Constant voltage and constant temperature operating mode (CV, CT)

The Vac sensors can be used in two operation modes.

Constant voltage mode CV: The simplest way is to use the Vac sensor's resistors (Rp and Rk) as one leg of a symmetrical Wheatstone bridge circuit. The bridge circuit is calibrated to zero at atmospheric pressure or alternatively at absolute vacuum. The resistance of Rp is changing with pressure p and therefore the signal voltage as well (voltage potential between the legs' midpoints). This mode is best suited for lower pressures and for low power operations.

Constant temperature mode CT: The constant temperature or constant resistor mode is commonly used. It is best suited for fine and rough vacuum regimes (see Fig. 1). Most circuits used are based on an operation amplifier (opamp), which balances some kind of measurement bridge (classical Wheatstone, or transistor based circuits). The opamp's inputs are connected to the legs' midpoints. When the potential across the leaves is unequal to zero, the opamp increases its output power, which is feeding the bridge circuit. This output varies with pressure due to the pressure sensitive measurement resistor's behavior and can be used as signal voltage U(p).

➔ Some circuit proposals can be found in the datasheet.

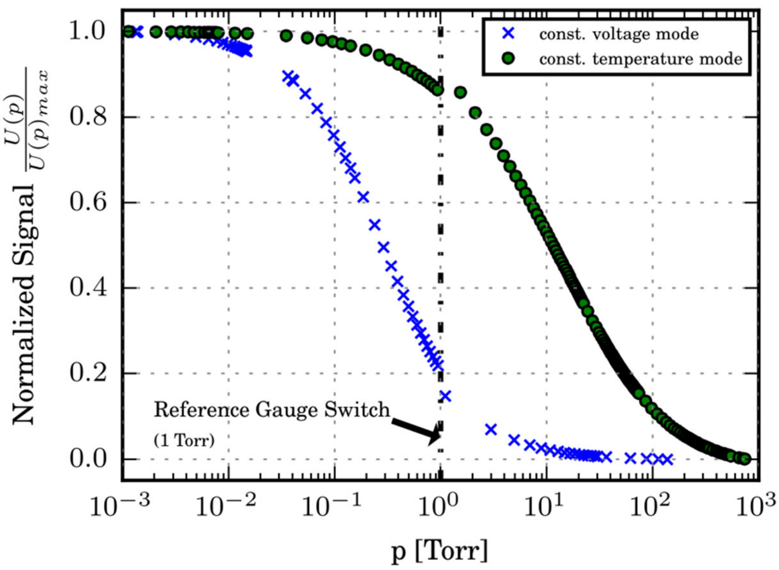

Fig. 1: Normalized signal voltage as function of pressure p for constant voltage and constant temperature mode. [2]

Sensitivity

Figure 2 shows the normalized signal voltage change per decade. The signal voltage was normalized to one by dividing the actual signal voltage by the maximum signal voltage in high vacuum conditions (HV) for constant voltage mode (CV) and at atmospheric pressure

(ATM) for constant temperature mode (CT).

Normalized signal:
for constant voltage mode (CV operation mode): U(p)/U(p=HV)
for constant temperature/resistance mode (CT operation mode): U(p)/U(p=ATM)

Next the first derivative of this normalized signal is formed to show its slope over the pressure range. Hence, the maximum of this slope indicates the pressure at which the signal is changing the most with pressure p. This way a comparison is possible which does not depend on the electrical circuit used.

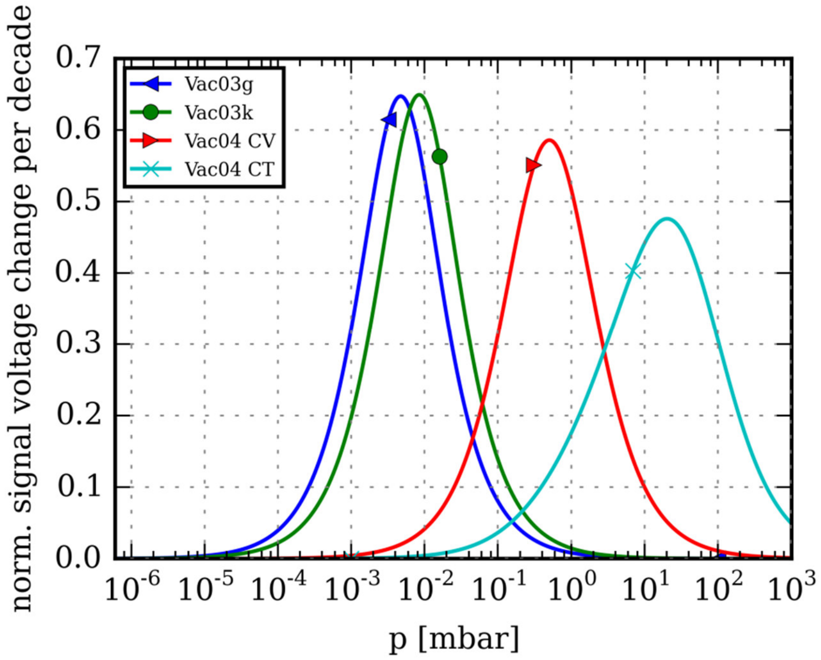

Fig. 2: Normalized signal voltage change per decade as function of pressure p for Vac03g, Vac03k and Vac04. Vac04 is shown for constant voltage and constant temperature mode. Vac03g,k are shown in constant voltage mode only. [3]

Temperature increase of measurement resistor Rp

The measurement principle is based on the temperature coefficient of resistance (TCR) of the measurement resistor. In constant voltage mode the temperature of the measurement resistor changes with pressure p. In constant temperature mode the power needed to keep the bridge balanced changes with pressure p. Both effects are related to the TCR β.

The TCR β is defined by: $Rp(T)=Rp(T_0)(1+\beta\Delta T)$, with $\beta=\beta_1+\beta_2\Delta T$

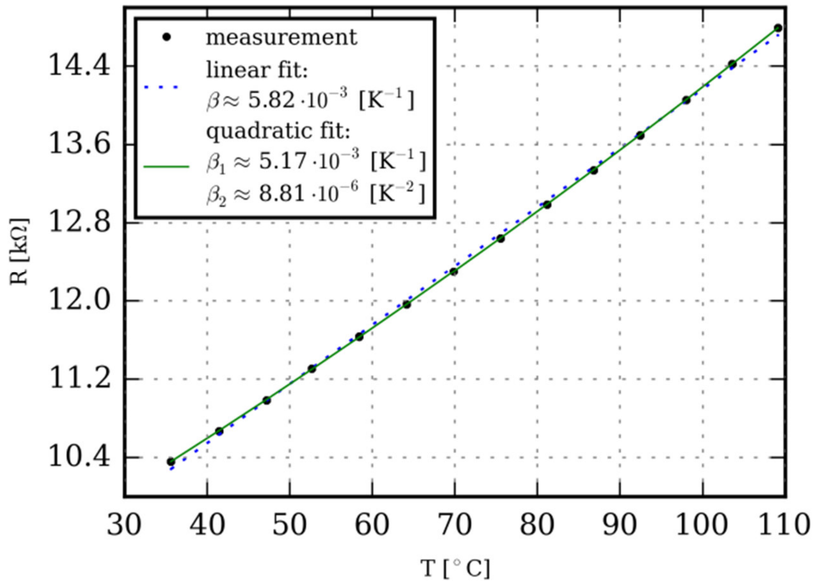

Fig. 3: TCR of Vac03g,k and Vac04, *for low temperature differences a linear TCR is sufficient!*

Signal drift caused by changing ambient temperature T_0

The signal voltage changes with pressure, which is the principle of these thermal conductivity vacuum gauges. Additionally, the signal voltage is influenced by changing ambient temperature T_0. This has various reasons, which can only be partially compensated. Moreover this dependency varies with pressure p. This is true for every thermal vacuum gauge and is commonly compensated by calibration. The following table shows the relative change in signal for the different sensors. The Vac04 is shown in CV and CT mode, while the Vac03g is only shown in CV mode. *The constant temperature mode reduces this unwanted signal drift* as the measurement resistor's temperature is kept constant and most of the times way below maximum temperature of constant voltage operation. Hence, the CT mode is recommended for most usage scenarios. For high vacuum measurement and low power operation the CV mode is better suited. In such scenarios temperature stabilization or an advanced calibration are strongly advised.

Tab. 1: Exemplary data on signal drift caused by changing ambient temperature. The maximum signal capacity is used for normalization.

Vac03g, CV	% of signal capacity per K
p = 1.6E-6 Torr	0.70
p= 7.5E-4 Torr	0.58
Vac04, CV	
p = 2 Torr	0.17
p = 8 Torr	0.09
p = 80 - 750 Torr	0.02 – 0.03
Vac04, CT	
p = 5 Torr	0.05
p = 760 Torr	0.01

Additional information can be found in the following publications:

1. F. Völklein, M. Grau, A. Meier, G. Hemer, L. Breuer, P. Woias; ”Optimized MEMS Pirani sensor with increased pressure measurement sensitivity in the fine and high vacuum regime”, Journal of Vacuum Science & Technology A, vol. 31, no. 6, 2013.
2. M. Grau, F. Völklein, A. Meier, C. Kunz, I. Kaufmann, P. Woias; ”Optimized MEMS Pirani sensor with increased pressure measurement sensitivity in the fine and rough vacuum regimes”, Journal of Vacuum Science & Technology A, vol. 33, no. 2, 2015.
3. M. Grau, F. Völklein, A. Meier, C. Kunz, J. Heidler, P. Woias; ”Method for measuring thermal accommodation coefficients of gases on thin film surfaces using a MEMS sensor structure”, Journal of Vacuum Science & Technology A, vol. 34, no. 4, 2016.