

# 振動之量測介紹

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必凱科技股份有限公司

## 課程大綱

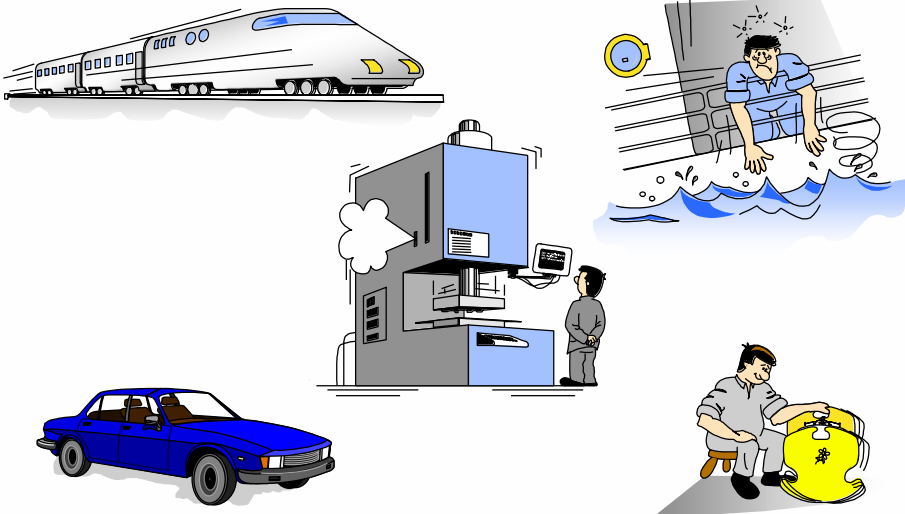
- 振動的定義
- 振動的參數
- 振動的原理
- 振動訊號型式
- 參數之關係
- 量測單位
- 訊號量測鏈
- 振動量測探頭
- 分析方法
- 顯示方式

## 振動之定義

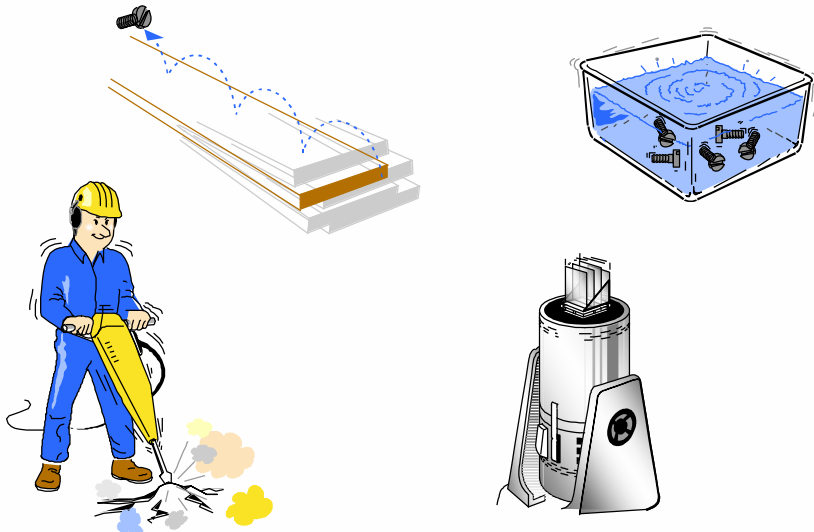
**振動(Vibration)**：一種機械系統的震盪(oscillation)行為。振動的大小是機械系統運動的一個參數(a parameter)。

**震盪(Oscillation)**：隨著時間的過去，相對於參考位置，有著大小量的變化。

## 日常生活之振動



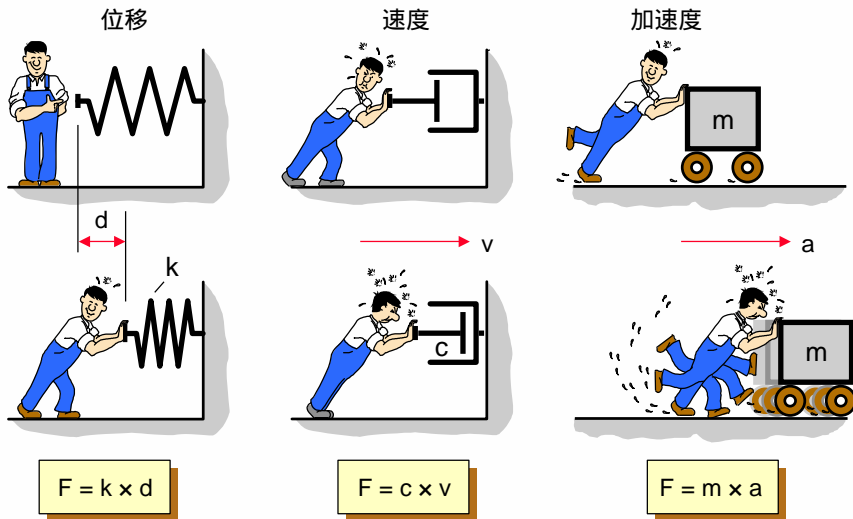
# 工業上的振動應用



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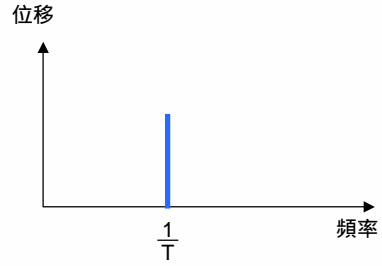
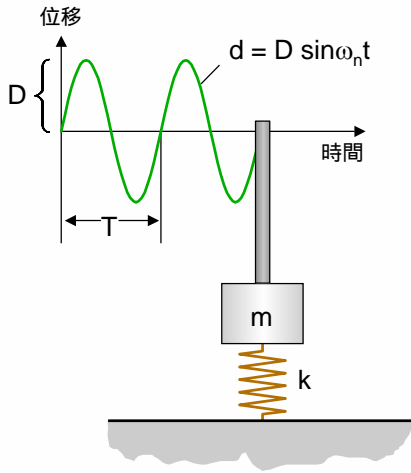
# 振動量測參數



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# 簡單的振動系統

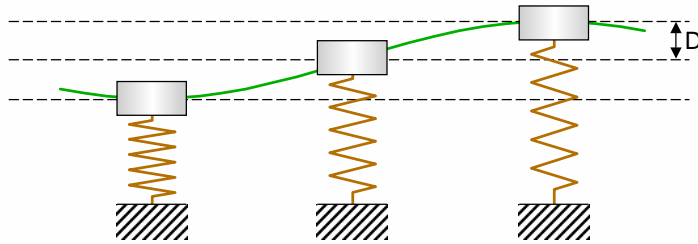


週期,  $T_n$  in [sec]

頻率,  $f_n = \frac{1}{T_n}$  in [Hz = 1/sec]

$$\omega_n = 2 \pi f_n = \sqrt{\frac{k}{m}}$$

# 自由振動



能量在動能及位能之間轉換  
(assuming no damping)

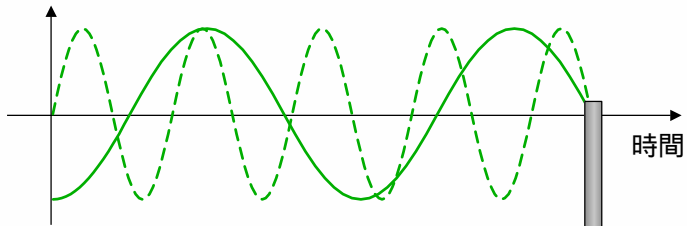
$$\Delta \text{動能} = - \Delta \text{位能}$$

$$\frac{1}{2} m V^2 = \frac{1}{2} k D^2, \text{ and } V = (2\pi f_n) D$$

$$\frac{1}{2} m (2\pi f_n)^2 D^2 = \frac{1}{2} k D^2$$

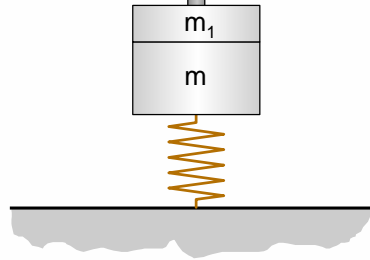
$$f_n = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$

## 質量與彈簧系統



$$\omega_n = 2\pi f_n = \sqrt{\frac{k}{m + m_1}}$$

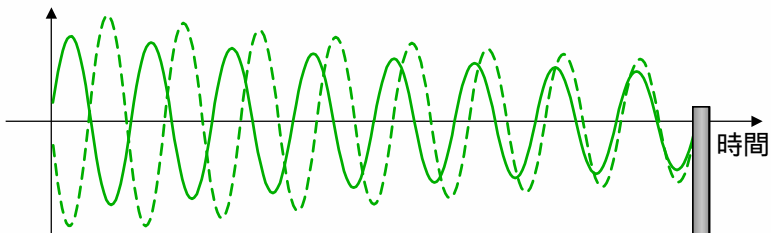
質量增加時  
頻率降低



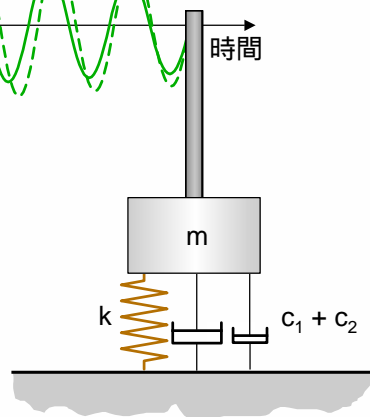
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## 質量,彈簧與吸振器系統



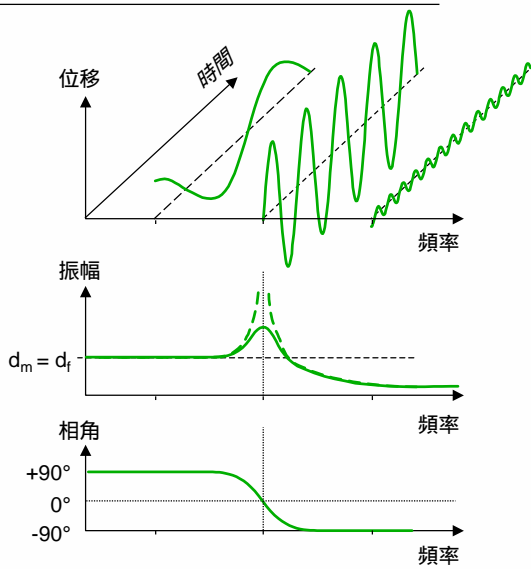
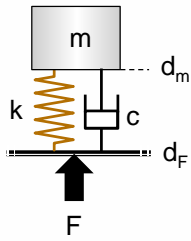
阻尼增加時  
振幅減少



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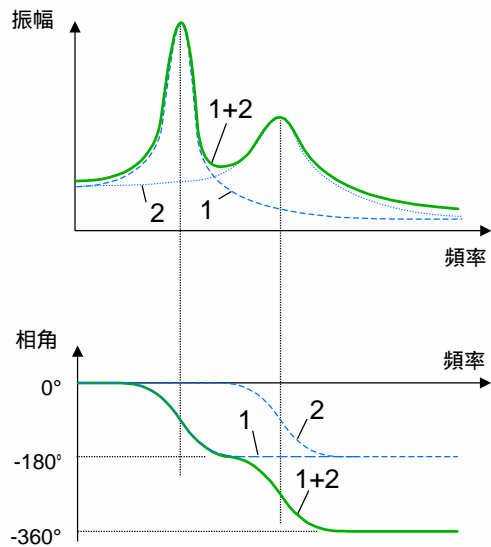
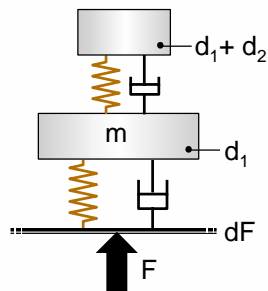
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# 強制振動



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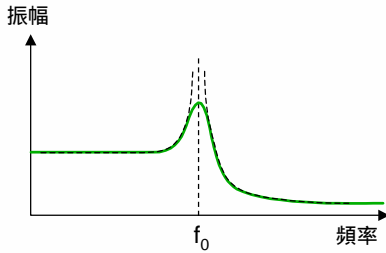
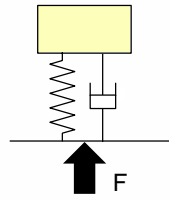
# 複合的反應



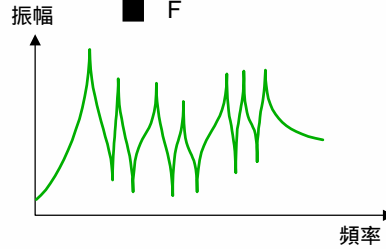
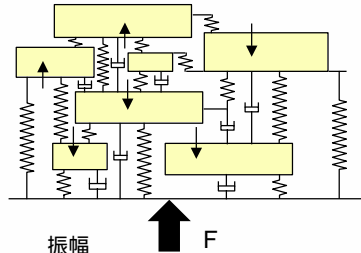
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# 反應的模式

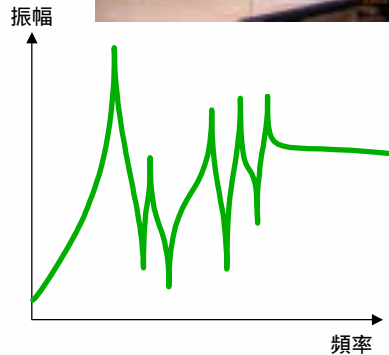
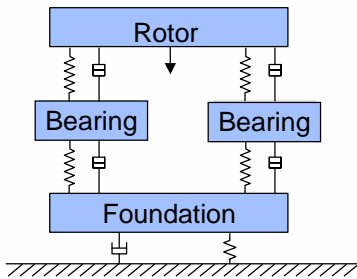
單一自由度之反應  
SDOF



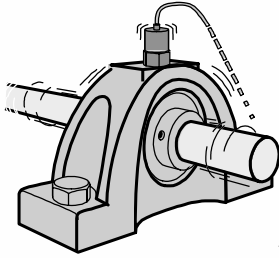
多自由度之反應  
MDOF



# “真實世界” 的反應



# 力量與振動



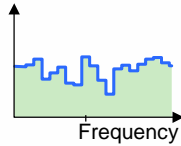
力量  
輸入

+

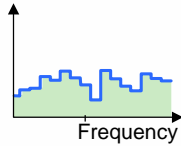
系統  
響應  
(Mobility)

=

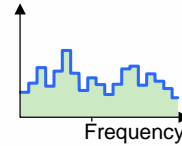
振動



+



=



力量的產生

- 不平衡
- 衝擊
- 摩擦
- 聲音

結構參數:

- 質量
- 剛性
- 阻尼

振動參數:

- 加速度
- 速度
- 位移

# 振動量測的目的



- 確認其大小及次數未超乎材料的極限 (例如 金屬疲勞常用的S-N Curve 或稱 Wöhler curves)
- 避免激發機器上的特定元件之自然頻率
- 能抑制或隔離振動源
- 進行機器之狀況監測
- 用於建構或確認結構之計算模型 (system analysis)



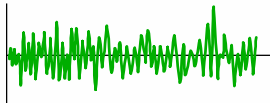
## 振動的量化

- 進行量測
- 分析量測資料(位準與頻率)

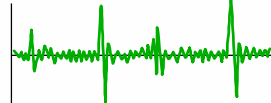
進行分析時, 我們需探討我們所面對的振動訊號型式  
並需對各種訊號型式之單位選擇有所了解

## 訊號型式

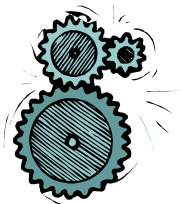
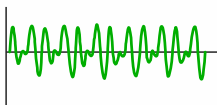
穩態訊號



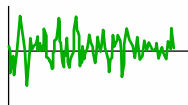
非穩態訊號



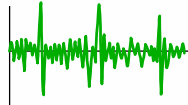
穩定訊號



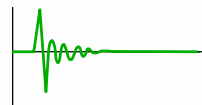
隨機訊號



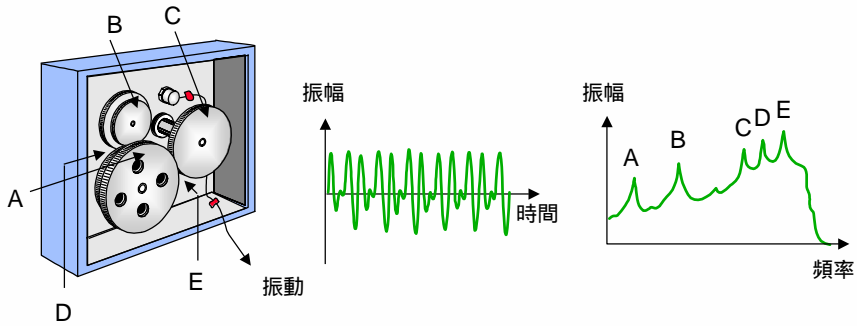
連續訊號



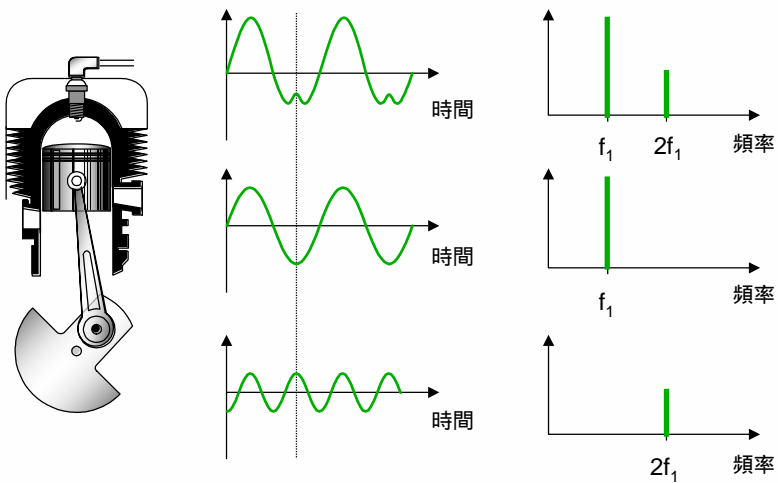
暫態訊號



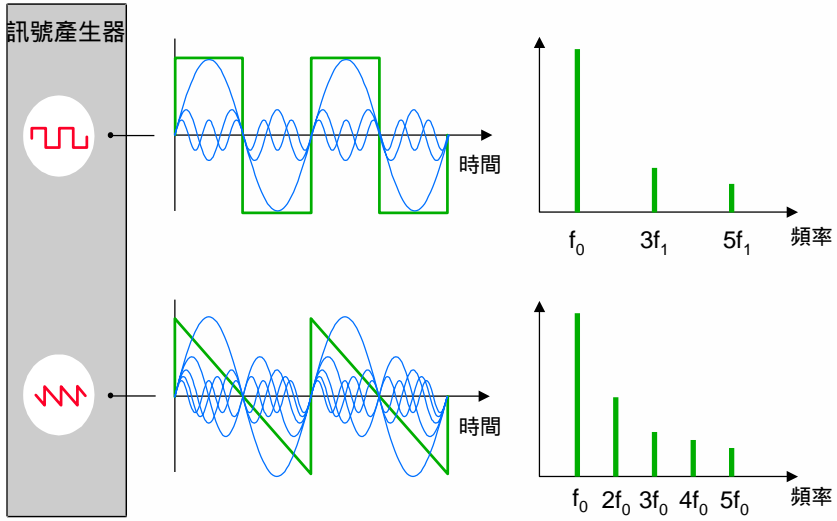
# 穩定的訊號



# 穩定訊號的組成



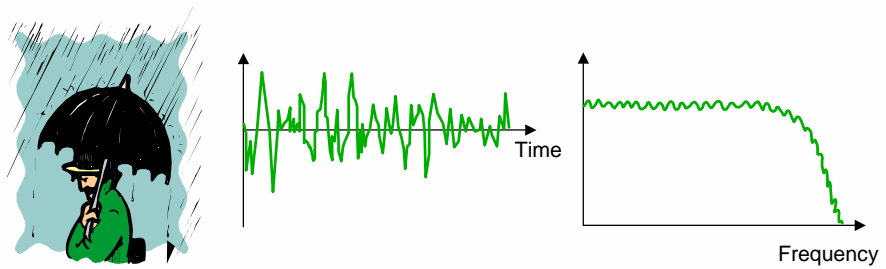
# 譜波之時頻關係



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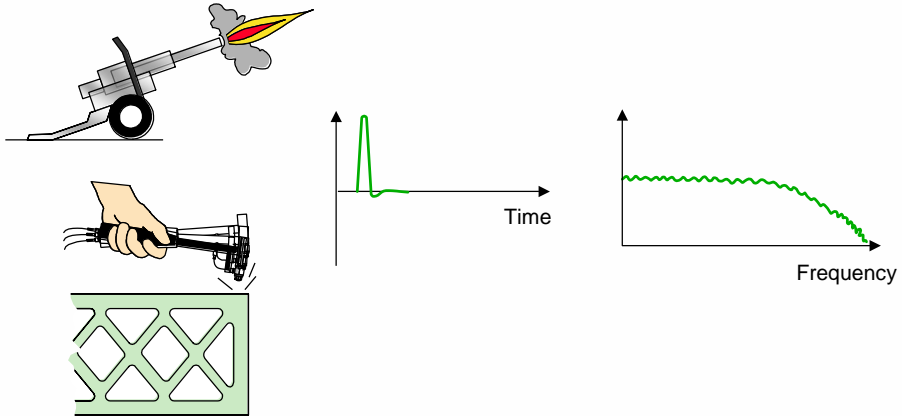
# 隨機訊號



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## 衝擊訊號



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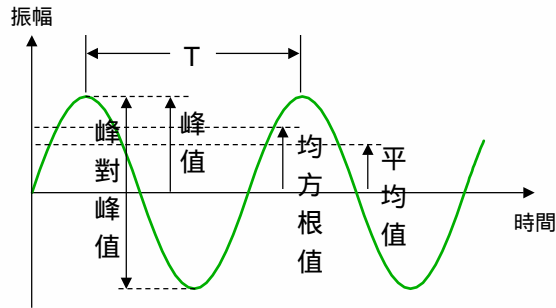
## 時域參數的選用

- 峰值(Peak)
- 峰對峰值(Peak-Peak)
- 平均值(Average)
- 均方根值(RMS)
- Crest Factor
- 持續時間(Duration)

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## 參數的意義

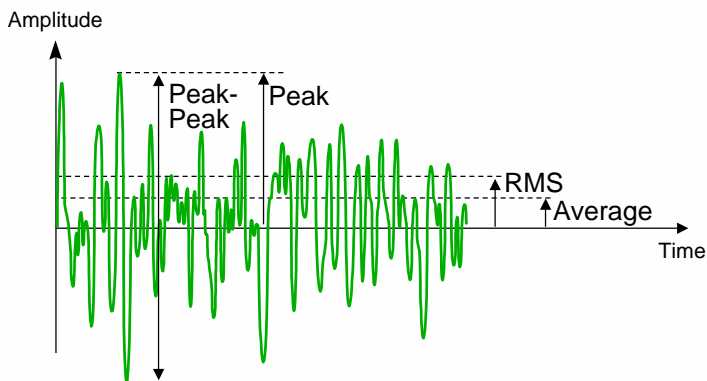


$$\text{均方根值} = \sqrt{\frac{1}{T} \int_0^T x^2(t) dt}$$

$$\text{平均值} = \frac{1}{T} \int_0^T |x(t)| dt$$

$$\text{Crest Factor} : \frac{\text{Peak}}{\text{RMS}}$$

## 實際訊號之參數

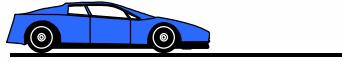


$$\text{均方根值} = \sqrt{\frac{1}{T} \int_0^T x^2(t) dt}$$

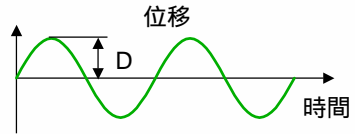
$$\text{平均值} = \frac{1}{T} \int_0^T |x(t)| dt$$

$$\text{Crest Factor} : \frac{\text{Peak}}{\text{RMS}}$$

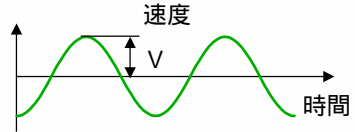
## 直線與震盪之移動



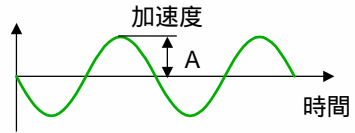
台北  
35 公里



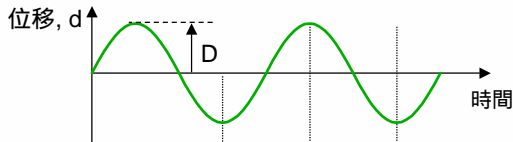
速限  
60  
公里/時



測試  
0-60 公里/時  
8.6秒

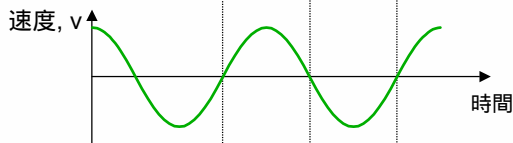


## 位移轉換至加速度之關係



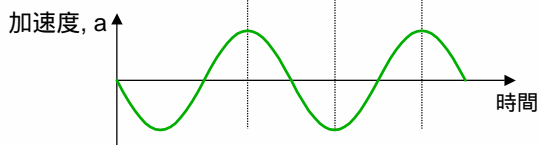
$$d = D \sin \omega t$$

$$d = D$$



$$v = \frac{dd}{dt} = D\omega \cos \omega t$$

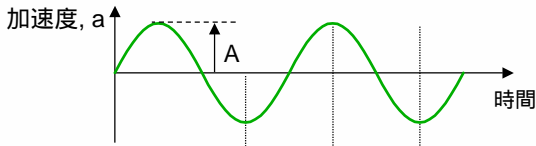
$$v = D\omega = D2\pi f$$



$$a = \frac{d^2d}{dt^2} = D\omega^2 \sin \omega t$$

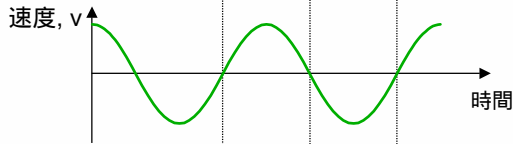
$$a = D\omega^2 = D4\pi^2 f^2$$

# 加速度轉換至位移之關係



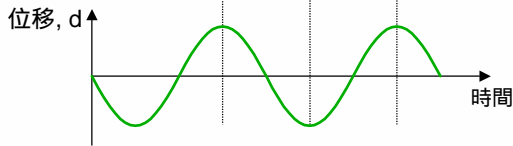
$$a = A \sin \omega t$$

$$a = A$$



$$v = \int a \, dt = -\frac{A}{\omega} \cos \omega t$$

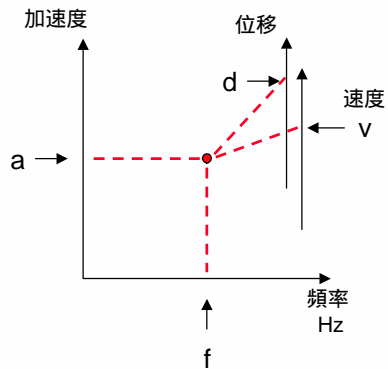
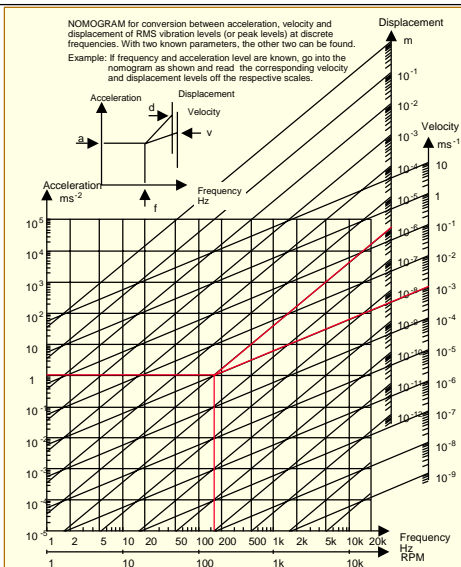
$$v = \frac{A}{\omega} = \frac{A}{2\pi f}$$



$$d = \iint a \, dt \, dt = -\frac{A}{\omega^2} \sin \omega t$$

$$d = \frac{A}{\omega^2} = \frac{A}{4\pi^2 f^2}$$

# 轉換關係表



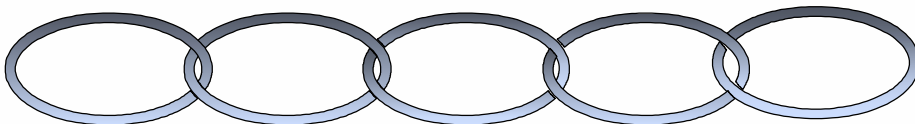
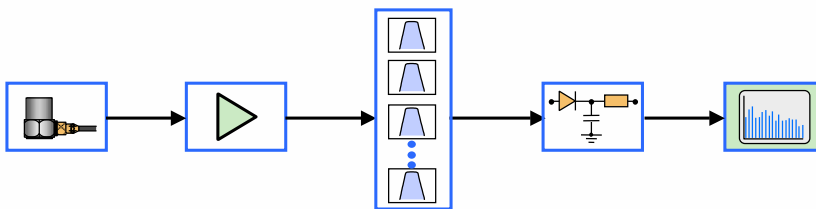
## 振動之單位

加速度 a	$1\text{ms}^{-2}$ (m/s <sup>2</sup> )	= 0.102g = 39.4 in/s <sup>2</sup>
速度 v	$1\text{ms}^{-1}$ (m/s)	= 3.6 km/h = 39.4 in/s
位移 d	1m	= 1000 mm = 39.4 in

$$1g \equiv 9.80665 \text{ ms}^{-2}$$

## 訊號量測鏈

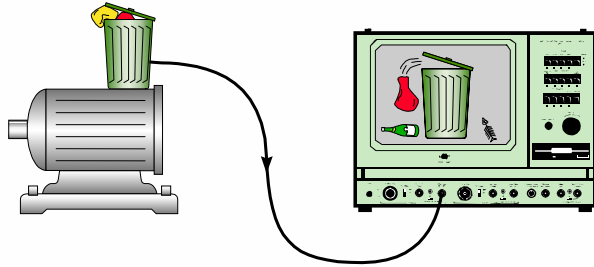
傳感器      前置放大器      濾波器      偵測器      輸出





# GIGO

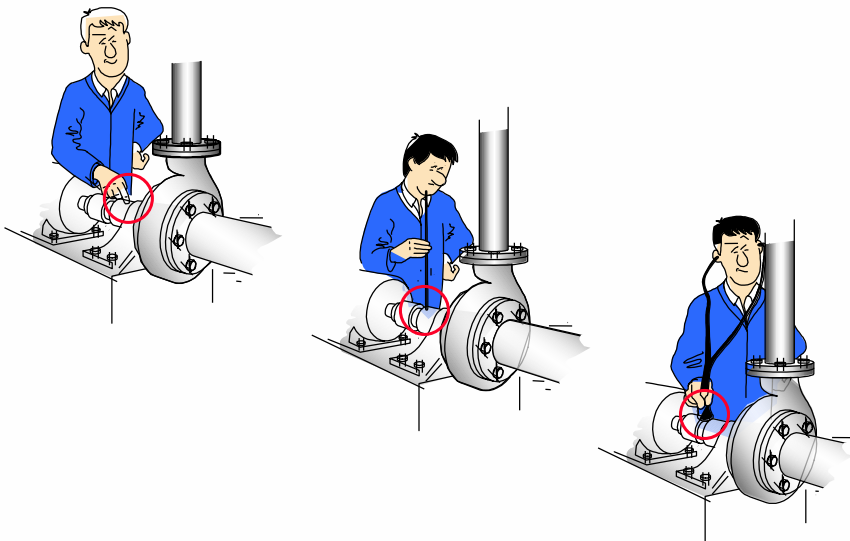
Garbage In = Garbage Out



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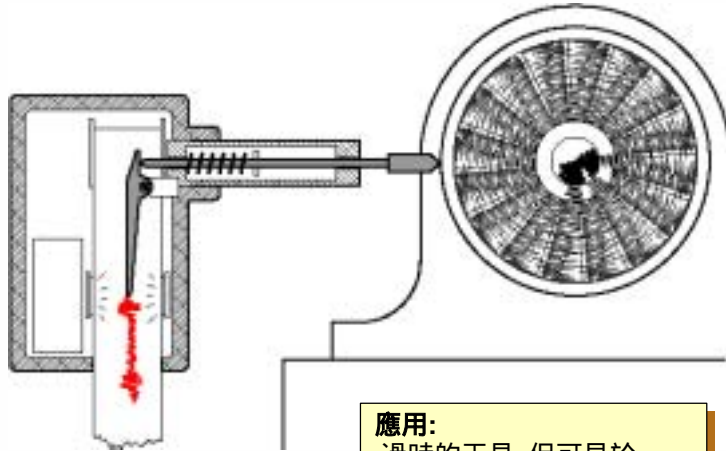
# 早期之振動量測



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## 機械槓桿

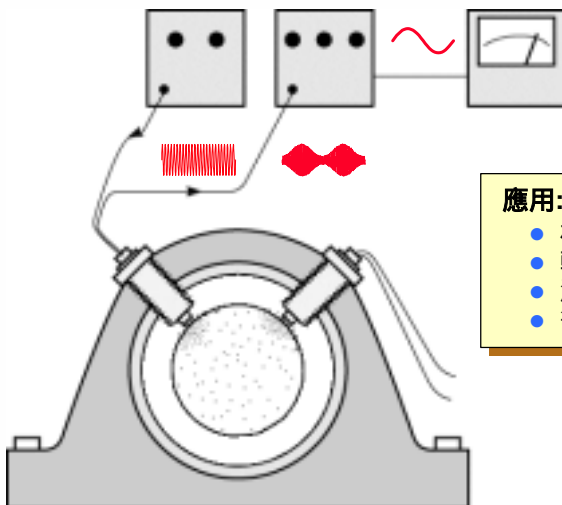


應用：  
過時的工具，但可見於  
一些水力電廠

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## 位移近接渦電流探頭



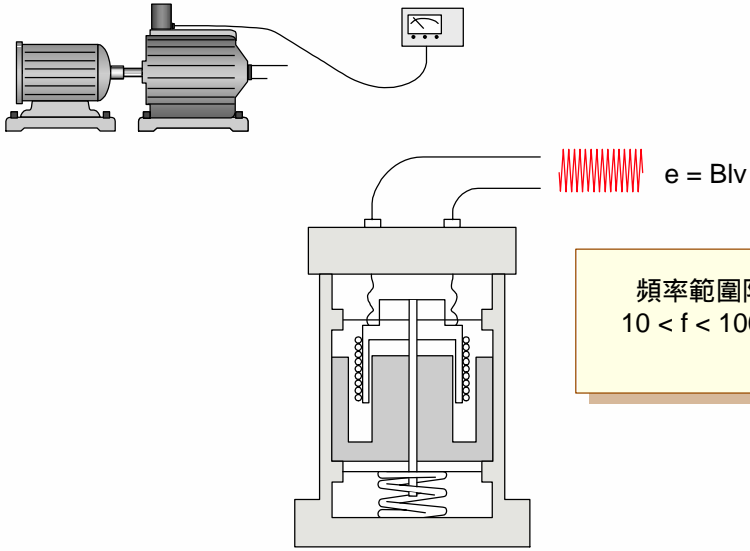
應用：

- 相對移動
- 軸偏心
- 油膜厚度
- 等等.

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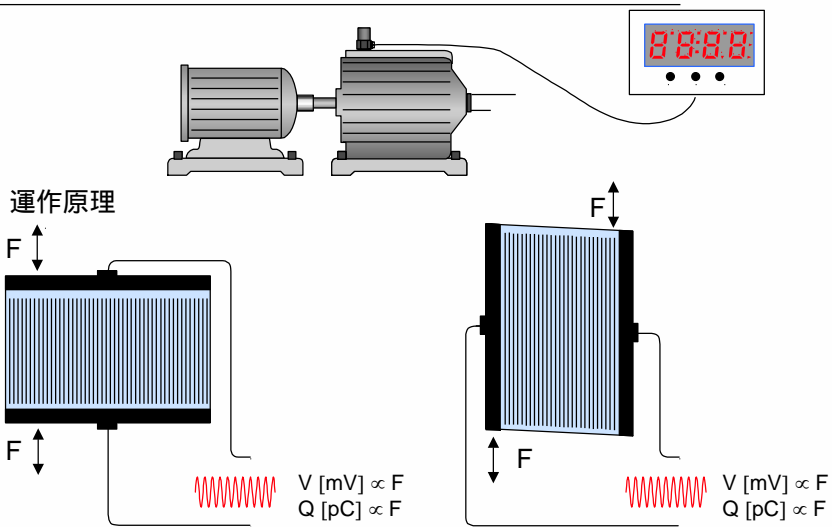
# 速度探頭



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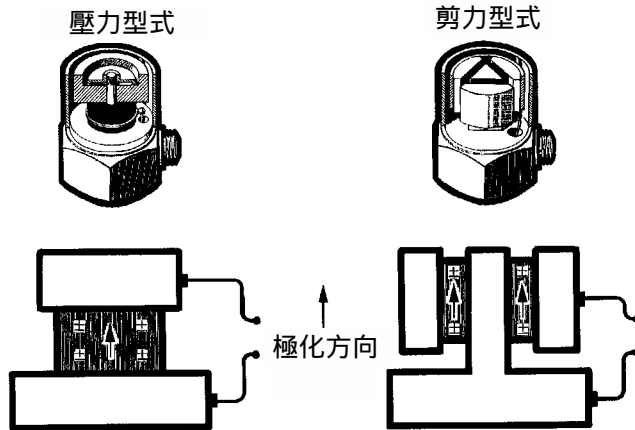
# 壓電加速規



BA 7674-12, 3800290/2

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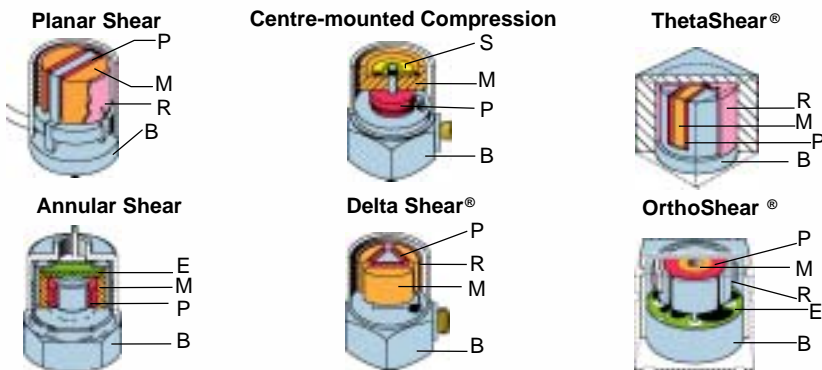
# 加速規之基本型式



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# 壓電加速規型式



P: Piezoelectric Elements    E: Built-in Electronics    S: Spring  
 R: Clamping Ring            B: Base                            M: Seismic Mass


BA 7674-12, 40 800284

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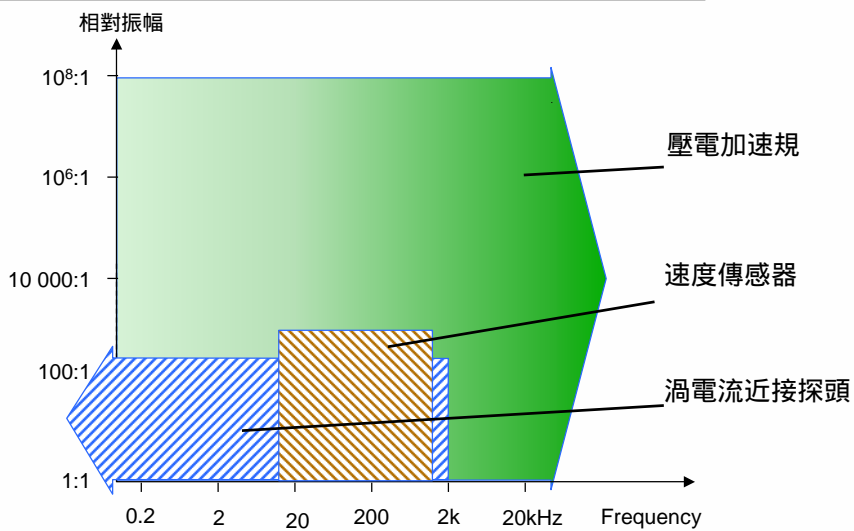
## 加速規之輸出訊號型式

- 電荷型
- 電壓型
- 電流型

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## 各型振動探頭之量測範圍

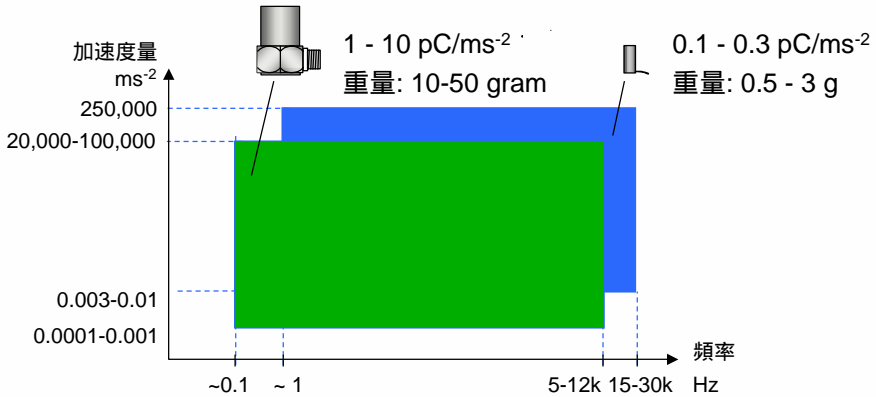


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## 加速規之選用

- 一般用途, 中等重量及感度
- 或
- 小、輕而高頻



BA 7674-12, 43 800299

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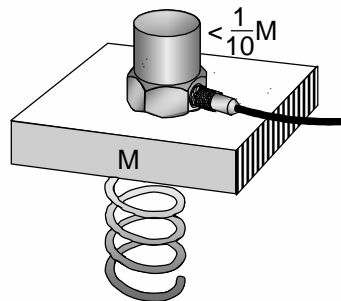
## 加速規之選用-質量效應

0,1  $pC/ms^{-2}$   
0.65 g  $\Rightarrow M > 7$  g

10  $pC/ms^{-2}$   
54 g  $\Rightarrow M > 600$  g

1000  $pC/ms^{-2}$   
470 g  $\Rightarrow M > 5$  kg

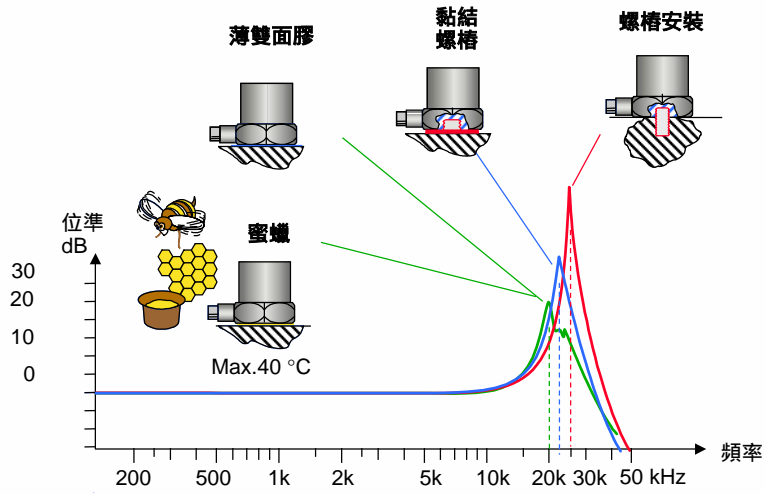
動態質量



BA 7674-12, 44 800304

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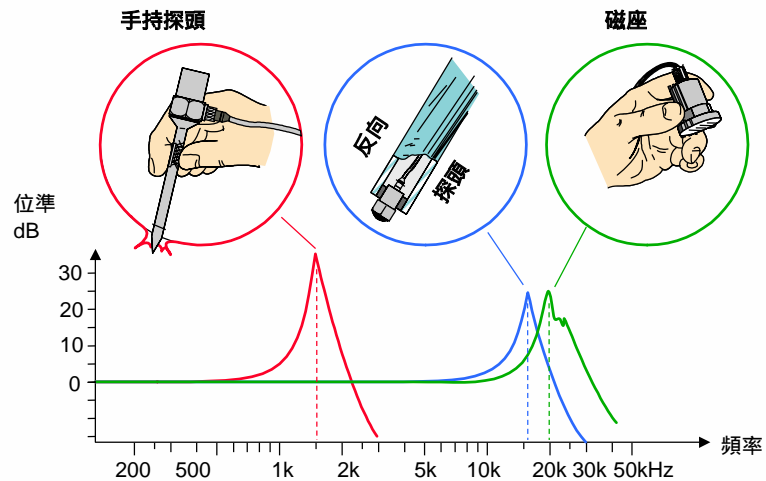
## 加速規之安裝(一)



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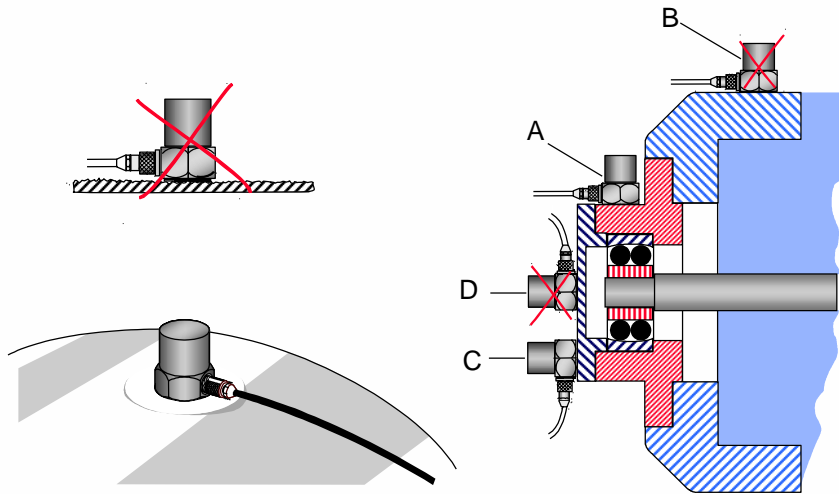
## 加速規之安裝(二)



BA 7674-12, 46 930617

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## 位置之選擇



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## 分析方法

- 總量分析(Overall Analysis)
- 頻率分析(Frequency Analysis)
  - FFT Analysis
  - 1/N Octave Analysis
- 階次分析(Order Analysis)

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## 總量分析

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- 峰值(Peak)
- 均方根值(RMS)
  - 線性平均
  - 指數平均

## 頻率分析

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- 等頻寬(Constant Bandwidth)分析
- 等比頻寬(Constant Percentage Bandwidth)分析

## 階次分析

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- 用於分析轉速相關倍數之振幅成分

## 顯示方式

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- 振幅座標軸
  - 線性(Linear)
  - 對數(Logarithmic)
  - 分貝(decibel, dB)
- 頻率座標軸
  - 線性(Linear)
  - 對數(Logarithmic)
  - CPB

## 結論

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- 振動的定義
- 振動的參數
- 振動的原理
- 振動訊號型式
- 參數之關係
- 量測單位
- 訊號量測鏈
- 振動量測探頭
- 分析方法
- 顯示方式