DGS2 – Temperature Compensation Addendum

DGS2 TEMPERATURE COMPENSATION & CALCULATION OF GAS CONCENTRATION

The electrochemical sensor utilized in the DGS2 has an output current that is linearly proportional to the gas concentration measured at the gas sensor inlet (at standard temperature and pressure) that is represented by the sensor sensitivity factor (S_f [nA/ppm]). A transimpedance amplifier (TIA) converts and amplifies the sensor current to a voltage via *Rgain* [V/A]. The voltage output of the transimpedance amplifier is measured with an ADC.

The system voltage at the output of the TIA amplifier is calculated from the ADC value with the transfer function:

$$V[V] = 1.82[V] \cdot \frac{ADC - 2^{15}}{2^{15}} \left[\frac{cnts}{cnts}\right] \qquad \text{Eq. 1}$$

An ideal sensor would generate zero current when there is zero gas present, but practical sensors have a small non-zero baseline current. Additionally, the DGS2 electronics have a small non-zero offset voltage. These are accounted for with *Vzero* and *Voc*, respectively:

$$Vzero[V] = 1.82[V] \cdot \frac{ADCzero - 2^{15}}{2^{15}} \left[\frac{cnts}{cnts}\right] \qquad \text{Eq. 2}$$

$$Voc[V] = 1.82[V] \cdot \frac{ADCoc - 2^{15}}{2^{15}} \left[\frac{cnts}{cnts}\right] \qquad \text{Eq. 3}$$

Voc is a circuit constant that is calculated and saved in the module EEPROM at the factory. It may be recalculated by removing the sensor from the module and sending command ‘O’. However, most users do not need to change the factory setting.

Vzero is a system constant that is initially calculated and saved in the module EEPROM at the factory but it is imperative that the user re-zeros the system with command ‘Z’. The value of the temperature sensor is also saved as *Tzero*.

The gas concentration is calculated:

$$C[ppb] = \frac{1000\left[\frac{ppb}{ppm}\right] \cdot 1 \cdot 10^9 \left[\frac{nA}{A}\right]}{Sf\left[\frac{nA}{ppm}\right]} \cdot \left(\frac{V[V] - Voc[V]}{Rgain\left[\frac{V}{A}\right]} - \frac{Vzero[V] - Voc[V]}{Rgain\left[\frac{V}{A}\right]} \cdot e^{\frac{T[°C] - Tzero[°C]}{N[°C]}}\right). \qquad \text{Eq. 4}$$

By default, *Rgain* is $85 \cdot 10^3 \left[\frac{V}{A}\right]$ for the EtOH sensor (110-202) and for all other sensors, *Rgain* is $512 \cdot 10^3 \left[\frac{V}{A}\right]$. *N* is the *zero* temperature compensation factor, or the temperature compensation factor of the system in a clean-air environment with zero analyte gas present. The value of *N* is factory set to a large number (2^{16}), effectively turning off temperature compensation by making its effect on the calculation negligible. When *Voc = Vzero* and/or if $N \gg T[°C] - Tzero[°C]$, then Eq. 4 simplifies to:

$$C[ppb] = \frac{1000\left[\frac{ppb}{ppm}\right] \cdot 1 \cdot 10^9 \left[\frac{nA}{A}\right]}{Sf\left[\frac{nA}{ppm}\right]} \cdot \frac{V[V] - Vzero[V]}{Rgain\left[\frac{V}{A}\right]} \qquad \text{Eq. 5}$$

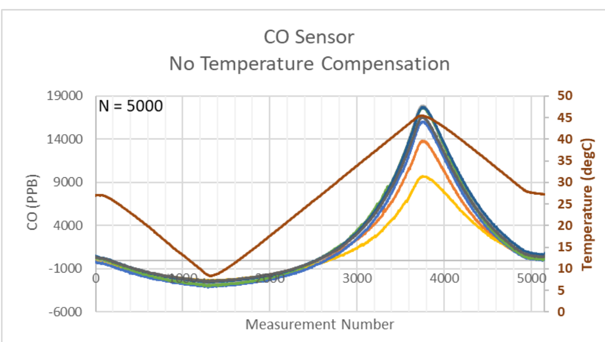
To implement temperature correction, the user may adjust the value of *N* with command ‘N’. The following table lists average value of *N* for each sensor type.

DGS2 970-SERIES TEMPERATURE COMPENSATION FACTORS

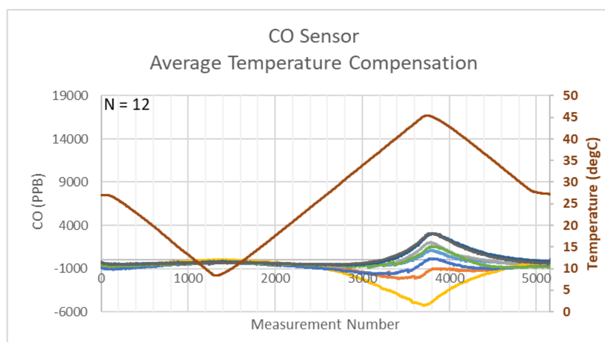
DGS2 PN	Gas Type	Gas Sensor PN	Average *N* Value
970-100	CO	110-102	12
970-110	CO	110-114	13
970-200	EtOH	110-202	7
970-300	H2S	110-303	40
970-400	O3	110-406	38
970-500	NO2	110-507	38
970-600	SO2	110-610	20
970-800	IAQ	110-801	16
970-900	RESP	110-901	18
970-001	H2	110-005	20

The average *N* values listed in the table are derived from empirical testing of many sensors and represent a first-order temperature correction factor. In practice, this average compensation may over- or under-compensate the PPB calculation for your application. The ability of this average *N* value to compensate all sensors for temperature depends greatly on the lower detection limit, resolution, accuracy, and temperature range ***of the application***, among other factors.

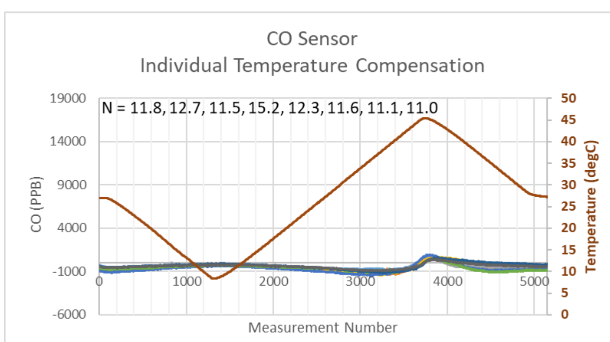
The plots below represent the same data for a subset of 8 CO sensors, plotted with different values of *N* applied. For these tests, the CO concentration was 0 ppm and the temperature was ramped from 25 to 5 to 45 to 25 °C, as represented by the brown line and the right axis. For plot (a), *N* = 5000, which effectively turns off the temperature compensation, resulting in the normal temperature response of the sensor. For plot (b), *N* = 12, which improves the overall temperature response across the subset of sensors, reducing the overall temperature effect at 45 °C from a spread of 9 - 18 ppm to -5 - 4 ppm. Applying the average *N* value under-corrects the temperature effect for some sensors and over-corrects for other sensors. The temperature compensation of individual sensors may be further improved by tuning the value of *N* for each sensor, as exhibited in plot (c), which shows that the measurement error spread across the 5 - 45 °C temperature range is reduced to ± 1.5 ppm.



(a)



(b)



(c)