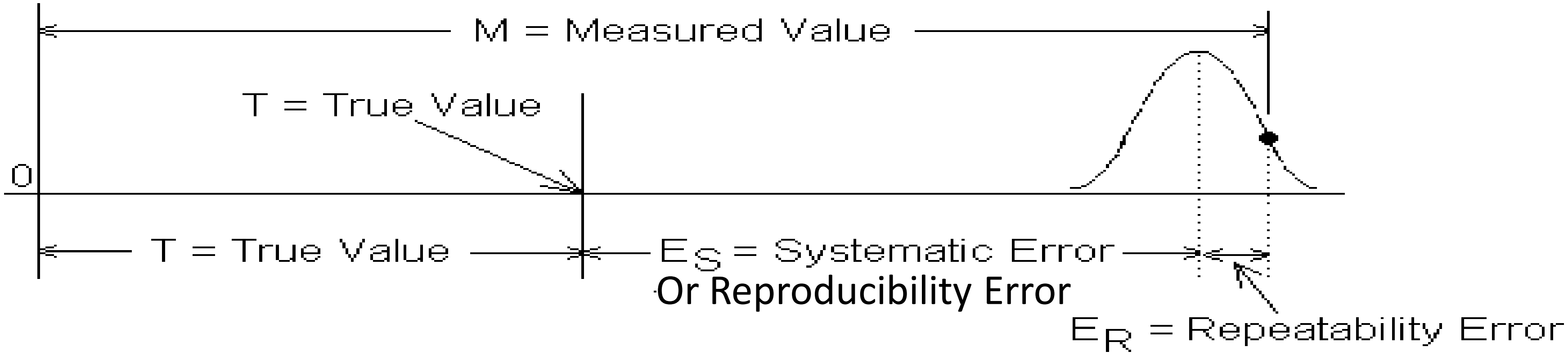
测试数据分析及验证术语的介绍

2014-4-27

Measured Value, True Value, Systematic Error, and Repeatability Error

Measured Value = True Value + Systematic Error + Repeatability Error



THE MEASURED VALUE:
The Measured Value, M, is the sum of three terms:

1. The TRUE VALUE,
2. The SYSTEMATIC ERROR of the test system, and
3. The REPEATABILITY ERROR of the test system.

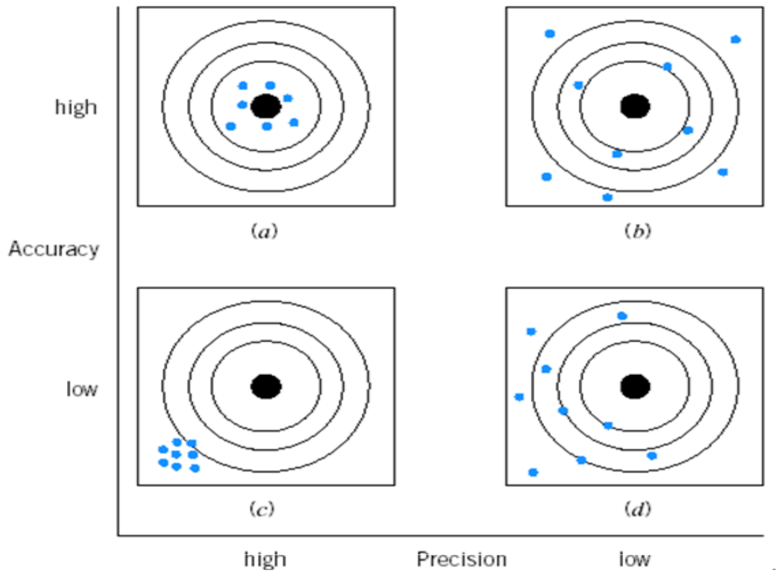
This is represented as:

$$M = T + E_S + E_R$$

M = Measured Value
T = True Value
E_S = Systematic Error
E_R = Repeatability Error

名词解释

- Accuracy和Precision
  - Accuracy-准度，用来定义测试值与真实值的差异，即到底准不准。
  - Precision-精度，用来表示数据的变异大小，也就是重复测量之间的差异性，也可用Repeatability来表示。



- Resolution (Quantization Error) 测量分辨率、解析度

www.keithley.com

Resolution – Bits and Counts

- 12 bit A/D – 4096 counts – approx 3.5 digits
- 16 bit A/D – 65,536 counts – approx 4.5 digits
- 18 bit A/D - 262,144 counts – approx 5.5 digits
- 22 bit A/D – 4,194,304 counts – approx 6.5 digits
- 25 bit A/D – 33,554,304 counts – approx 7.5 digits
- 28 bit A/D – 268,435,456 counts – approx 8.5 digits

KEITHLEY

www.keithley.com

Sensitivity

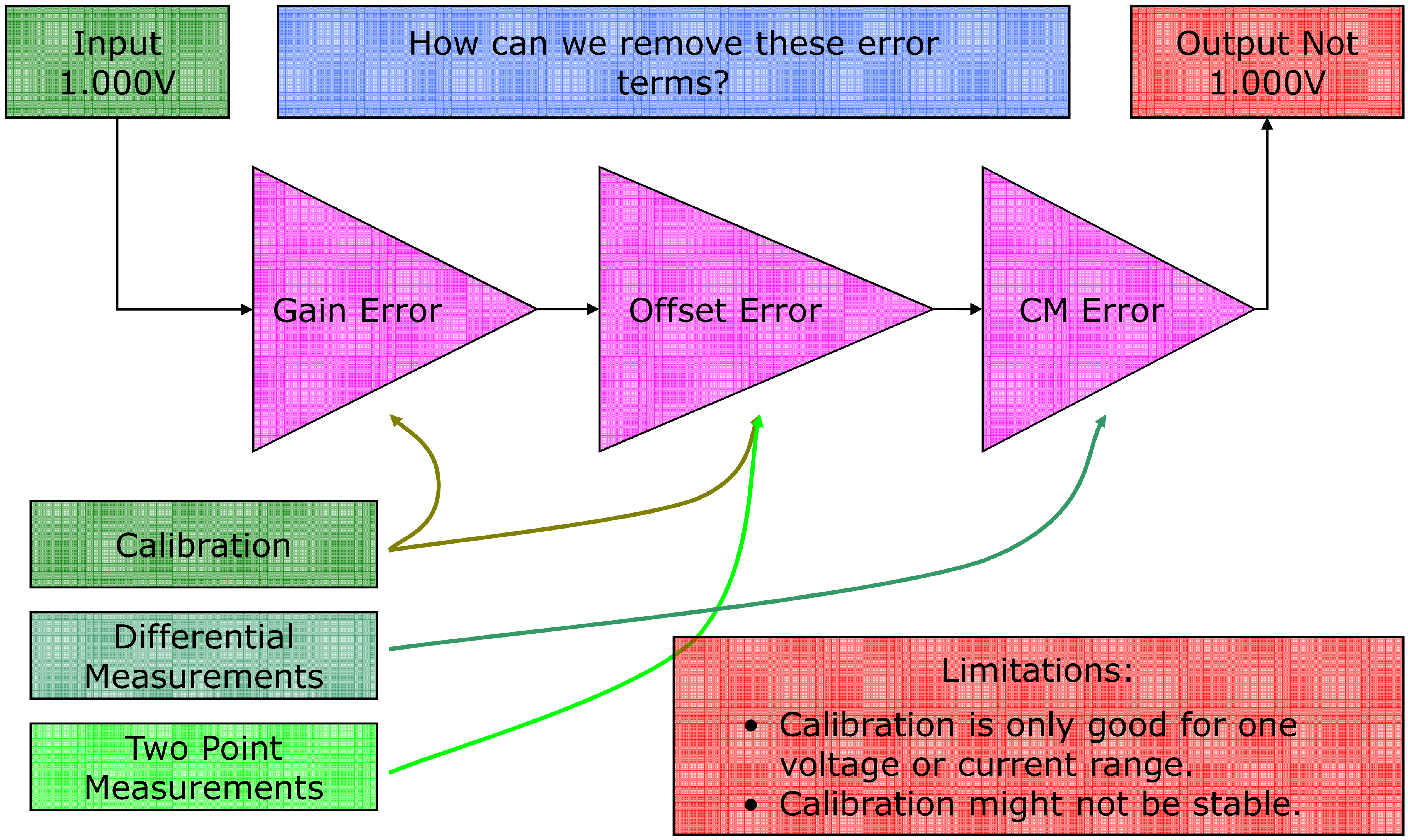
- The smallest *change* that can be detected
- Specified in units of the measured value
  - Volts, ohms, degrees
- Examples:
  - 3-1/2 digits (2000) on 2V range = 1mV
  - 4-1/2 digits (20000) on 2Ω range = 100μΩ
  - 16-bit (65536) A/D on 2V range = 30μV
  - 8-1/2 digits on 200 mV range = 1nV

KEITHLEY

名词解释

- Repeatability
  - 要保证测量一致性，对于测试工程师来说，需要花费很多的时间来调试，因为随机误差的产生对测试一致性的影响，始终存在。事实上，如果当你在测量某个参数时，发现连续测试10次得到的数值都是完全一样的，这个时候，往往是表明该测试有问题。很有可能是，测量的量程过大，导致分辨率不够，而导致测量结果显示一样。
- Reproducibility（可重复性）
  - Reproducibility和Repeatability有着不同的概念，Repeatability被定义于使用同一台测试设备，同一块测试板测试时，得到一致的测试结果。而Reproducibility，则是从统计上来分析测试一致性，测试机台、测试人员、测试板的变化等，都必须保证其测试一致性。
- 如何来更好的理解Repeatability和Reproducibility？

DC Instruments Error

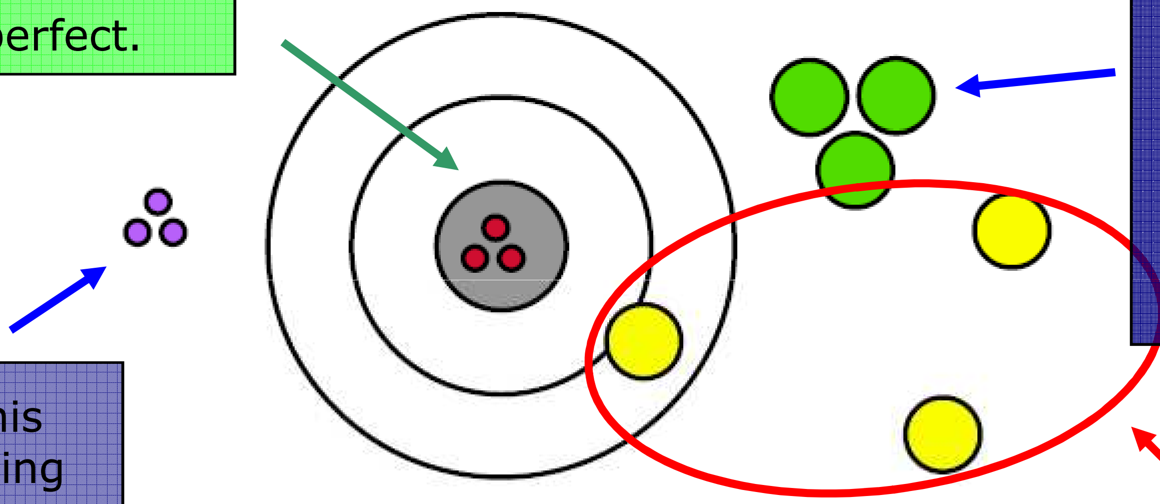


Which one of these would we want?
How we would fix the error? Example/Question 10

Resolution, Accuracy, Repeatability

This one is perfect.

Maybe over-sampling and offset calibration could work.



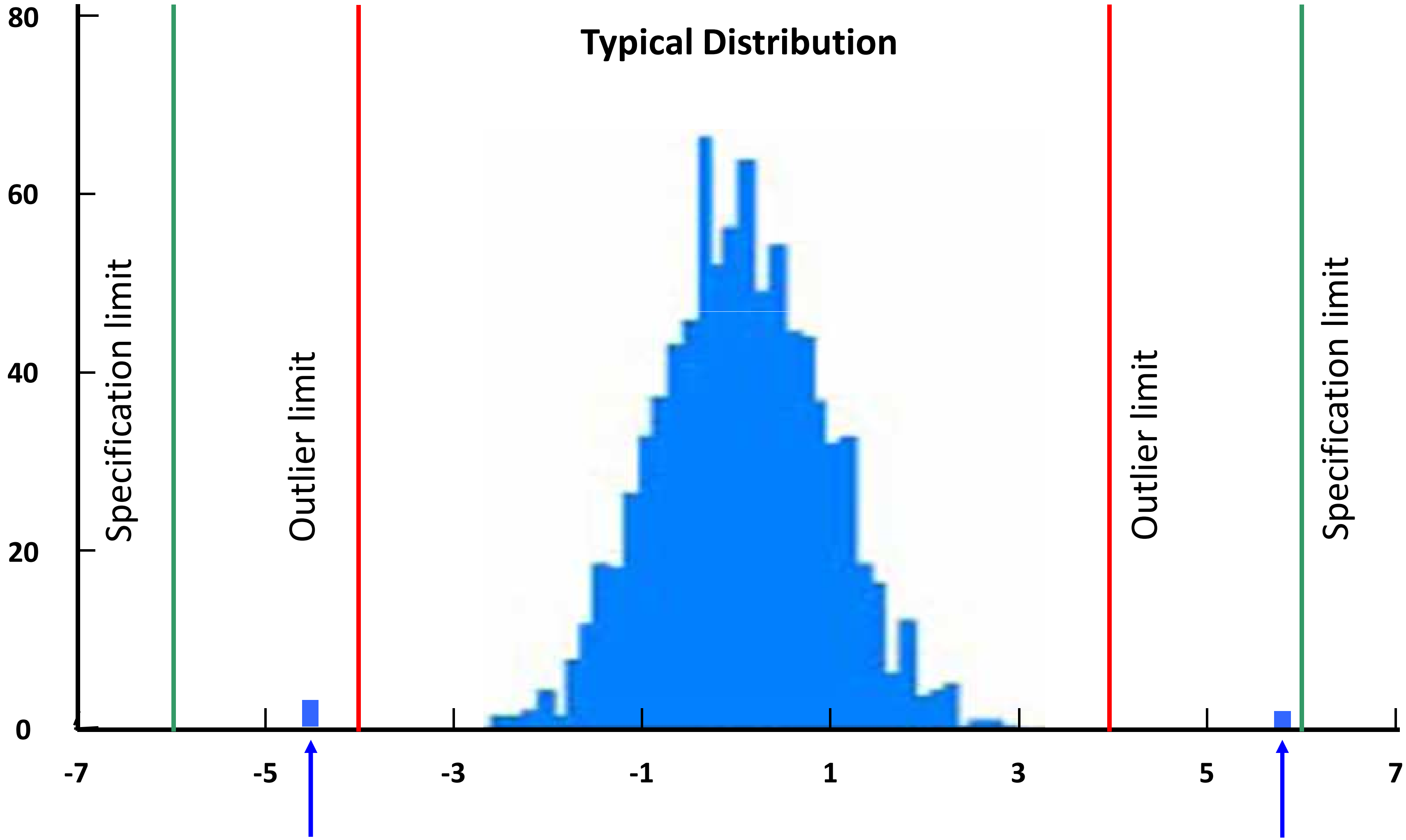
We can use this one by calibrating the offset.

We don't want this one.

	Resolution	Accuracy	Repeatability
	High	High	High
	High	Low	High
	Low	Low	High
	Low	Low	Low

KEITHLEY

测试数据及正态分布



Typical Distribution
80
60
40
20
0
Specification limit
Outlier limit
Outlier limit
Specification limit
-7
-5
-3
-1
1
3
5
7

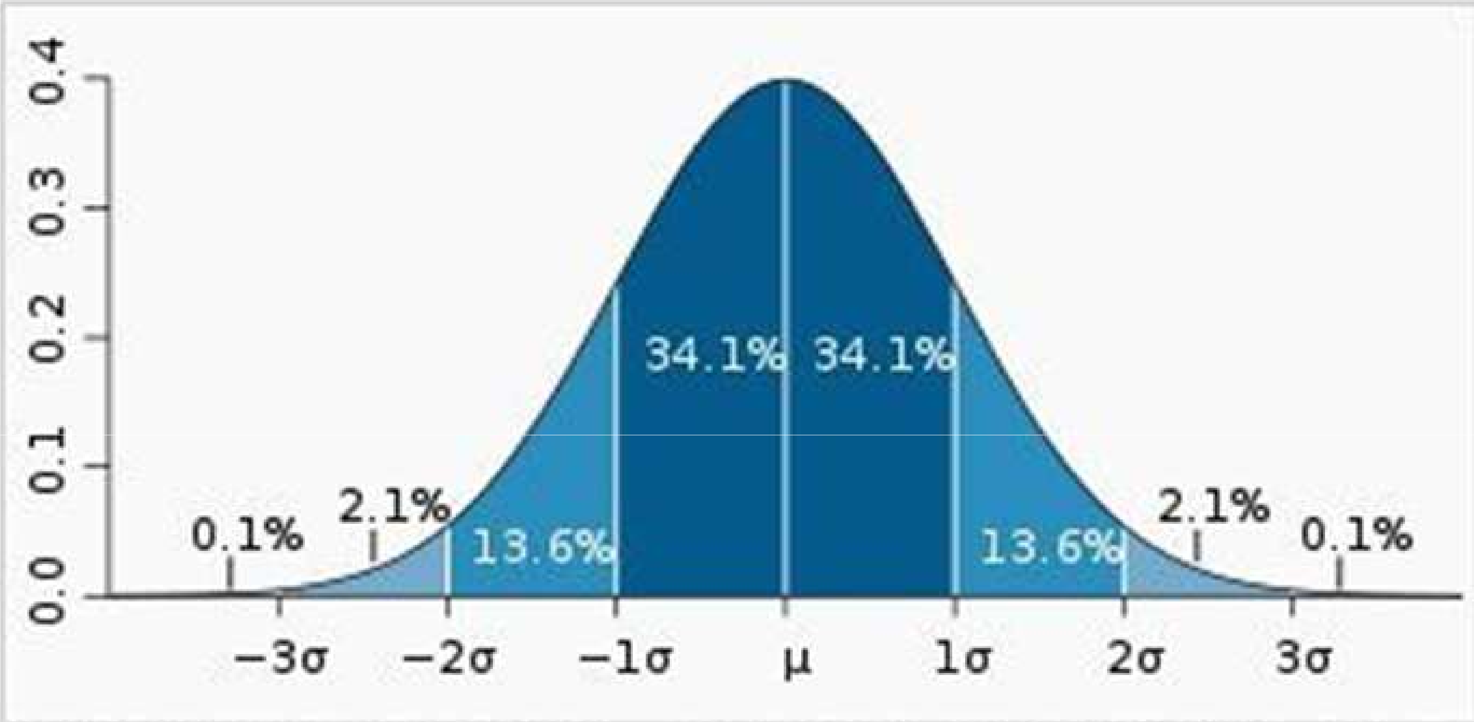
名词解释

标准差σ（**Standard Deviation**），在概率统计中最常使用作为统计分布程度（statistical dispersion）上的测量。标准差定义是总体各单位标准值与其平均数离差平方的算术平均数的平方根。它反映组内个体间的离散程度。
标准差也被称为标准偏差，或者实验标准差。

标准计算公式：
假设有一组数值$x_1, x_2, x_3, \ldots\ldots x_N$（皆为实数），其平均值为μ，公式如下：

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

平均值μ与标准方差σ的关系



深蓝区域是距平均值小于一个标准差之内的数值范围。在正态分布中，此范围所占比率为全部数值之 68%。根据正态分布，两个标准差之内（深蓝，蓝）的比率合起来为 95%。根据正态分布，三个标准差之内（深蓝，蓝，浅蓝）的比率合起来为 99%。

名词解释

C_p与C_{pk}

C_p: 制程精密度。 在衡量「规格公差宽度」与「制程变异宽度」之比例。对於单边规格，
只有上限和中心值，$C_{pu} = (USL- \mu) / 3\sigma_p$
只有下限和中心值，$C_{pl} = (\mu -LSL) / 3\sigma_p$
对於双边规格：$C_p=(USL-LSL) / 6\sigma_p$

UTL = Upper Specification Limit

LTL = Lower Specification Limit

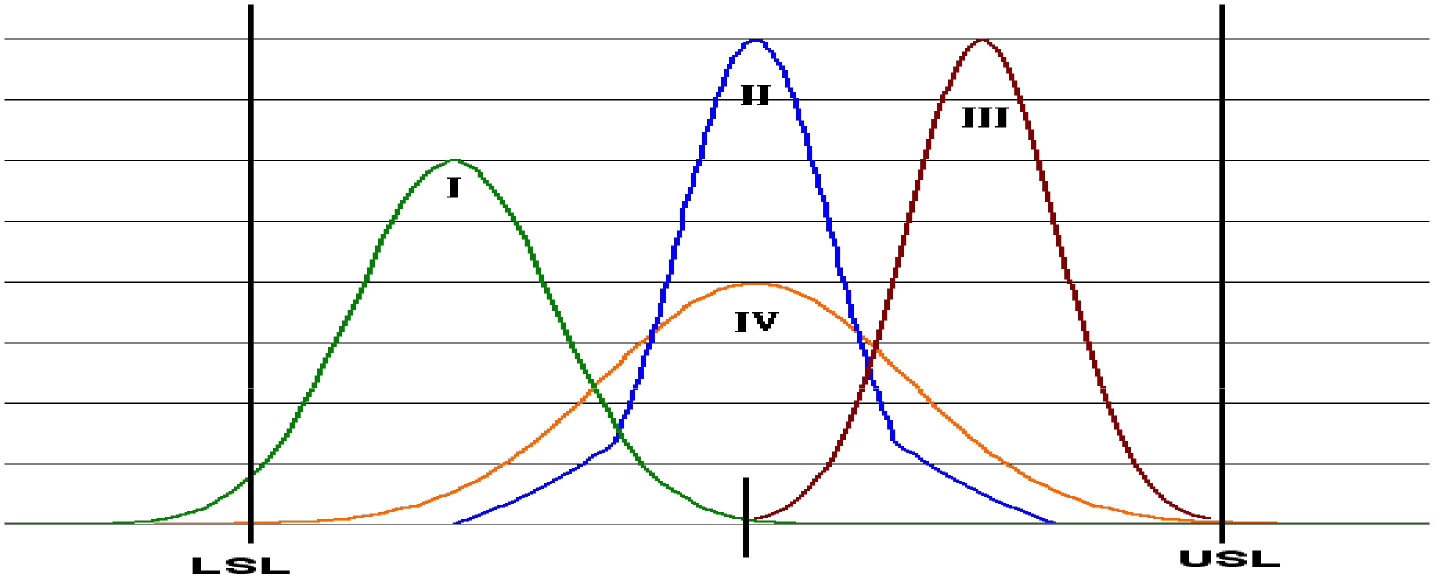
C_{pk}的中文定义为：制程能力指数，是某个工程或制程水准的量化反应，也是工程评估的一类指标。

$$C_{pk} = \frac{\min\left(USL - \mu_p, \mu_p - LSL\right)}{3\sigma_p}$$

制程控制-测验

$$Cp = \frac{(USL - LSL)}{6\sigma}$$

$$CpK = \min\left[\left(\frac{(USL-\mu)}{3\sigma}\right), \left(\frac{(\mu - LSL)}{3\sigma}\right)\right]$$



Process	Cp	Cpk
I	$\frac{5\sigma * 2}{6\sigma} = 1.67$	$\frac{2\sigma}{3\sigma} = 0.67$
II	$\frac{6\sigma * 2}{6\sigma} = 2.0$	$\frac{6\sigma}{3\sigma} = 2.0$
III	$\frac{6\sigma * 2}{6\sigma} = 2.0$	$\frac{3\sigma}{3\sigma} = 1.0$
IV	$\frac{6\sigma}{6\sigma} = 1.0$	$\frac{3\sigma}{3\sigma} = 1.0$

名词解释

GR&R

Gauge Repeatability and Reproducibility

$$GRR = \sigma_x = \sqrt{\sigma_r^2 + \sigma_R^2}$$

$$Cp = \frac{USL - LSL}{6\sigma_x}$$

$$\%\ GRR = \frac{1}{Cp} * 100$$

制程控制能力

What is an acceptable Cpk value?

Cpk Value		Acceptance
< 1.00	$< 3\sigma / 3\sigma$	Unacceptable
1.00	$3\sigma / 3\sigma$	Marginal
1.33	$4\sigma / 3\sigma$	OK
1.67	$5\sigma / 3\sigma$	GOOD
2.00	$6\sigma / 3\sigma$	Excellent
> 2.00	$> 6\sigma / 3\sigma$	

Cpk和制程良率换算

Cpk	每一百万件之不良	合格率 %
0.33	317310	68.3
0.67	45500	95.5
1	2700	99.73
1.33	63	99.9937
1.67	0.57	99.99995
2	0.002	100

%GRR Acceptance Criteria

Analog or Mixed Signal Parameters (Continuous)

Measurement C_p	%GRR	Rating
1	100%	Unacceptable
3	33%	Unacceptable
5	20%	Marginal
10	10%	Acceptable
50	2%	Good
100	1%	Excellent

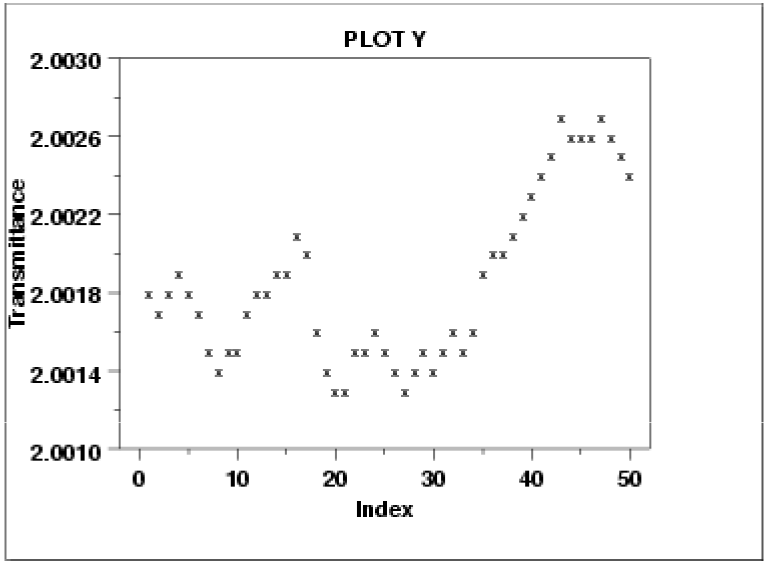
What does high %GR&R mean?

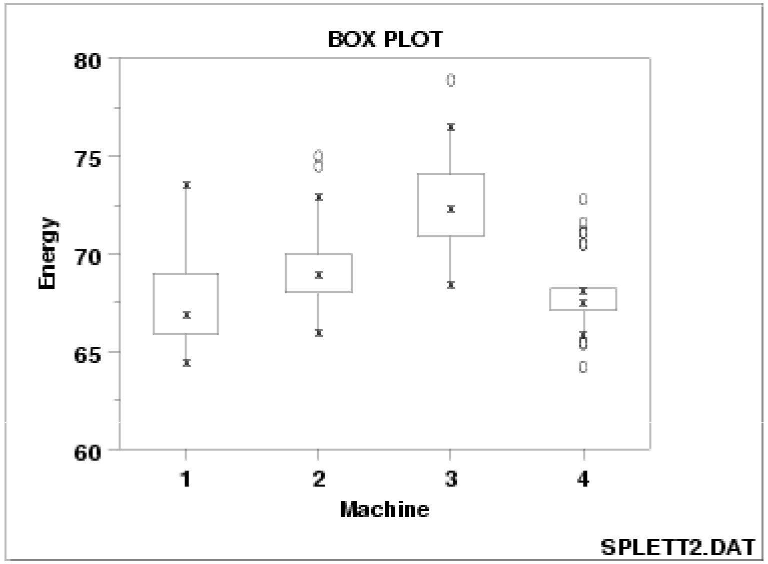
Thank you!

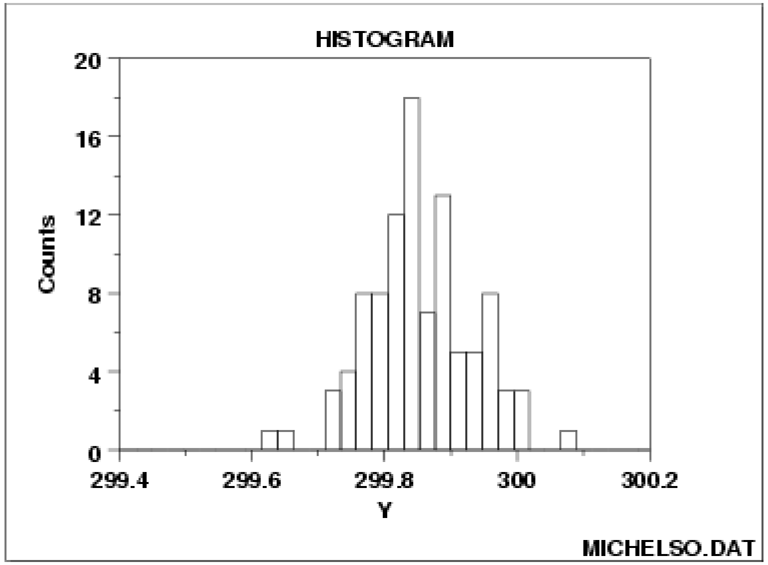
数据分析方法

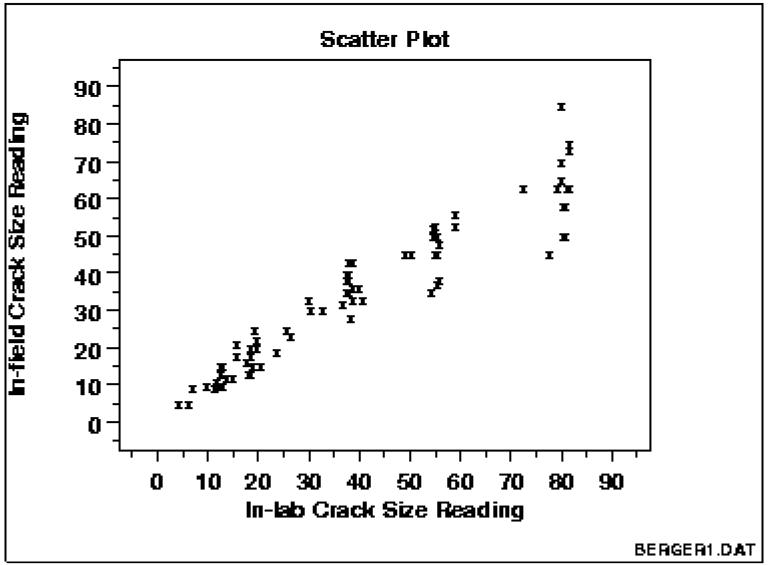
Graphical Techniques

http://www.itl.nist.gov/div898/handbook/eda/eda.htm









The calculations in the GRR-cont

D = number of devices,
T = number of test setups,
R = number of repeated measurements for each test setup,
$i = 1, 2, \ldots, T$ = index for the test setup,
$j = 1, 2, \ldots, D$ = index for the device, and
$k = 1, 2, \ldots, R$ = index for the repeated measurements.
$x_{ijk} = k^{th}$ parameter measurement on test setup i and device j

Then to estimate the repeatability variance:

$$\bar{x}_{ij} = \frac{1}{R}\sum_{k=1}^{R} x_{ijk}$$ = mean of the repeated measurements for test setup i and device j

$$s_{ij}^{2} = \frac{1}{R-1}\sum_{k=1}^{R}(x_{ijk} - \bar{x}_{ij})^2$$ = sample variance of the repeated measurements for test setup i and device j

$$s_{rj}^{2} = \frac{1}{T}\sum_{i=1}^{T} s_{ij}^{2}$$ = mean of s_{ij}^{2} across all test setups

$$s_{r}^{2} = \frac{1}{D}\sum_{j=1}^{D} s_{rj}^{2}$$ = mean of s_{rj}^{2} across all devices

s_r = estimated standard deviation of the repeatability error

The calculations in the GRR-cont

Then to estimate the reproducibility variance:

$$\bar{\bar{x}}_j = \frac{1}{T}\sum_{i=1}^{T}\bar{x}_{ij} \quad = \text{grand average for device } j$$

$$s_{Tj}^{\ 2} = \frac{1}{T-1}\sum_{i=1}^{T}(\bar{x}_{ij} - \bar{\bar{x}}_j)^2 = \text{sample variance of test setup means for device } j$$

$$s_{Rj}^{\ 2} = \max\left\{0, \left(s_{Tj}^{\ 2} - \frac{s_{rj}^{\ 2}}{R}\right)\right\} = \text{estimated reproducibility variance of device } j$$

$$s_R^{\ 2} = \frac{1}{D}\sum_{j=1}^{D} s_{Rj}^{\ 2} = \text{mean of } s_{Rj}^{\ 2} \text{ across all devices}$$

s_R = estimated standard deviation of the reproducibility error

Finally,

$$s_x = \sqrt{s_r^{\ 2} + s_R^{\ 2}}$$, where s_x = estimate of the measurement standard deviation, σ_t, for parameter x.

GRR