eyc-tech
風速感測原理
Air Velocity Sensing Principle

簡述 Brief

熱線式風速傳感器根據傳感元件之間的熱傳遞，例如熱絲線或金屬片和周圍的流體。移動的流體造成熱損失，改變電阻。藉由冷卻的效果可平衡流體的速度。在電路上保持傳感器溫度恆定。因此，流體造成電壓降可從傳感器所消耗的功率直接測量。圖為一恆溫風速計(Constant Temperature Anemometer,CTA)的基本設計。

Hot-wire anemometers rely on heat transfer between sensing elements, such as a hot wire or sheet of metal, and the surrounding fluid. The moving fluid causes heat loss, changing the resistance. Cooling helps balance the fluid velocity. The sensor temperature is kept constant in the circuit. Therefore, the voltage drop caused by the fluid can be directly measured from the power consumed by the sensor. The figure shows a basic design of a constant temperature anemometer (CTA).

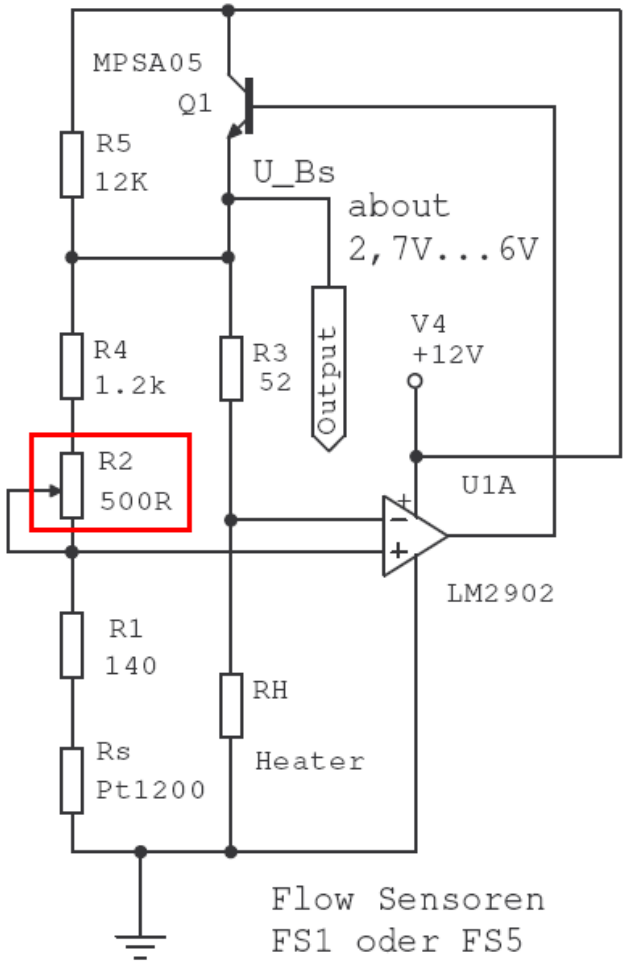


圖1.恆溫風速計的基本設計

Figure 1. Basic design of a constant temperature anemometer

熱線元件 Hot wire element

恆溫風速計一般分為熱線、熱膜、熱膜集成和鉑膜電阻元件

Thermostatic anemometers are generally classified into hot wire, hot film, integrated hot film, and platinum film resistance elements.

熱線元件選用的金屬絲材料，通常為鎢絲或鉑鎢絲。熱線元件的機械強度不高，能承受的電流較小，因此不適合在帶有顆粒的氣體中工作如圖2.。

The metal wire material used for hot wire elements is usually tungsten wire or platinum-tungsten wire. Hot wire elements have low mechanical strength and can withstand relatively small currents, therefore they are not suitable for operation in gases containing particles, as shown in Figure 2.

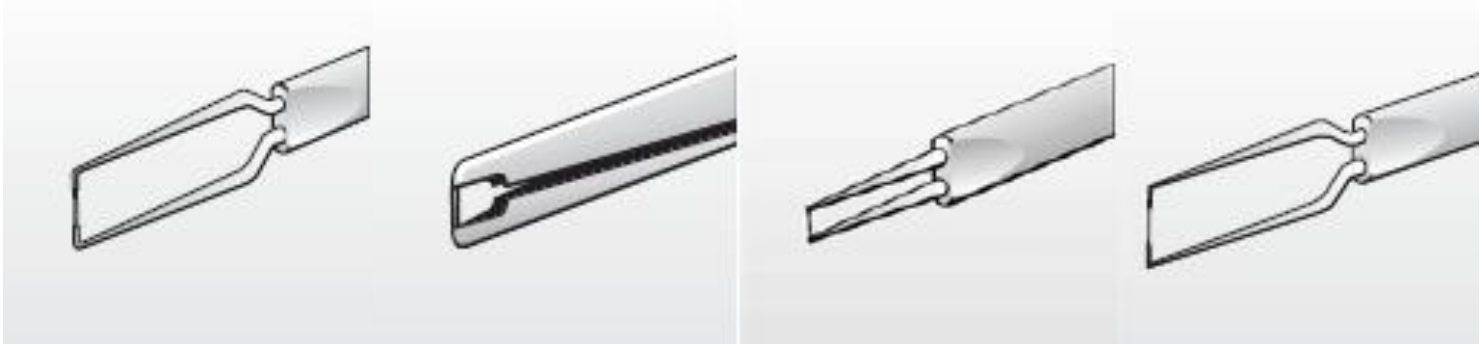


圖2.熱線元件

Figure 2. Hot wire element

熱膜集成元件
Thermal film integrated element

基於MEMS技術，利用濺射方法在半導體晶片或陶瓷底片上行成多個鉑膜電阻，分別作為為加熱器和溫度傳感器。其工作原理是以流體的熱傳遞為基礎，通過計算加熱電組的熱量損失來確定流量，圖3.為ST10集成元件的內部結構。

Based on MEMS technology, multiple platinum film resistors are fabricated on semiconductor wafers or ceramic substrates using sputtering methods, serving as heaters and temperature sensors, respectively. Its working principle is based on the heat transfer of the fluid; the flow rate is determined by calculating the heat loss of the heating element. Figure 3 shows the internal structure of the ST10 integrated element.

集成熱膜元件具有靈敏度高、尺寸小、動態響應快等優點，且穩定性高、精度高、壓損小與一致性高。

Integrated hot film elements have advantages such as high sensitivity, small size, fast dynamic response, high stability, high precision, low pressure loss and high consistency.

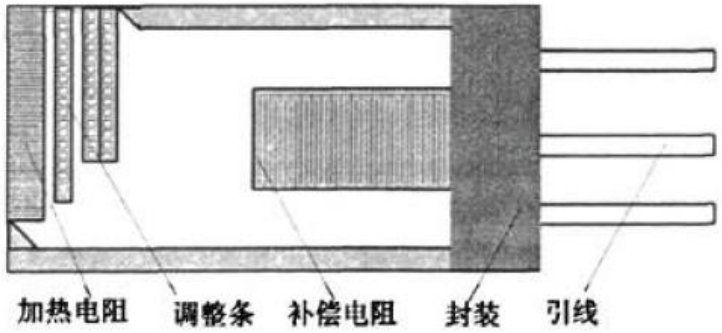


圖3.集成熱膜元件ST10內部結構[10]

Figure 3. Internal structure of the integrated thermal film element ST10 [10]

氣體流量測量的電路包括氣體流量傳感器電路、差動放大電路、同相放大電路、電流輸出電路及MSP430單機片，圖4.。

The gas flow measurement circuit includes a gas flow sensor circuit, a differential amplifier circuit, a non-inverting amplifier circuit, a current output circuit, and an MSP430 microcontroller, as shown in Figure 4.

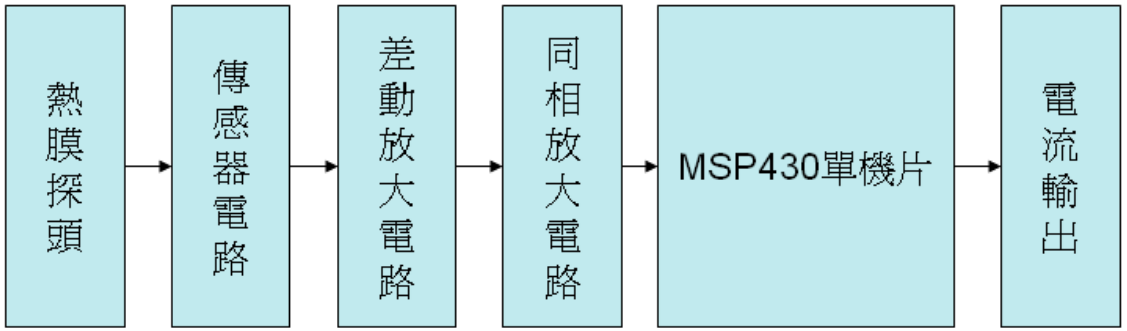


圖4.氣體流量測量電路

Figure 4. Gas flow measurement circuit

現代CTA風速計通常包括三個要素

Modern CTA anemometers typically include three elements.

1. 類比/數位轉換器和數據採集軟件，採樣CTA的風速信號，並執行數位信號處理。
2. CTA應提供用戶配置選項的範圍。
3. 校準設施，涵蓋量測速度範圍。液體校準系統通常從數cm/s到10m/s的速度範圍。氣體較準系統通常從幾cm/s到1馬赫的速度範圍。

1. Analog-to-digital converters and data acquisition software sample the wind speed signal from the CTA and perform digital signal processing.
2. The CTA should offer a range of user-configurable options.
3. Calibration facilities covering the measurement speed range.
   Liquid calibration systems typically cover speeds from a few cm/s to 10 m/s.
   Gas calibration systems typically cover speeds from a few cm/s to Mach 1.

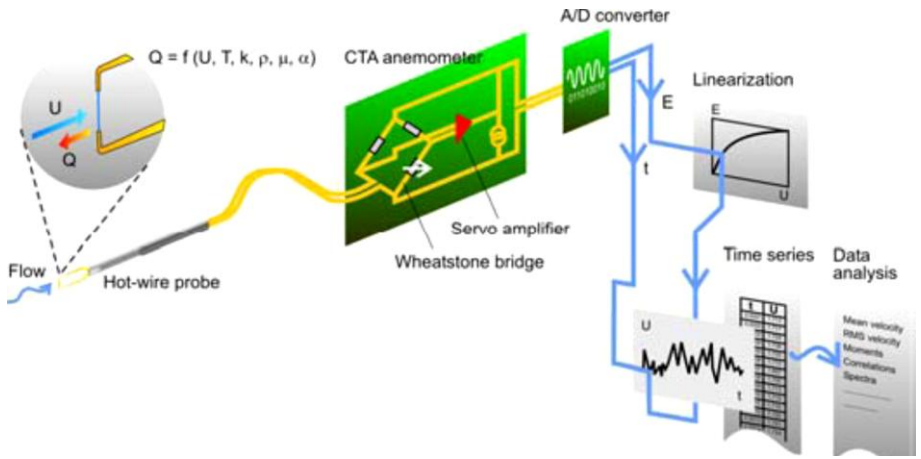


圖5.典型恆溫風速計(CTA)
Figure 5. Typical Cryogenic Anemometer (CTA)

熱膜探頭接入傳感器電路，將氣體流量信號轉為電壓信號，經差動放大電路和同相放大電路後，送入MSP430單機片的12位AD通道。單機片根據採集的信號計算出氣體的流速，同時根據用戶的需求輸出4-20mA電流。

CTA的電壓輸出E和流體速度U，顯示傳遞函數有一個幕次定律相關的非線性關係，它最常使用四階多項是關係建模。此外，任何流量變量，如流體的密度和溫度都會影響熱傳。因此，CTA傳感器需要進行使用前的速度響應校準。環境溫度逐漸增加可通過分析溫度測量電壓更正。

The hot-film probe is connected to the sensor circuit, converting the gas flow signal into a voltage signal. After passing through differential and non-inverting amplifier circuits, the signal is sent to the 12-bit AD channel of the MSP430 microcontroller. The microcontroller calculates the gas velocity based on the acquired signal and simultaneously outputs a 4-20mA current according to user requirements. The CTA's voltage output E and fluid velocity U display a nonlinear relationship related to a fourth-order polynomial law, most modeled using this relationship. Furthermore, any flow variable, such as fluid density and temperature, will affect heat transfer. Therefore, the CTA sensor requires velocity response calibration before use. Gradual increases in ambient temperature can be corrected by analyzing the temperature measurement voltage.

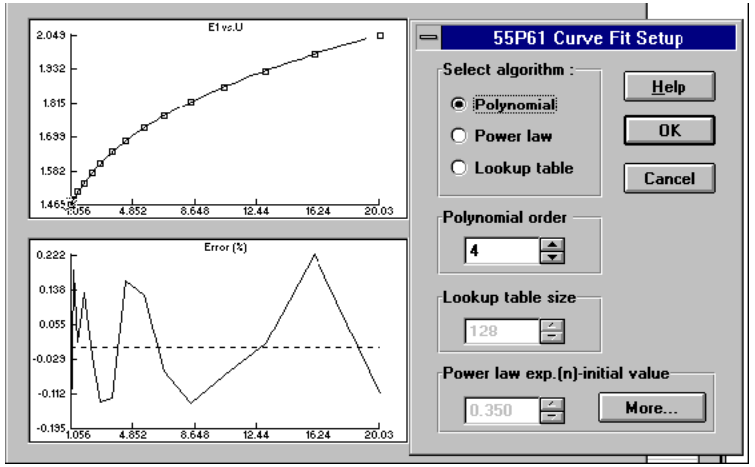
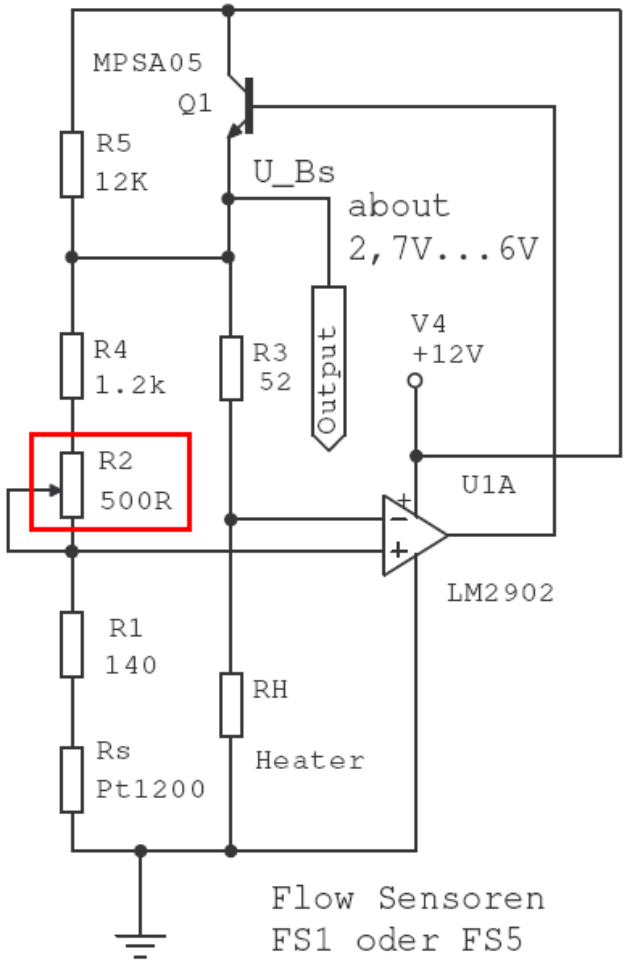


圖6.典型的單探頭的探頭校準曲線擬合
Figure 6. Typical probe calibration curve fitting for a single probe.

溫度補償 Temperature compensation

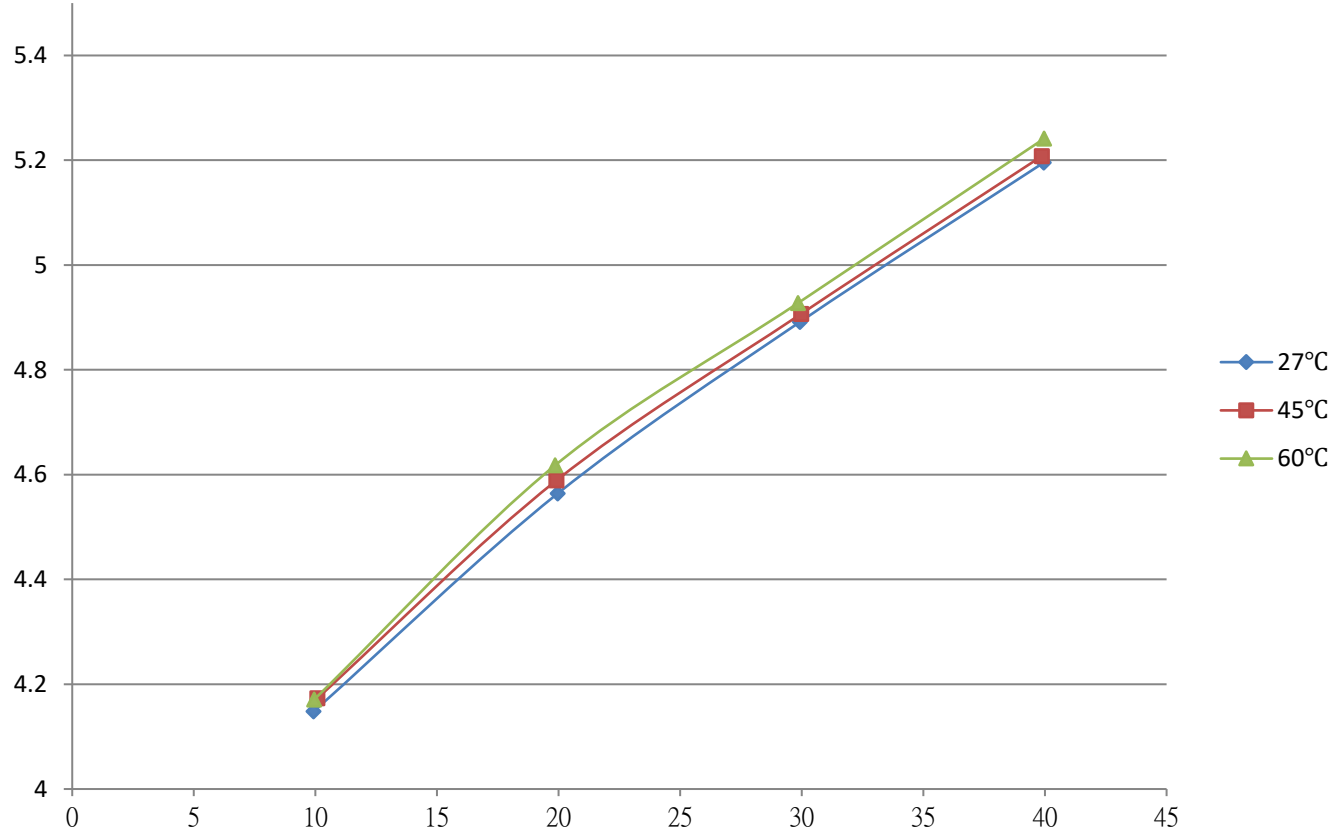
為實現溫度補償，RS與Rh電阻上的電壓要保持定值，所以Rf與Rh的**電阻值**要保持比例，Vout才不會被影響；但是Rh 上的阻值會因為溫度的差異而造成阻值上比例的不相等。

To achieve temperature compensation, the voltage across resistors RS and Rh must remain constant, so the resistance values of Rf and Rh must be kept in proportion so that Vout is not affected; however, the resistance value of Rh will be unequal due to temperature differences.



閉迴路熱傳風洞之量測

Measurement of closed-loop heat transfer wind tunnel



不同溫度風速及溫度下之曲線

Curves at different temperatures, wind speeds, and temperatures

閉迴路熱傳風洞之量測

Measurement of closed-loop heat transfer wind tunnel

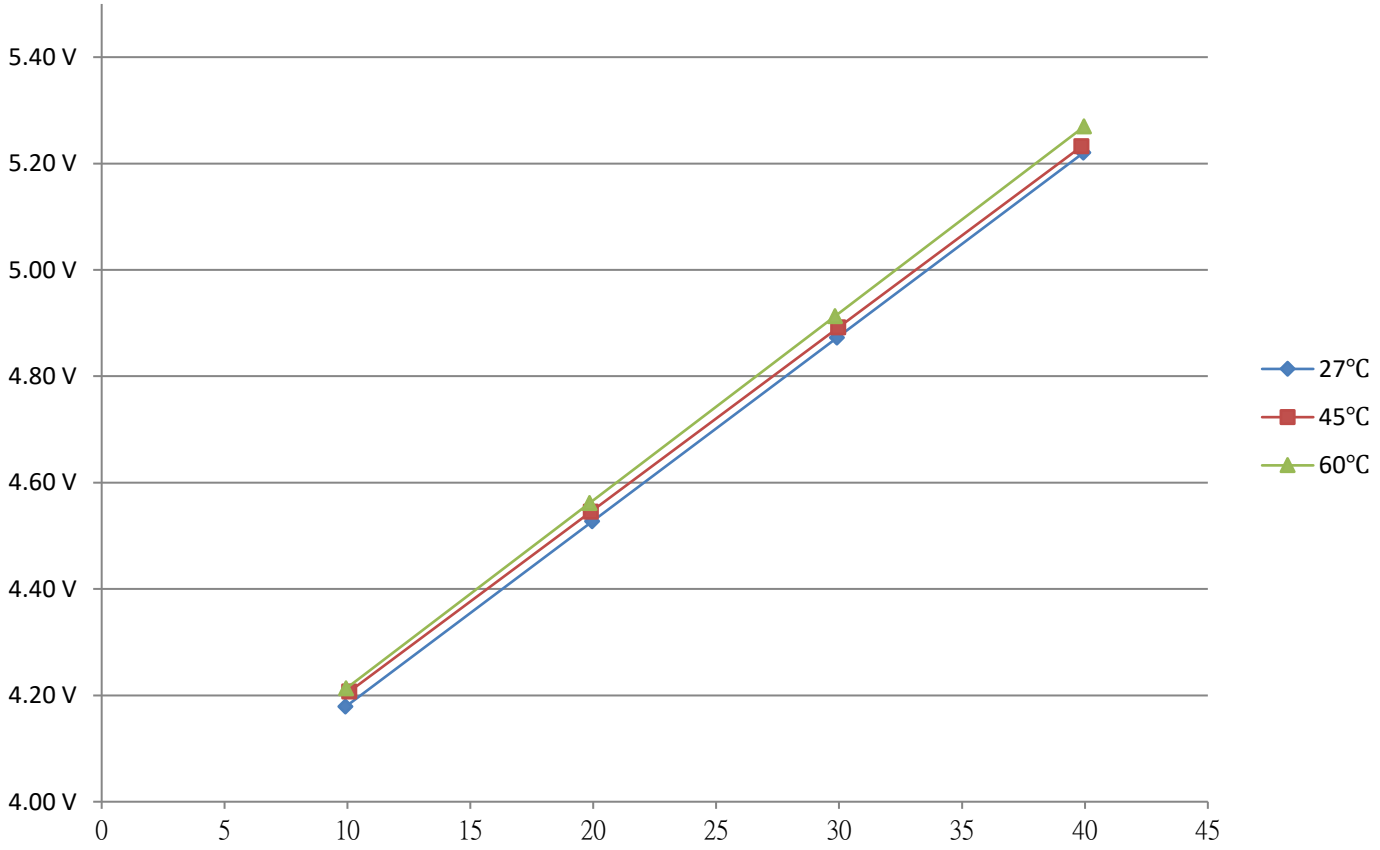


圖-線性回歸校正後之直線

Figure - Linear line after linear regression correction