Process Fallout

Calculated Capability Ratio	Cp Fallout (both sides combined)	Cpk Fallout (one side only)
0.50	133,620	66,810
0.60	71,860	35,930
0.70	35,720	17,860
0.80	16,400	8,200
0.90	6,940	3,470
1.00	2,700	1,350
1.10	966	483
1.20	318	159
1.30	96	48
1.40	26	13
1.50	7	3
1.60	2	0.800
1.70	0.340	0.170
1.80	0.060	0.030
1.90	0.012	0.006
2.00	0.002	0.001

Fallout rates expressed in PPM (Parts Per Million)

Control Chart Constants

	Xbar and R Control Charts				Xbar and S Control Charts				
n	A_2	D_3	D_4	D_2	n	A_3	B_3	B_4	C_4
1	2.660	0	3.265	1.128	10	0.975	0.248	1.715	0.9727
2	1.880	0	3.265	1.128	11	0.927	0.321	1.679	0.9754
3	1.023	0	2.574	1.693	12	0.886	0.354	1.646	0.9776
4	0.729	0	2.282	2.059	13	0.850	0.382	1.618	0.9794
5	0.577	0	2.114	2.326	14	0.817	0.406	1.594	0.9810
6	0.483	0	2.004	2.534	15	0.789	0.428	1.582	0.9823
7	0.419	0.076	1.924	2.704	16	0.763	0.448	1.552	0.9835
8	0.373	0.136	1.864	2.847	17	0.739	0.466	1.534	0.9845
9	0.337	0.184	1.816	2.970	18	0.718	0.482	1.518	0.9854
10	0.308	0.223	1.777	3.078	19	0.698	0.497	1.503	0.9862
11	0.285	0.256	1.744	3.173	20	0.680	0.510	1.160	0.9869
12	0.266	0.283	1.717	3.258	21	0.663	0.523	1.477	0.9876
					22	0.647	0.524	1.133	0.9882
					23	0.633	0.545	1.455	0.9887
					24	0.619	0.555	1.445	0.9892
					25	0.606	0.565	1.435	0.9896

Control Chart Formulas

Variable Data Control Charts

Plot Points		Centerline	Control Limits	$\hat{\sigma}$
Std.	Target			
$\overline{X}$	$\overline{X}$ - Tar	$\overline{\overline{X}} = \dfrac{\sum \overline{X}}{k}$	$UCL_{\overline{X}} = \overline{\overline{X}} + A_2\overline{R}$ $LCL_{\overline{X}} = \overline{\overline{X}} - A_2\overline{R}$	$\overline{R}/d_2$
R	R	$\overline{R} = \dfrac{\sum R}{k}$	$UCL_R = D_4\overline{R}$ $LCL_R = D_3\overline{R}$	
IX	IX-Tar	$\overline{IX} = \dfrac{\sum IX}{k}$	$UCL_{IX} = \overline{IX} + A_2\overline{MR}$ $LCL_{IX} = \overline{IX} - A_2\overline{MR}$	$\overline{MR}/d_2$
MR	MR	$\overline{MR} = \dfrac{\sum MR}{k-1}$	$UCL_{MR} = D_4\overline{MR}$ $LCL_{MR} = 0$	
s	s	$\overline{s} = \dfrac{\sum s}{k}$	$UCL_s = B_4\overline{s}$ $LCL_s = B_3\overline{s}$	$\overline{s}/c_4$

Attribute Data Control Charts

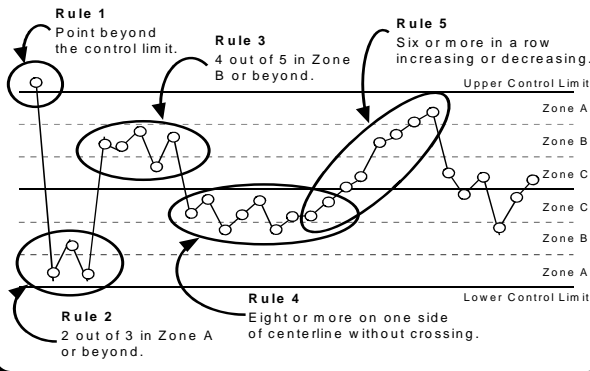| Chart	Plot Point	Centerline	Control Limits	$\hat{\sigma}$
p	p	$\overline{p} = \dfrac{\sum p}{k}$	$UCL_p = \overline{p} + 3\sqrt{\dfrac{\overline{p}(1-\overline{p})}{n}}$ $LCL_p = \overline{p} - 3\sqrt{\dfrac{\overline{p}(1-\overline{p})}{n}}$	$\sqrt{\dfrac{\overline{p}(1-\overline{p})}{n}}$
np	np	$n\overline{p} = \dfrac{\sum np}{k}$	$UCL_R = D_4\overline{R}$ $LCL_R = D_3\overline{R}$	$\sqrt{n\overline{p}(1-n\overline{p})}$
c	c	$\overline{c} = \dfrac{\sum c}{k}$	$UCL_{IX} = \overline{IX} + A_2\overline{MR}$ $LCL_{IX} = \overline{IX} - A_2\overline{MR}$	$\sqrt{\overline{c}}$
u	u	$\overline{u} = \dfrac{\sum u}{k}$	$UCL_{MR} = D_4\overline{MR}$ $LCL_{MR} = 0$	$\sqrt{\overline{u}/n}$

Glossary of Symbols

A_2 = Control limit constant used for Xbar and IX charts.

A_3 = Control limit constant used for sigma charts.

B_3 = Control limit constant used for sigma charts.

B_4 = Control limit constant used for sigma charts.

C = Number of defects. Plot point on c chart.

C_4 = Control limit constant used for sigma charts.

Cp = Process potential capability ratio.

Cpkl = Process performance capability ratio (lower side).

Cpku = Process performance capability ratio (upper side).

d_2 = Calculation constant used to estimate process sigma.

D_3 = Control limit constant used in for Range charts.

D_4 = Control limit constant used in for Range charts.

k = Number of subgroups.

LCL = Lower control limit.

LSL = Lower specification limit.

MR = Moving-range.

n = Number of measurements in a subgroup (sample size).

np = Number defective. Plot point on an np-chart.

PPM = Parts per million.

R = Range.

s = Sample standard deviation.

S = Population standard deviation.

S = Estimated population standard deviation.

S = Summation of.

Tar = Desired process centering (e.g., engineering nominal).

u = Average defects per unit. Plot point on u-chart.

UCL = Upper control limit.

USL = Upper specification limit.

X or IX = Individual measurement.

X = Average.

X = Average of averages.
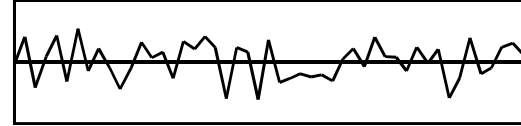
Control Chart Selection Trees

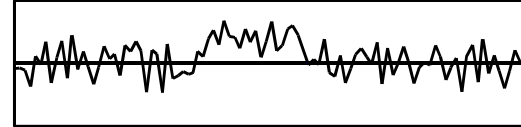**Variable Data Control Charts**

	Sample Size	Different averages on same chart?	Use this chart
	1	Yes	Target IX - MR
	1	No	IX - MR
	>1 <10	Yes	Target $\overline{X}$ - R
	>1 <10	No	$\overline{X}$ - R
	>9	Yes	Target $\overline{X}$ - s
	>9	No	$\overline{X}$ - s

Attribute Data Control Charts

	Type of data	Does sample size vary?	Use this chart
	Sort	Yes	p chart
	Sort	No	np chart
	Count	Yes	u chart
	Count	No	c chart

Special Cause Rules

Rule 1 Point beyond the control limit.

Rule 3 4 out of 5 in Zone B or beyond.

Rule 5 Six or more in a row increasing or decreasing.

Rule 2 2 out of 3 in Zone A or beyond.

Rule 4 Eight or more on one side of centerline without crossing.

Upper Control Limit
Zone A
Zone B
Zone C
Zone C
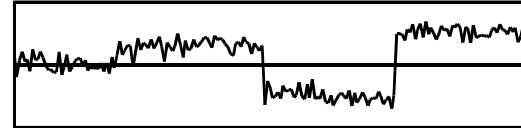Zone B
Zone A
Lower Control Limit

Common Control Chart Patterns

Random Pattern

Run (above centerline in this example)

Shift

Trend

DESIMONE
Quality International

2129 West Paseo Del Mar
San Pedro, CA 90732
Office: 424.772.6371

SPC Tri-Fold Card

Empirical Rule

SPC is based on this formula: Average ± 3 σ

99.7%
95%
68%

$\overline{X}$

-3σ -2σ -1σ +1σ +2σ +3σ

Capability Study

Lower Specification Limit

Upper Specification Limit

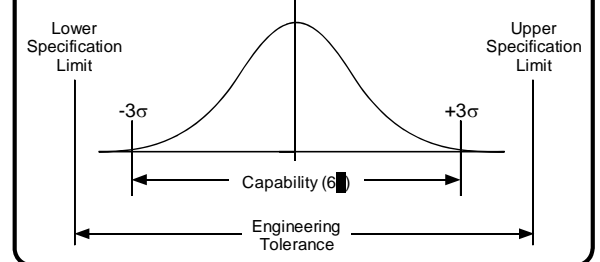-3σ +3σ

Capability (6σ)

Engineering Tolerance
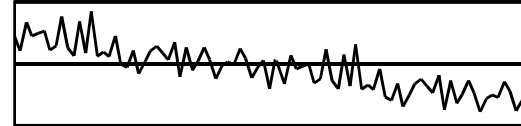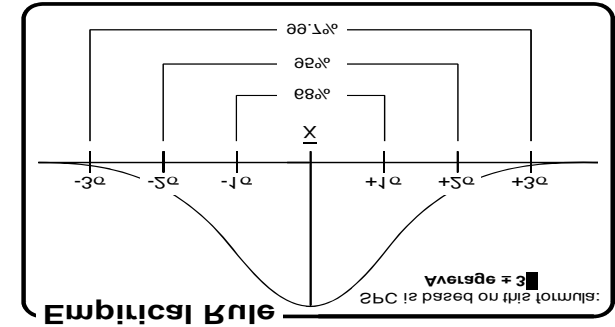
Capability Study Formulas

$Cp = \dfrac{USL = LSL}{6\sigma}$	$\overline{X} = \dfrac{\sum X}{n}$
$Cpk_L = \dfrac{\overline{X} - LSL}{3\sigma}$	$\sigma = \sqrt{\dfrac{\sum (X_i - \overline{X})^2}{n-1}}$ (Root mean square method)
$Cpk_U = \dfrac{USL - \overline{X}}{3\sigma}$	$\hat{\sigma} = \dfrac{\overline{R}}{d_2}$ (Range control chart method)