**: A specific occurrence of a condition that does not conform to specification.

NOTE 1 Such an occurrence is sometimes called a discrepancy.

NOTE 2 See also "nonconformance".

**Pareto analysis:** A technique for problem-solving in which all potential problem areas or sources of variation are ranked according to their contribution.

**precision:** The degree of refinement with which an operation is performed or a measurement is stated; e.g., the number of significant digits defining a number.

**probability distribution:** A collection of all possible outcomes of a random event, together with their respective probabilities.

**probability distribution function:** A mathematical representation of a probability distribution.

**problem solving:** The process of moving from effects to causes (special or common) to actions that improve performance.

**Annex G (informative) Other terms and definitions related to SPC (cont'd)**

**process average:** The location of the distribution of measured values of a particular process characteristic.

**process spread:** The extent to which the individual values of a process characteristic vary.

**product performance:** The totality of the capability of characteristics of a product.

**quality function deployment (QFD):** A technique for analysis of the interrelationships between different requirements.

**randomness:** A condition in which individual values are not predictable, although they may come from a definable distribution.

**random sample**: A set of individuals taken from a population in such a way that each possible individual has an equal chance of being selected.

**range:** The difference between the maximum and minimum values—a measure of spread.

**repeatability:** The natural variation in measurements taken by a single person and instrument on the same item and under the same conditions.

**run chart:** A time-ordered graphic representation of a characteristic of a process showing plotted values of some statistic gathered from the process and a central line that can be analyzed for runs.

**scatter diagram:** A graph of the value of one characteristic versus another characteristic.

**shape:** A general concept for the overall pattern formed by a distribution of values.

**short-term capability:** The process capability under controlled conditions over a brief period of time.

**stability:** The absence of special causes of variation—the property of being in statistical control.

**stable process:** A process that is in statistical control.

**variables data:** A measure of a characteristic for which every value within a given interval is possible.

**yield:** The ratio of the number of units that pass some inspection criteria to the number submitted.

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