# 精密度的計算與測量

# Accuracy calculation and measurement

**根據IEC 61298-2/Ed.2**

過程量測和控制裝置通用性能評定方法

**According to IEC 61298-2/Ed.2 General performance evaluation method for process measurement and control devices.**

# 簡述 Brief

What is 精密度 準確度？

精度的計算方法和意義

不少客戶經常詢問精度怎樣計算，儀錶精度到底代表什麼呢？

我們的工程師詳細的解釋下精度的概念，在正常的使用條件下,儀錶測量結果的誤差程度為準確度。

**誤差越小,儀錶的準確度越高,而誤差與儀錶的量程範圍有關**

What is Precision/Accuracy?

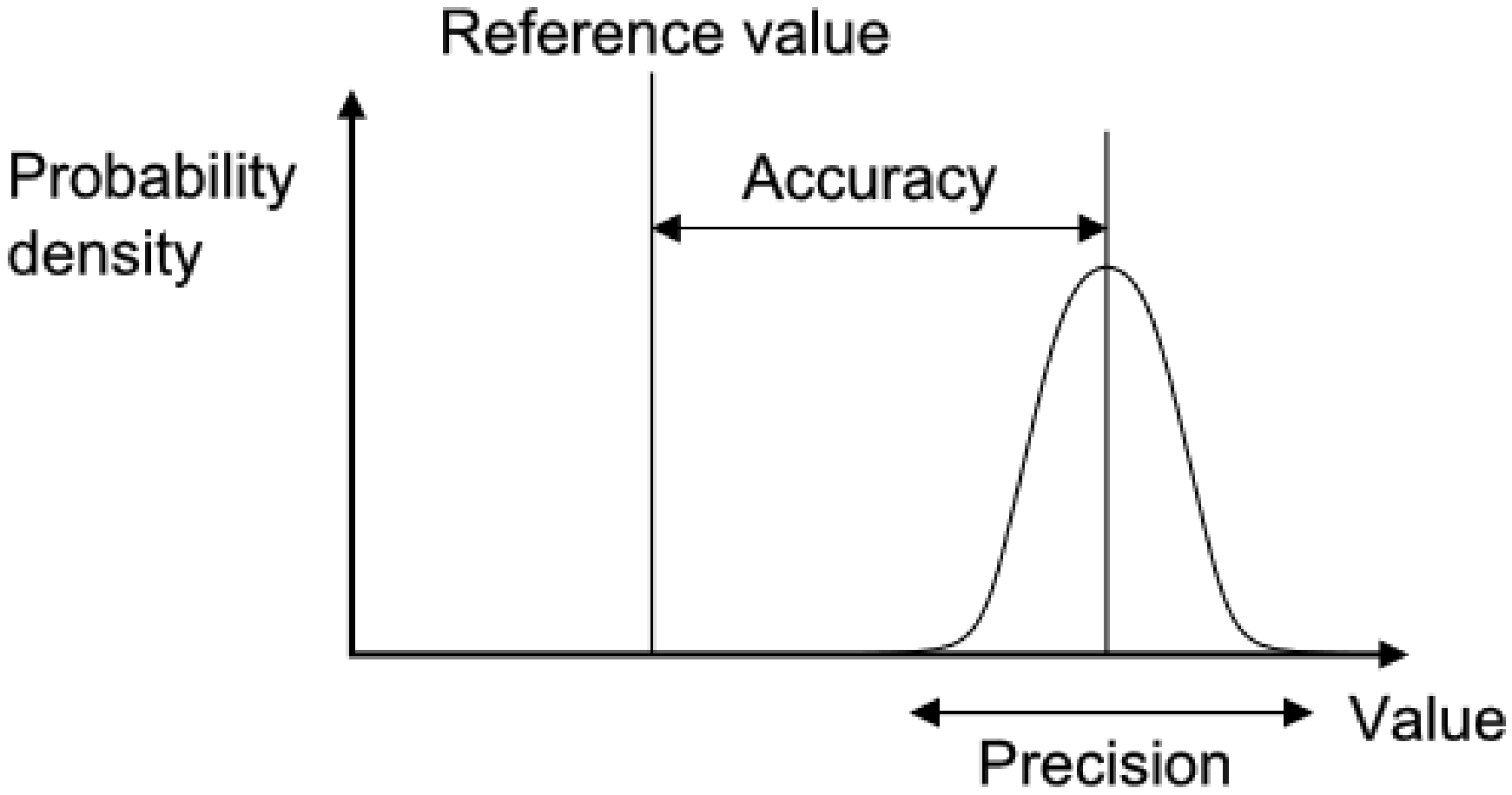
Calculation Methods and Significance of Accuracy

Many customers frequently ask how accuracy is calculated and what instrument precision represents.

Our engineers will explain the concept of precision in detail. Under normal operating conditions, the degree of error in an instrument's measurement results is called accuracy.

The smaller the error, the higher the accuracy of the instrument. Error is related to the instrument's measuring range.

# 準確度 (Accuracy)和精確度Precision)



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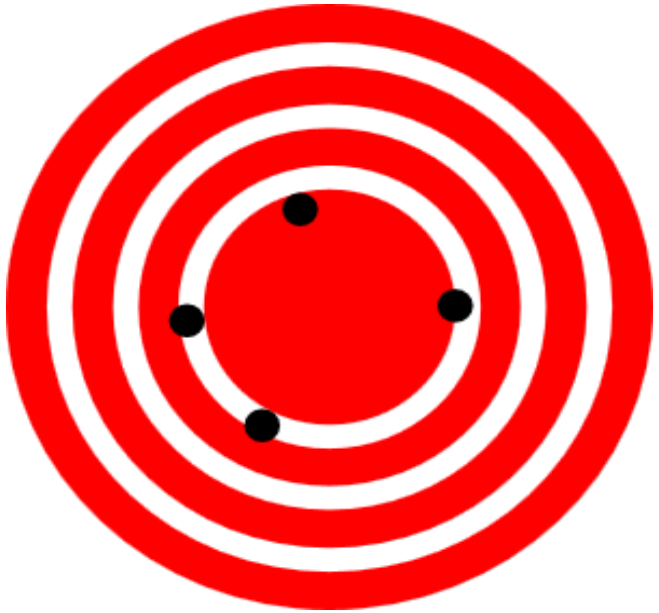

準確度低，精密度差，真實性好
Low accuracy, poor precision, good trueness

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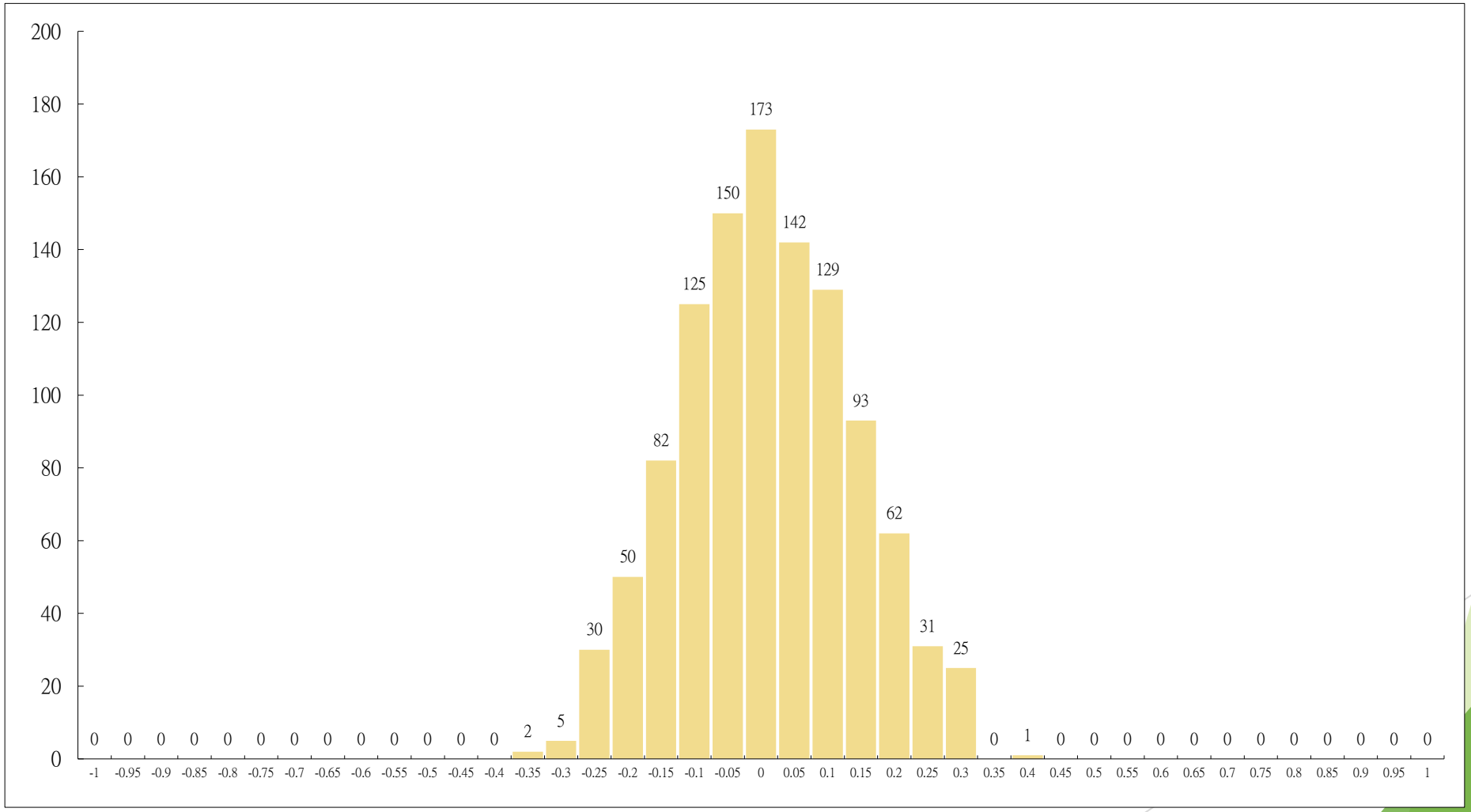
Low accuracy, good precision, poor trueness

# 品檢常態分配
# Routine quality inspection allocation



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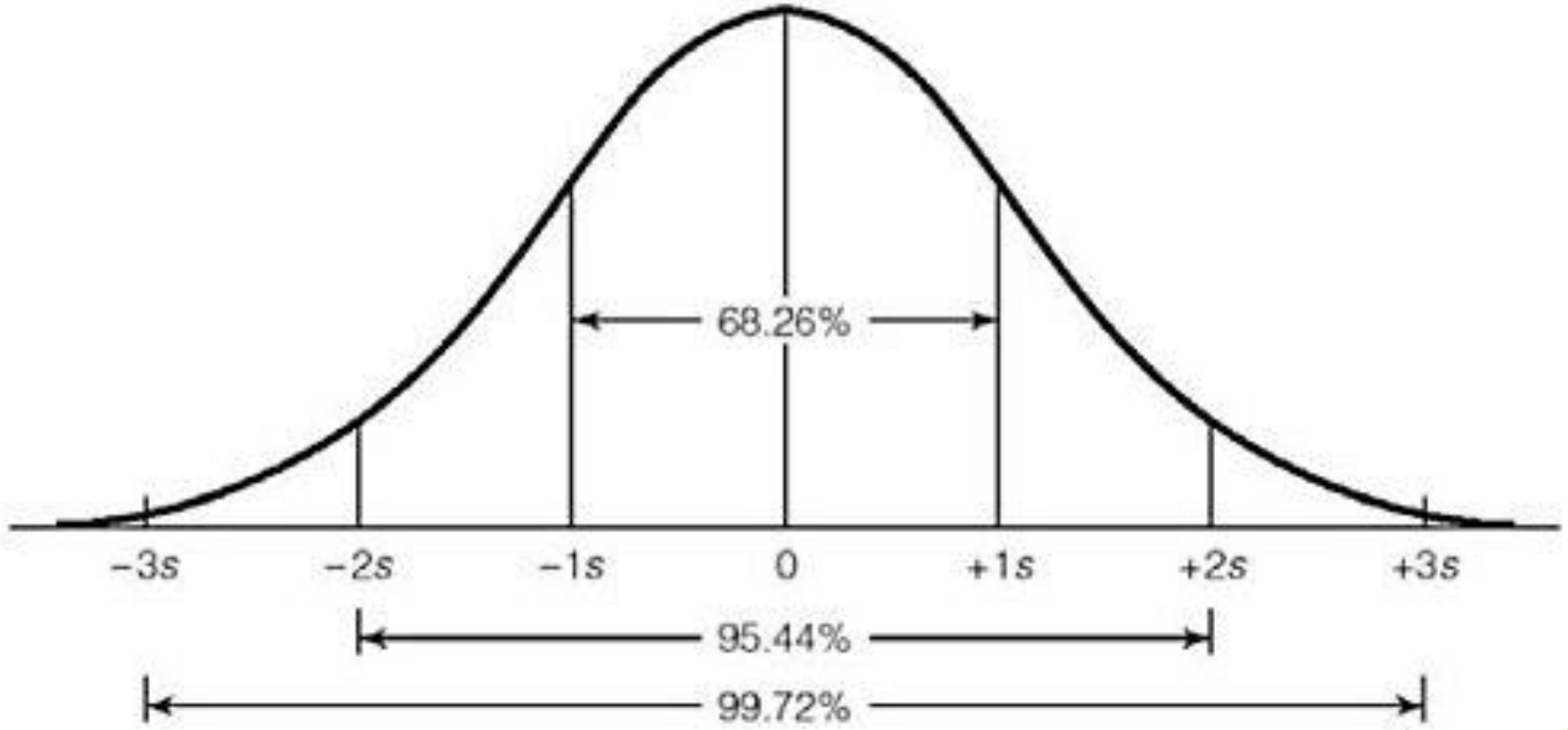


# 準確度(Accuracy)

- 一般而言準確度可以利用絕對誤差(absolute error)、相對誤差(relative error)等兩種方式表示，其數學定義如下：
- 絕對誤差： 以誤差量測單位為讀值
- 相對誤差： 以誤差百分比為讀值

- Generally, accuracy can be expressed in two ways: absolute error and relative error. Their mathematical definitions are as follows:
- Absolute error: The value is measured in units of error measurement.
- Relative error: The value is expressed as a percentage of error.

# 準確度 (Accuracy)和精確度 (Precision)

- 精確度(accuracy)同樣是一個統計學上的概念，指各次獨立實驗數據之分佈的「集中程度」。通常多次測量值的彼此之間的差距小，顯示精確度高；反之若多次測量值彼此之間的差距較大，則此系列實驗不夠精確，即精確度低。
- 在定量分析當中，經常以所有測量值的平均值為測量之準確值，如此一來便無法計算準確度，造成系統誤差被忽略，因此需要建立一個反覆測量且具良好再現性參考標準。現今常用的標準值由美國國家標準與技術研究所(NIST, National Institute of Standard and Technology)等機構所建立。
- Accuracy, also a statistical concept, refers to the "central tendency" of the distribution of data from multiple independent experiments. Generally, a small difference between multiple measurements indicates high accuracy; conversely, a large difference between multiple measurements indicates that the series of experiments is not accurate enough, i.e., low precision.
- In quantitative analysis, the average of all measurements is often used as the accurate value. However, this makes it impossible to calculate accuracy, as systematic errors are ignored. Therefore, it is necessary to establish a reference standard with repeated measurements and good reproducibility. Currently commonly used standard values are established by institutions such as the National Institute of Standards and Technology (NIST).

# 什麼是系統誤差?
# What is systematic error?

- 系統誤差又叫做規律誤差。它是在一定的測量條件下，對同一個被測尺寸進行多次重覆測量時，誤差值的大小和符號（正值或負值）保持不變；或者在條件變化時，按一定規律變化的誤差。
- 相同待測量大量重覆測量的平均結果和待測量真值的差。一般而言，由於測量步驟的不盡完善會引起測量結果的誤差，其中有的來自系統誤差，有的來自隨機誤差。隨機誤差被假設來自無法預測的影響量或影響的隨機的時間和空間變異。系統誤差和隨機誤差一樣無法刪除，但是通常可以降低，如果系統來自影響量對測量結果的可辨識效應。
- Systematic error, also known as regular error, refers to the error that, under certain measurement conditions, maintains its magnitude and sign (positive or negative) when the same dimension is measured repeatedly, or that changes according to a certain regularity when conditions change.
- Systematic error is the difference between the average result of many repeated measurements of the same measurand and the true value of the measurand. Generally, imperfections in the measurement process can cause errors in the measurement results, some of which come from systematic errors and others from random errors. Random errors are assumed to originate from unpredictable influences or random temporal and spatial variations in those influences. Like random errors, systematic errors cannot be eliminated, but they can usually be reduced if the systematic error stems from the identifiable effect of the influence on the measurement result.

# 誤差分類
# Error classification

- 絕對誤差：是測量值對真值偏離的絕對大小，因此它的單位與測量值的單位相同。
- 相對誤差：則是絕對誤差與真值的比值，因此它是一個百分數。相對誤差等於測量值減去真值的差的絕對值除以真值，再乘以百分之一百。
- 系統誤差：是由一些固有的因素（如測量方法的缺陷）產生的，理論上總是可以通過一定的手段來消除。如天平的兩臂應是等長的，可實際上是不可能完全相等的；天平配置的相同質量的砝碼應是一樣的，可實際上它們不可能達到一樣。
- 隨機誤差：是由於在測定過程中一系列有關因素微小的隨機波動而形成的具有相互抵償性的誤差（也稱為偶然誤差和不定誤差）。
- Absolute error: The absolute magnitude of the deviation of the measured value from the true value; therefore, its unit is the same as the unit of the measured value.
- Relative error: The ratio of the absolute error to the true value; therefore, it is a percentage. The relative error equals the absolute value of the difference between the measured value and the true value, divided by the true value, and then multiplied by 100%.
- Systematic error: Caused by inherent factors (such as defects in the measurement method), theoretically always achievable through certain means. For example, the two arms of a balance should be of equal length, but they cannot be perfectly equal; weights of the same mass on a balance should be identical, but they cannot be identical.
- Random error: Errors that are mutually compensating due to small random fluctuations in a series of related factors during the measurement process (also called accidental error or uncertain error).

# 隨機誤差
# Random error

隨機誤差也稱為偶然誤差和不定誤差，是由於在測定過程中一系列有關因素微小的隨機波動而形成的具有相互抵償性的誤差。

特點：大小和方向都不固定，也無法測量或校正。隨機誤差的性質是：隨著測定次數的增加，正負誤差可以相互低償，誤差的平均值將逐漸趨向於零。

原因：產生隨機誤差的原因有許多。例如，在測量過程中由於溫度、濕度以及灰塵等的影響都可能引起數據的波動。再比如在讀取滴定管數據時，估計的小數點後第二位的數值，幾次讀數不一致。這類誤差在操作中不能完全避免。

隨機誤差的大小、正負在同一個實驗室中不是恆定的，並很難找到產生的確切原因，所以又稱不定誤差。

Random error, also known as accidental error or indeterminate error, is an error that compensates for each other due to small random fluctuations in a series of related factors during the measurement process.

Characteristics: Its magnitude and direction are not fixed, and it cannot be measured or corrected. The property of random error is that as the number of measurements increases, positive and negative errors can compensate for each other, and the average error will gradually tend towards zero.

Causes: There are many causes of random error. For example, the influence of temperature, humidity, and dust during the measurement process can cause data fluctuations. Another example is that when reading burette data, the estimated value of the second decimal place may differ between several readings. This type of error cannot be completely avoided in operation.

The magnitude and sign of random error are not constant in the same laboratory, and it is difficult to find the exact cause; therefore, it is also called indeterminate error.

# 精密度計算
# Precision calculation

| | |
|---|---|
| **精密度誤差** | **Precision error** |
| 線性度誤差(linearity error) | Linearity error |
| 遲滯性誤差(hysteresis error) | Hysteresis error |
| 重複性誤差(repeatability error) | Repeatability error |
| **溫度誤差** | **Temperature error** |
| 熱零點誤差(thermal zero point error) | Thermal zero point error |
| 熱靈敏度誤差(thermal sensitivity error) | Thermal sensitivity error |
| **系統誤差** | **Systematic error** |
| **調整誤差** | **Adjustment error** |
| **顯示誤差(display error)** | **Display error** |
| **標準件不確定性誤差** | **Standard part uncertainty error** |

# 精密度規格範例如下
# Precision specifications are as follows

linearity error : < ±0.3% of span

hysteresis error : < ±0.1% of span

repeatability error : < ±0.1% of span

thermal zero point error : < 0.1% of span/°C

thermal sensitivity error : < 0.1% of span/°C

Factory adjustment error : < ±0.15% of span

(Zero and span)

Long term stability : < ±0.1% of span / year

Display error : < 0.1% of span

# 線性誤差精度
# Linear error accuracy

線性誤差：實測曲線與理想直線之間的偏差

精度：由感測器的基本誤差極限和影響量如溫度變化、濕度變化、電源波動、頻率改變等，引起的改變量極限確定。

Linearity error: The deviation between the measured curve and the ideal straight line.

Accuracy: Determined by the basic error limit of the sensor and the limit of changes caused by influencing factors such as temperature changes, humidity changes, power fluctuations, frequency changes, etc.

# 遲滯誤差
# Hysteresis error

定義：在相同的工作條件下，上行曲線下行曲線值之間的最大誤差

測量器具對同一個尺寸進行正向和反向測量時，由於結構上的原因，其指示值不可能完全相同這種誤差被稱遲滯誤差。

Definition: Under the same working conditions, the maximum error between the values of the upward and downward curves.

When a measuring instrument performs forward and reverse measurements on the same dimension, due to structural reasons, its indicated values cannot be the same. This error is called hysteresis error.

# 重複性誤差
# Repeatability error

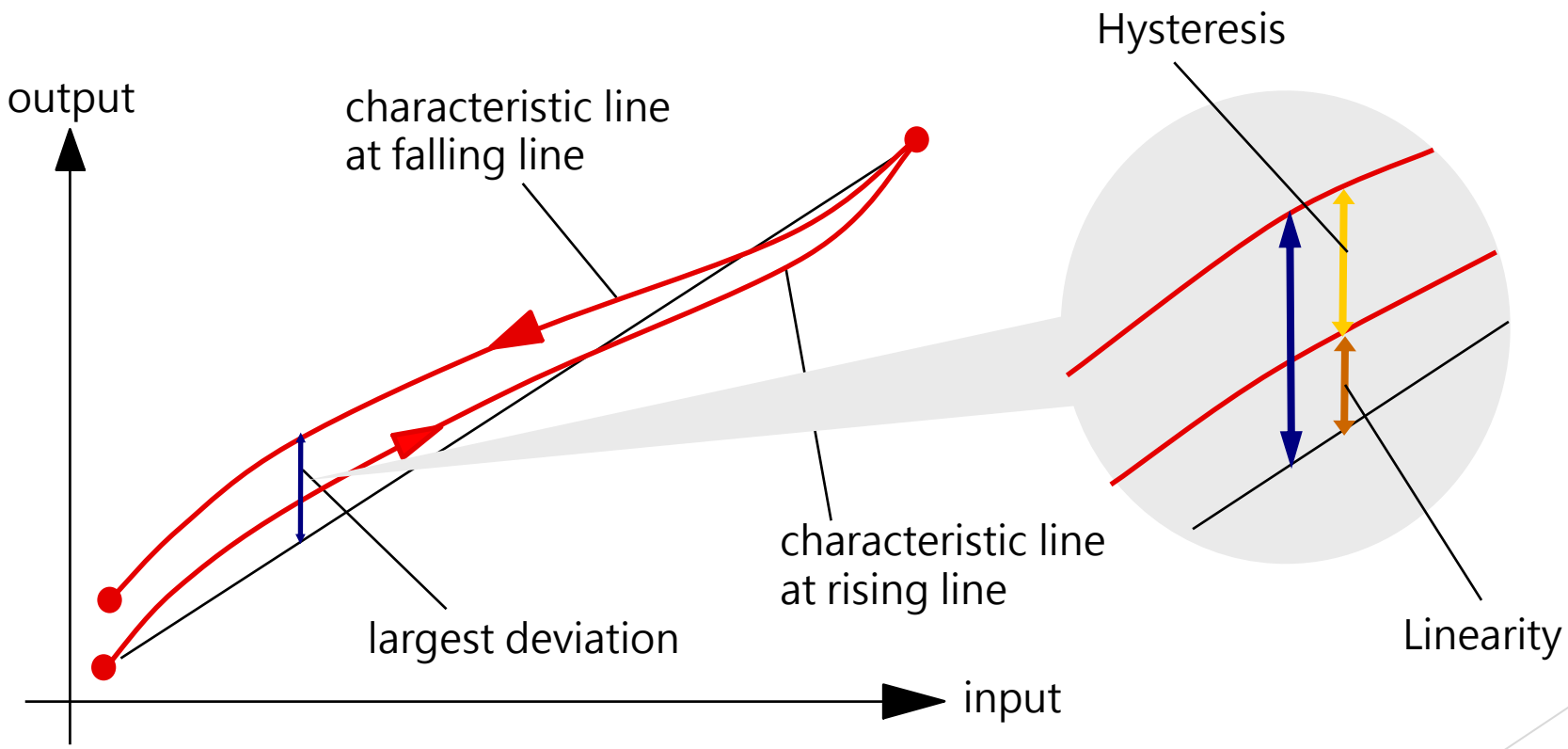
定義：在相同的工作條件下，對同一個輸入值在短時間內多次連續測量輸出所獲得的值之間的誤差。

在全測量範圍內和同一工作條件下，從同方向對同一輸入值進行多次連續測量所獲得的隨機誤差。

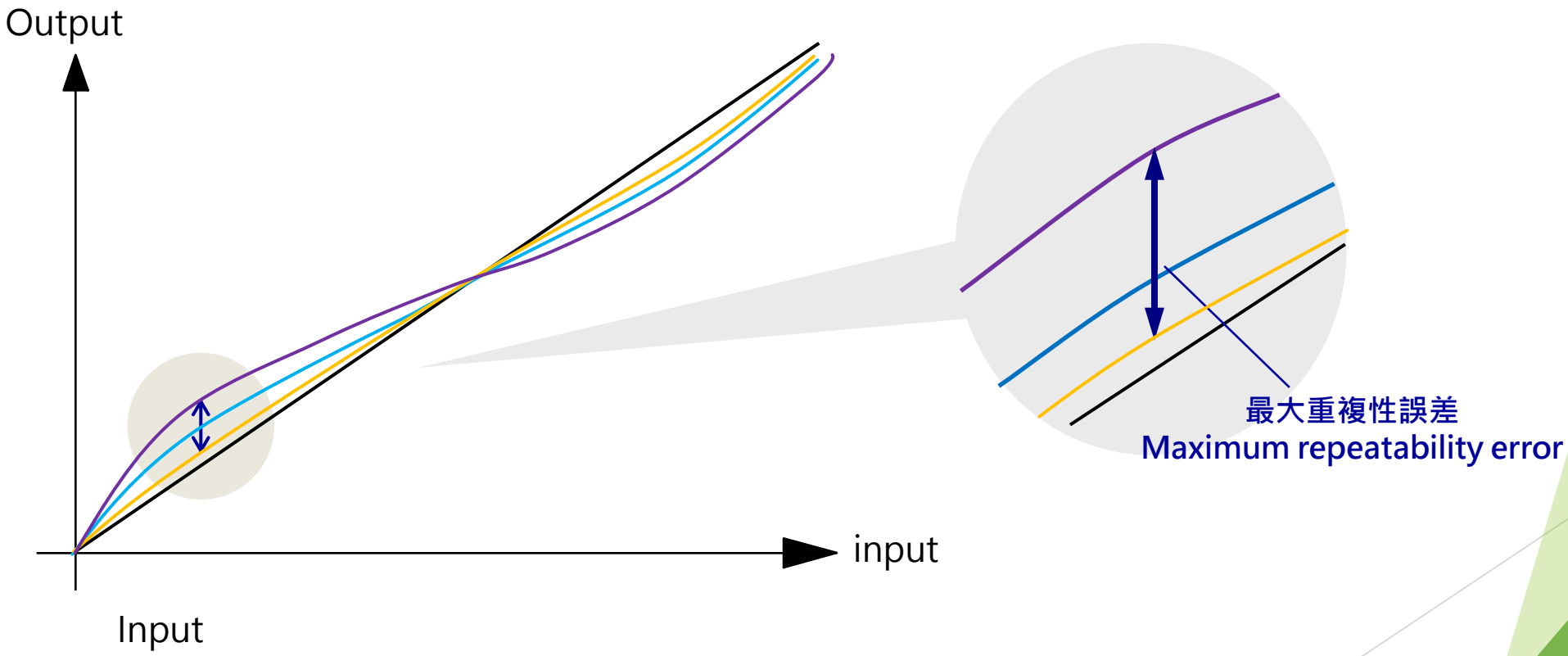
Definition: The error between the output values obtained from multiple consecutive measurements of the same input value within a short period of time, under the same operating conditions.

The random error obtained from multiple consecutive measurements of the same input value from the same direction within the entire measurement range and under the same operating conditions.

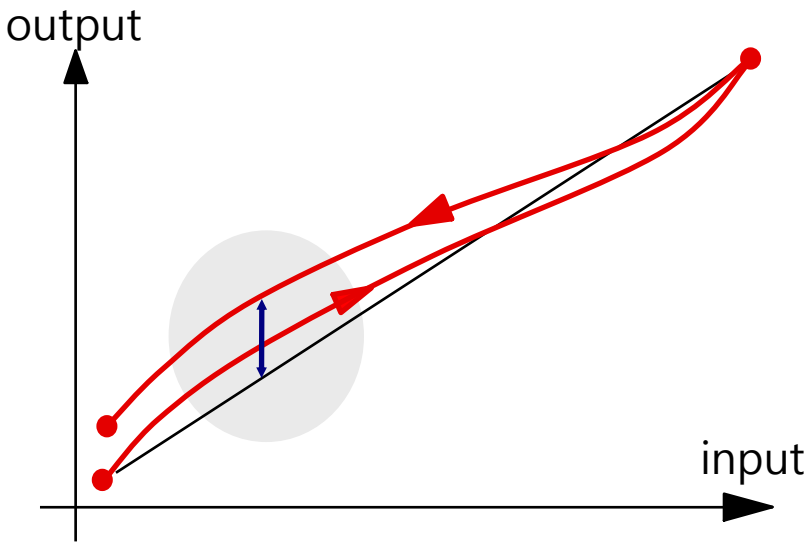
# 訊號校正調整 Accuracy
# Signal correction and adjustment Accuracy



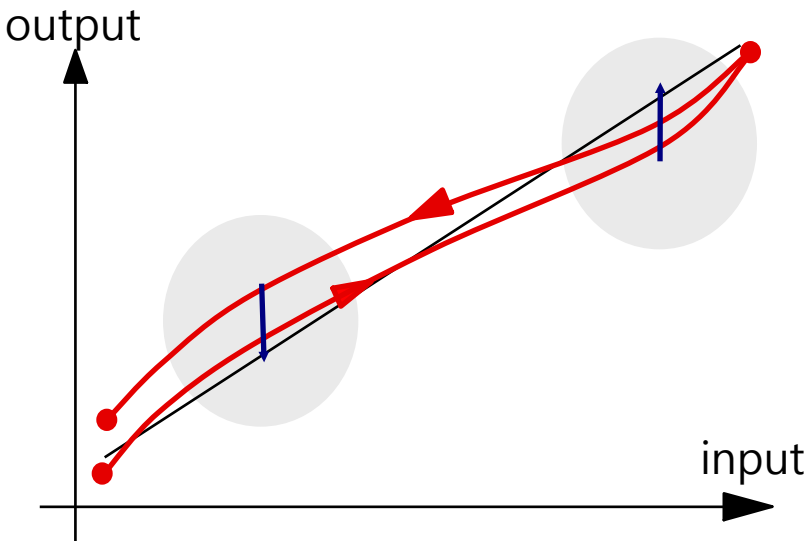
# 重複性誤差
# Repeatability error



# 最佳精度調整
# Signal conditioning circuit BFSL Accuracy

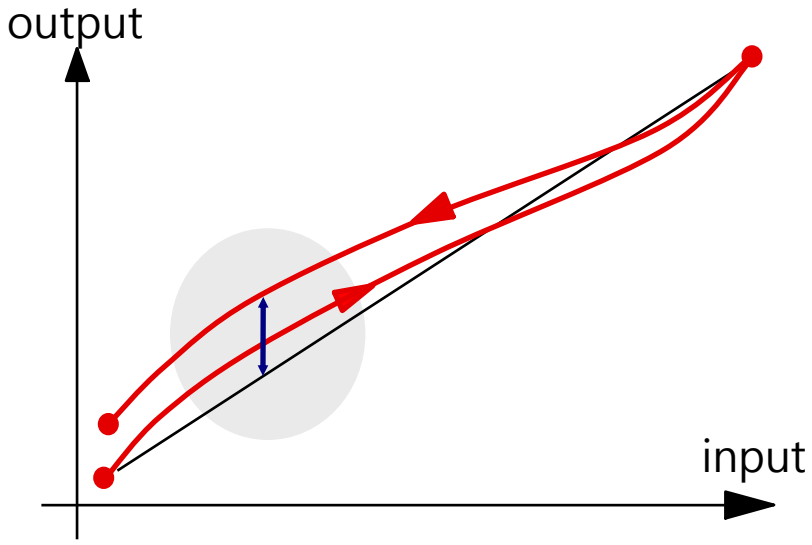



terminal point adjustment

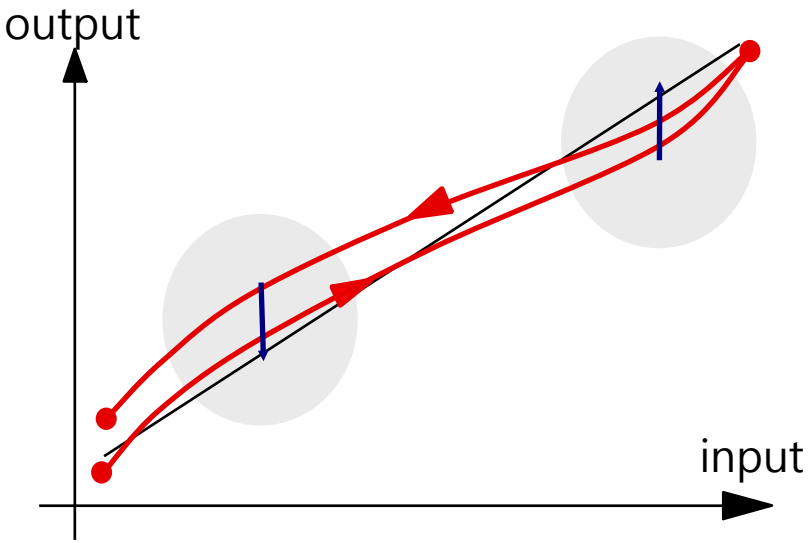



best fit straight line

# 最佳精度調整
# Signal conditioning circuit BFSL Accuracy




terminal point adjustment




best fit straight line

# 溫度誤差
# Temperature error

由於環境溫度或介質溫度改變引起的誤差通常是可以建立和校正的系統誤差。

其溫度誤差分為有兩種不同類的誤差：熱零點漂移、熱靈敏度漂移。

Errors caused by changes in ambient or medium temperature are usually systematic errors that can be established and corrected.

Temperature errors are divided into two different types: thermal zero-point drift and thermal sensitivity drift.

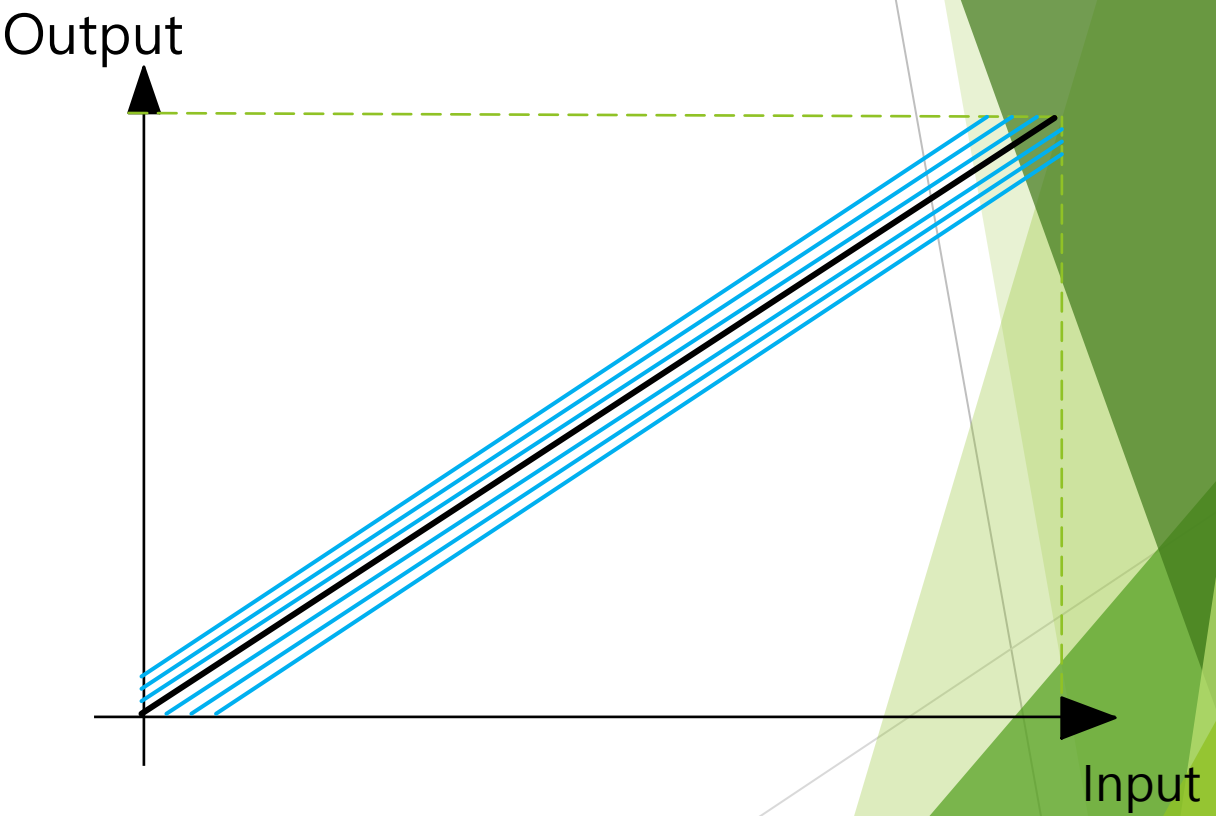
# 溫度誤差
# Temperature error

熱零點漂移

環境溫度改變了輸出信號偏離零點的變動。輸入信號為零，輸出信號偏離零 值的變化。它又被簡稱為：零漂TC。這種誤差可以利用電子線路補償消除。所有的測量值可以轉換並依賴於加以修正。

Thermal Zero Drift

Ambient temperature changes the output signal's deviation from zero. When the input signal is zero, the output signal deviates from zero by a certain value. This is also known as zero drift (TC). This error can be eliminated using electronic compensation. All measured values can be converted and corrected accordingly.



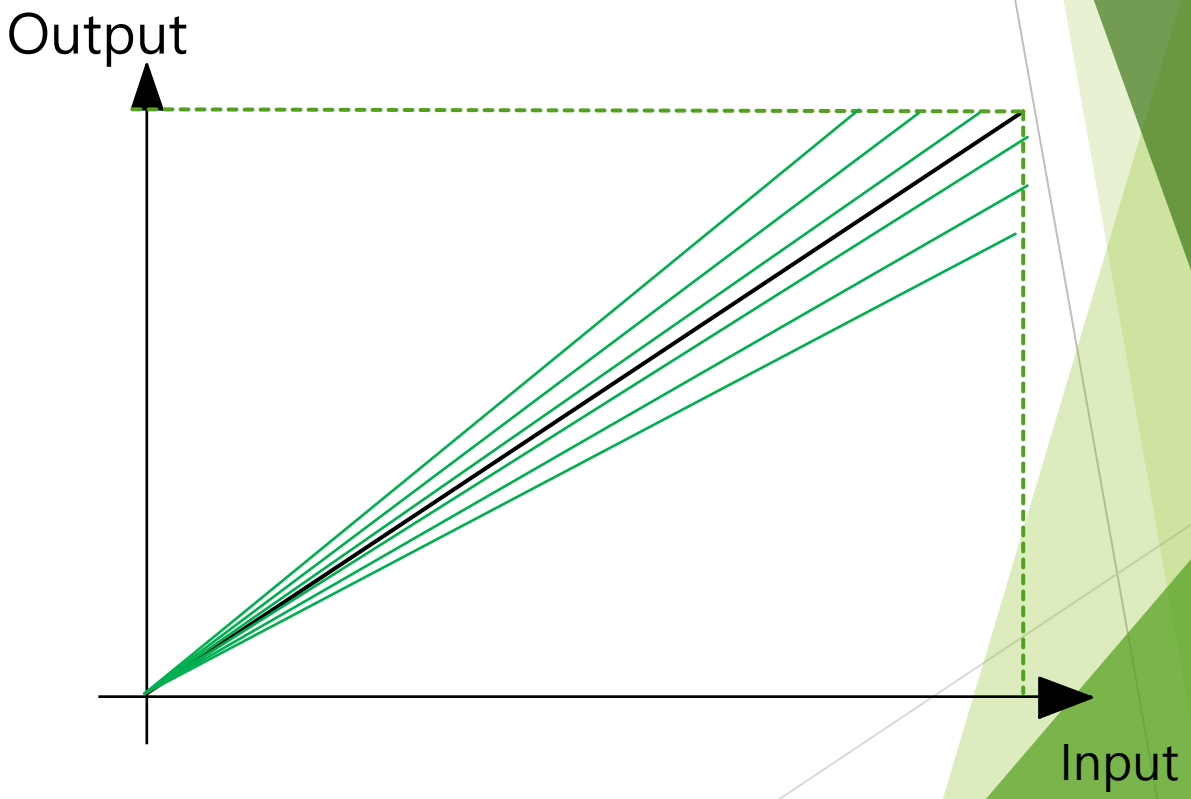
# 溫度誤差
# Temperature error

熱靈敏度漂移

隨著環境溫度以及感測器或內部的溫度的變化，都會引起靈敏度漂移TS，即在不同溫度下測試出的結果會發生相同的相對量的變化。

Thermal Sensitivity Drift

Changes in ambient temperature and the temperature of the sensor or its internal components can cause sensitivity drift (TS), meaning that the results measured at different temperatures will show the same relative change.



# 最大誤差(精密度)
# Maximum error (precision)

目前我們儀錶測試誤差基本分為：顯示誤差、 遲滯誤差、線性誤差、 重複性測量誤差、穩定性誤差、設備系統誤差、環境溫度波動漂移引起的誤差等。
但是我們產品是以線性精度作為研究的物件和品質說明的要素。也是測試過程中作為基準度來衡量的依據。

Currently, our instrument testing errors are basically categorized as follows: display error, hysteresis error, linearity error, repeatability measurement error, stability error, equipment system error, and errors caused by environmental temperature fluctuations.
However, our products use linear accuracy as the object of study and a key element in quality specification. It is also the benchmark used for measurement during the testing process.

# 靜態誤差帶(精密度)
# Static error band (precision)

事實上，靜態誤差是指當測量器件的測量值(或輸入值)不隨時間變化時，測量結果(或輸出值)會有緩慢的漂移，這種誤差稱為靜態誤差，或稱靜態誤差。靜態誤差是指誤差的幅值和方向是恒定的.

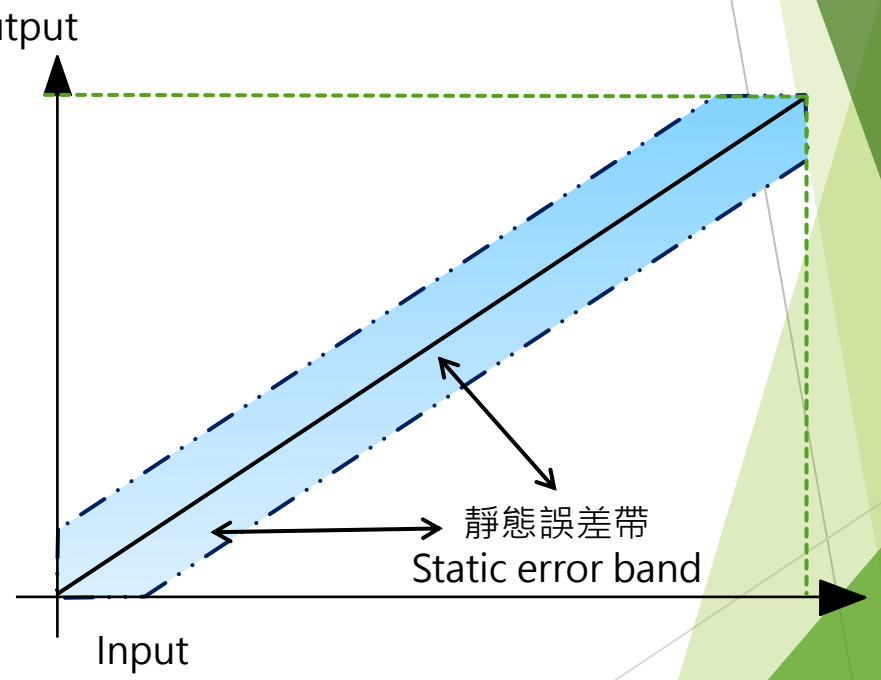
範例：傳感器的靜態誤差帶計算

線性度±0.5% FS /遲滯誤差+重複性誤差 ± 0.1% FS / 溫度誤差±0.4 % FS (zero and span)。

即：靜態誤差帶= $\pm\sqrt{0.5^2+0.1^2+0.4^2}$ = $\pm\sqrt{0.42}$ = ± 0.64%

線性誤差= $\pm\sqrt{0.5^2}$ =± 0.50%

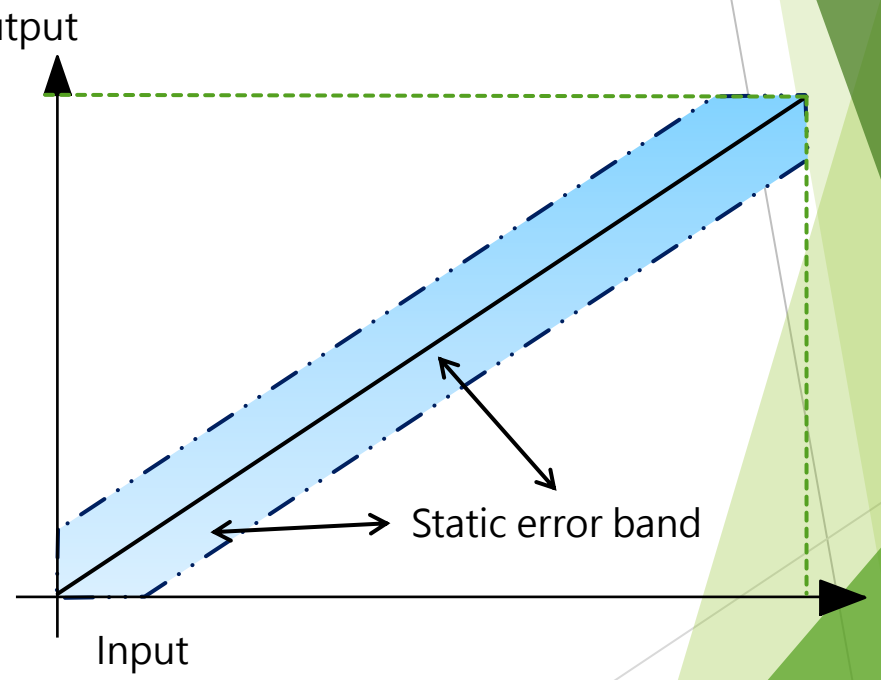
最大可能誤差= ± 1%



# 靜態誤差帶(精密度)
# Static error band (precision)

In fact, static error refers to the slow drift of the measurement result (or output value) when the measured value (or input value) of a measuring device does not change over time. This type of error is called static error, or simply static error. Static error means that the amplitude and direction of the error are constant.

Example: Calculation of the static error band of a sensor: Linearity ±0.5% FS / Hysteresis error + Repeatability error ±0.1% FS / Temperature error ±0.4% FS (zero and span).




i.e. : Static error band $= \pm\sqrt{0.5^2 + 0.1^2 + 0.4^2} = \pm\sqrt{0.42} = \pm$ 0.64%

linear error $= \pm\sqrt{0.5^2} = \pm$ 0.50%

Maximum possible error = ± 1%


# THANK YOU

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