

SEMI MS14-0422

GUIDE FOR CRITICAL PARAMETERS OF GAS SENSORS

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1 Purpose

1.1 As with many emerging technologies, gas sensor makers today do not conform to specific or well understood standards, whether it is with regards to parameter definitions, testing methods, reliability requirements, packaging, pin configurations, communication interfaces, etc., to name a few.

1.2 Given the state of technology evolution and the markets in this space, the timing is right for a set of defined standards regarding gas sensors. We envisage that not only will this encourage the important players to focus on innovation, but also contribute to quicker adoption in application areas where customization from the ground-up can often be a barrier to commercial success.

1.3 One example of such a barrier is that it is difficult for customers today to compare different gas sensors, or to use multiple devices within a single platform to sense different environmental gases.

2 Scope

2.1 This Guide describes a core of set of parameters that characterize a gas sensor and allow a data-driven comparison of gas sensor products for purposes of assessing suitability in end systems.

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3 Limitations

3.1 Designs of sensors for gaseous species (gases and vapors) are of two broad categories. Sensors of the first category directly measure intrinsic properties of a gas. Illustrative examples of such sensors utilize different detection principles such as molecular electronic absorption (using ultraviolet), vibrational overtone absorption (using near infrared), vibrational absorption (using infrared), thermal conductivity, paramagnetism, and photoionization. However, direct measurements of intrinsic properties of gases do not always provide sensing solutions with the needed range of measured gas concentrations and attractive size, weight, power, and cost (SWaP-C) characteristics. Thus, sensors of the second category perform gas measurements indirectly by utilizing a gas-responsive sensing material coupled with an appropriate principle and physical implementation. Illustrative examples of such sensors are based on electrical, thermal, electromechanical, and optical detection principles. At present, sensors that perform gas measurements indirectly by utilizing a gas-responsive sensing material are the most popular in different markets because of their ability to detect broader range of gases over the broader range of their concentrations with the attractive SWaP-C characteristics as compared to sensors that directly measure intrinsic properties of gases.

3.2 This Guide is intended to clarify the parameters associated with sensor elements that are intended to be used as a component in a system. The requirements for stand-alone gas detection instruments are described in ¶ 3.1.

4 Referenced Standards and Documents

4.1 *ASTM Standards*¹

ASTM E2885-13 — Standard Specification for Handheld Point Chemical Vapor Detectors (HPCVD) for Homeland Security Applications

NOTE 1: ASTM is developing a New Practice for Performance Evaluation of Ambient Air Quality Sensors and Other Sensor-Based Instruments for reference to this Standard.

4.2 *United States Military Standards*²

MIL-STD-810H — Department of Defense Test Method Standard: Environmental Engineering Considerations and Laboratory Tests

4.3 *UL Standards*³

UL 2075 — Standard for Gas and Vapor Detectors and Sensors

UL 2905 — Environmental Claim Validation Procedure for Indoor Air Quality (IAQ) Sensor Performance

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Units

5.1 Parts per billion (ppb) is measured by volume.

5.2 Parts per million (ppm) is measured by volume.

6 Terminology

6.1 *Abbreviations and Acronyms*

6.1.1 *ppb* — parts per billion

6.1.2 *ppm* — parts per million

6.2 *Definitions*

6.2.1 *accuracy* — closeness of agreement between a test result or the mean of a group of test results made on an object and its true value. [SEMI E89]

6.2.2 *cross-sensitivity* — the response of a sensor to a gas other than the primary gas(es) specified on the data sheet.

6.2.3 *drift* — the change in output over a specified time period for a constant input under specified reference operating conditions. [SEMI E56]

6.2.4 *drift, per unit humidity change* — the change in output over a specified humidity range for a constant input while other operating conditions are specified and held constant, expressed in ppm/%RH or ppb/%RH.

6.2.5 *drift, per unit pressure change* — the change in output over a specified pressure range for a constant input while other operating conditions are specified and held constant, reported in ppm/hPa or ppb/hPa.

6.2.6 *drift, per unit temperature change* — the change in output over a specified temperature range for a constant input while other operating conditions are specified and held constant, expressed in ppm/°C or ppb/°C.

6.2.7 *range or dynamic range* — the limits of gas concentrations that the sensor is specified to detect.

6.2.8 *recovery time* — the time between when an instantaneous change between the standard test gas and clean air happens and the time when the response reaches a stated percentage (x) of the stabilized signal on the standard test gas.

¹ ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA; Telephone: +1.610.832.9585, Fax: +1.610.832.9555, <http://www.astm.org>

² United States Military Standards, Available through the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099, USA; Telephone: +1.215.697.3321.

³ Underwriters Laboratory, 2600 N.W. Lake Road, Camas, WA 98607-8542, USA; Telephone: +1.877.854.3577, Fax: +1.360.817.6278, <http://www.ul.com>

6.2.9 *repeatability* — the closeness of agreement among a number of measured values at a setpoint, under the same operating conditions, operator, apparatus, laboratory and short intervals of time. It is usually measured as a non-repeatability and expressed as a repeatability in percent of reading. [SEMI E56]

6.2.10 *response time* — the time between when an instantaneous change between clean air and the standard test gas is produced and the time when the response reaches a stated percentage (x) of the stabilized signal on the standard test gas.

6.2.11 *warm-up time* — the time between power on in a specified environment and the time when the performance tolerances are reached.

7 Illustrative Parameter Definitions

7.1 This section provides the various core performance parameter illustrations associated with a gas sensor.

7.2 The parameters defined should be measured at specified values of several other confounding or aggressor variables. Here is a partial, generic list of such variables recommended for reporting gas sensor parameter values.

7.2.1 The parameters should be measured:

- At a specified concentration of the candidate gas;
- At specified constant values of other confounding environmental variables, viz., temperature, pressure, and humidity;
- At specified concentrations of other gases deemed to be interferants for the candidate gas to be detected;
- After the sensor's 'Response Time' (defined later) has passed; and
- When the sensor is 'ready' for operation (i.e., after any required warm-up or conditioning is complete).

7.3 In addition, when reporting the change in the value of a parameter over another variable (e.g., over a range of temperature), the following additional conditions are recommended to be specified:

- Over the full operating range of that variable (e.g., min to max temperature),
- After the variable has reached a steady state value, or has settled down (i.e., it is within 1% or less of the target value).

7.4 Illustration of Accuracy Parameter

7.4.1 To present the accuracy of a sensor, the sensor characteristics can be plotted as measured concentration by the sensor versus actual concentration measured by a reference instrument as shown in the Figure 1. Conventionally, Figure 1 is often known as a correlation plot. The correlation between the measured concentrations by the sensor versus actual concentrations measured by a reference instrument is often described by a correlation coefficient.

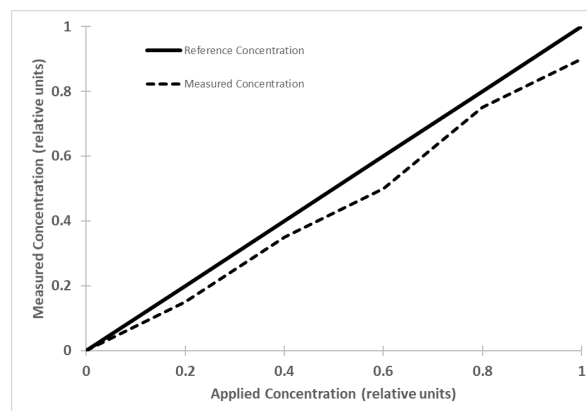


Figure 1
Example Accuracy Measurement of a Sensor