Application Note NDIR-Measurement

Introduction

Heimann Sensor components are exceptionally well suited to measure the concentration of several gases by the non-dispersive infrared (NDIR) method. Steady improvements on existing products as well as constantly developing innovations, puts us in the position of being able to provide the best support to all our customers.

This note gives an overview on the physics, available components, and the principles of measurement.

Physics

The NDIR gas detection method is based on the absorption of infrared radiation, which is shown by many polyatomic or heterodimer diatomic gases. For example CO_2 gas absorbs IR radiation at 4.26µm wavelength. The detected radiation intensity at this wavelength decreases if the concentration of CO_2 increases between source and detector. The extent of absorption mainly depends on the absolute number of CO_2-molecules between radiation source and detector. Accordingly, the given concentration for a measured intensity is a function of the cell length and the gas density.

The law of Lambert and Beer describes the transmitted intensity I in relation to the initial intensity I_0, where k is a specific absorption coefficient, c is the concentration and s is the absorption path length:

$$I = I_0 \cdot e^{-k \cdot c \cdot s} \qquad (1)$$

Note: In equation (1) the concentration c refers to the density, not to the total number of molecules. As the gas density is a function of the given pressure, the concentration in ppm is also pressure dependent.

Basic Set-Up

The basic set-up consists of an IR-source, the gas cell, an IR filter matching the absorption line of interest and the IR-Sensor (see Figure 1).

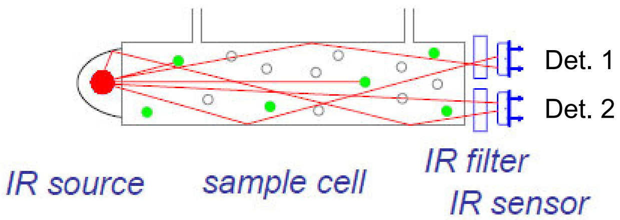

fig. 1 Example set-up with dual channel sensor

Optics for focusing the radiation can be integrated as well as measures to increase the reflectivity of inner walls.
The gas cell must ensure access to free flowing gas, but it is not necessary to have a single pass cell.
A design increasing the path length by folding the rays, forming a multi-pass cell, is also possible.

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Sensor Components

The main part of the set-up is the sensor with integrated optical filter(s). A single sensor could be used as well as a dual-channel sensor to manage source variations and minimize aging effects.

Also available are 4-channel-sensors for multi-gas-detection (see figure 2). The different channels vary in the use of diverse filters, according to the specific absorbing wavelength of the gases to be detected. One channel without sensitivity to any of the gases can be used as reference.

fig. 2 Dual and 4-channel sensor HTS E21 and HTS Q21

Thermopile infrared sensors create a voltage signal (U) proportional to the received radiation. The signal is generated by a difference of temperature of the object (T_{Object}) and the sensors own temperature (T_{amb}). Equation (3) describes the basic function, where K is an apparatus constant and the exponent n depends on the actual filter characteristics. n reaches a theoretically maximum of n=4 for a perfect “black” characteristic and unlimited wavelength.

$$U = K \cdot (T_{Object}^{n} - T_{amb}^{n}) \qquad (2)$$

All multichannel sensors can have crosstalk effects, where sensor chips might receive radiation passing through a different close-by filter. To avoid these effects all Heimann multichannel sensors are equipped with an optical barrier working as crosstalk suppression.

The following table gives an overview for the many different detector options available from Heimann Sensor.

type	size	TP chip	channels	integrated amplifier	output
HMS J21 F1	TO46	TP2	1	N	analog
HTS A21 F1	TO39	TP2	1	N	analog
HTS E21 F1/F2	TO39	TP2	2	N	analog
HTS Q21 F1/F2/F3/F4	TO39	TP2	4	N	analog
HIM J1C2 F1 G4300	TO46	TP1C	1	Y	analog
HIS A22 F1 G4300	TO39	TP2	1	Y	analog
HID A2x F1 G100	TO39	TP2	1	Y	digital
HIS E222 F1 F2 G4300	TO39	TP2	2	Y	analog
HID E22x F1 F2 G100	TO39	TP2	2	Y	digital
HCS C21 F1	SMD 3.8x3.8	TP2	1	N	analog
HCM C1C2 F1	SMD 3.8x3.8	TP1C	1	Y	analog
Plus many different highest detectivity pyroelectric sensors	TO39 TO8	various element sizes	1, 2, 4	voltage mode	analog

Note: F1 to F4: Filter matching infrared absorption lines of specific gases or reference filter (recommended filters in below list)

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Optical Filters

The following is a list of standard filters and specifications available from Heimann Sensor.

Gas	CWL /nm	Tol /%	Tol /nm	HPBW /nm	HPBW Tol /nm
CH_4	3300	±1	±33	160	±20
HC	3375	±1	±34	190	±20
CO_2	4260	±1	±43	180	±20
CO_2	4270	±1	±43	90	±20
CO_2	4430	±1	±44	60	±10
CO	4640	±1	±46	180	±20
Ref	3910	±1	±39	90	±20

Other filters can be sourced on demand if the customer provides the specification in terms of center wavelength, half power bandwidth and blocking.

If Heimann Sensor is asked to do the dicing of consigned filter material, we need to know about the substrate material so that we can calculate the dicing cost. The preferred thickness is 0.5 mm.
If a customer wants to consign diced filter windows, first we need to agree on the appropriate window specification.

The filter transmission curves will vary with temperature and angle of incidence.
If the angle deviates from normal condition, the filter shifts to shorter wavelength. Equation (3) describes this dependency.

$$\lambda_\Theta = \lambda_0 \cdot \frac{\sqrt{n^2 - \sin^2\Theta}}{n} \tag{3}$$

with λ_0 being the specific wavelength, n the index of refraction and Θ being the angle of incidence.

Sources

Besides infrared sensors Heimann Sensor offers infrared lamps and infrared radiation sources to be used together with our detectors in NDIR gas detection.

The infrared lamps HSL 5/115, HSL 5/60 or HSL 5/115/S are low cost and reliable IR sources with a long lifetime. They can be used for wavelengths up to approximately 4.5 µm and they can be operated in DC or AC mode. Typical operating conditions are 5 V and 115 mA respectively 60 mA. The version “S” has the leads fixed in a small ceramic sleeve.

The infrared sources are micro-machined thermal infrared emitters that allow fast electrical modulation for wavelengths range up to 16 µm. A patented technology enables manufacturing of sources with true black body characteristics and very high emissivity combined with low power consumption and long life time. The sources are available with and without a concentrating reflector mirror. The standard version comes without window in a TO39 package.

IR sources in TO46 or even micro TO packages (the smallest IR sources on the market) are also available.

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Circuitry

Thermopile detectors normally develop signals in the microvolt range, depending on the source/detector configuration and the power of the IR source. So in most cases it is necessary to amplify the voltage signal with a low noise amplifier. The amplification should fit to the input range of the following AD-Converter with a suitable Fast Fourier Transform (FFT) algorithm (2^n samples). Offset voltages, due to AC analysis, can be neglected as long as the output is still in the linear range.

Measurement Method

To make sure to process only source data, the emission of the source should be pulsed, generating time based sequences with a well defined frequency. To avoid thermal drifts, time of emission should be short to ensure a sufficient cool down time. Figures 3&4 show an example: a pulse sequence of 8 pulses, 140 ms/pulse at 1.33 Hz of the source and the corresponding received radiation of the sensor.

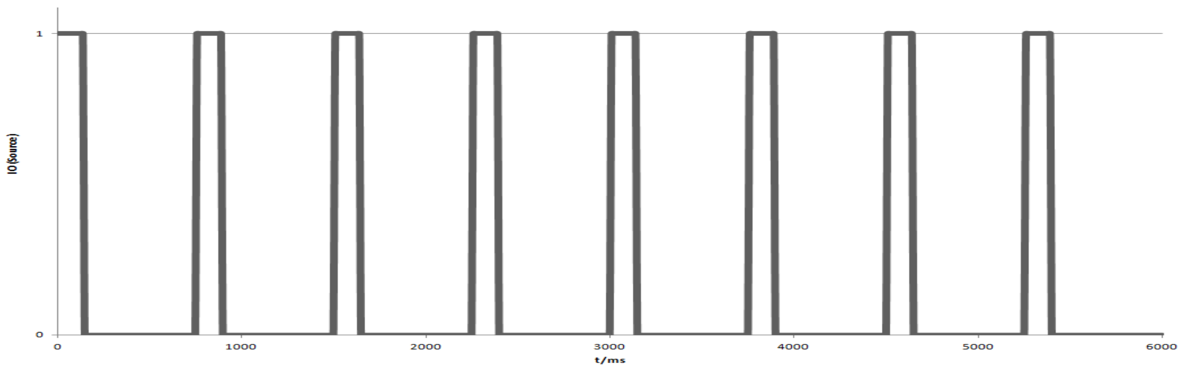

fig. 3 Pulse sequence of the source

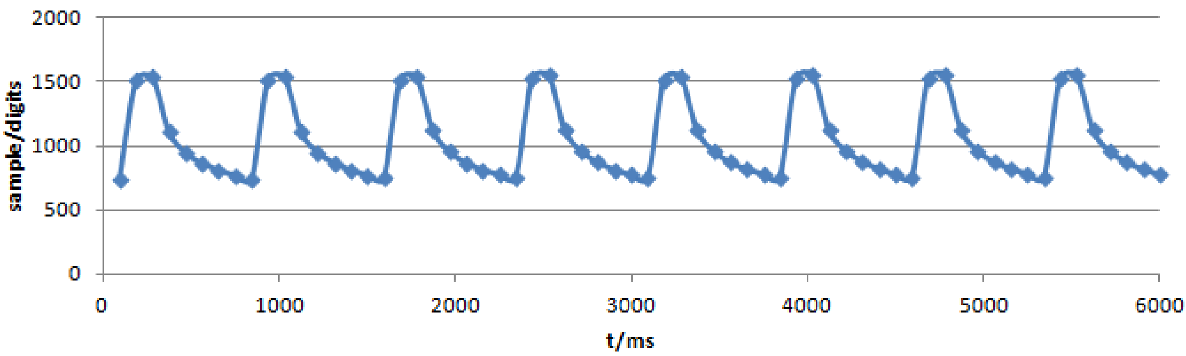

fig. 4 Sample sequence of the sensor

Reference channel and gas-sensitive channels can be recorded simultaneously. Data could be frequency-analyzed with a FFT (fig. 5&6) for a good signal-to-noise ratio.

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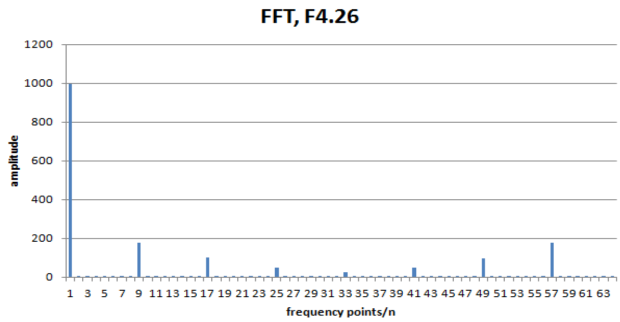

fig. 5 FFT of a CO_2 sensitive channel

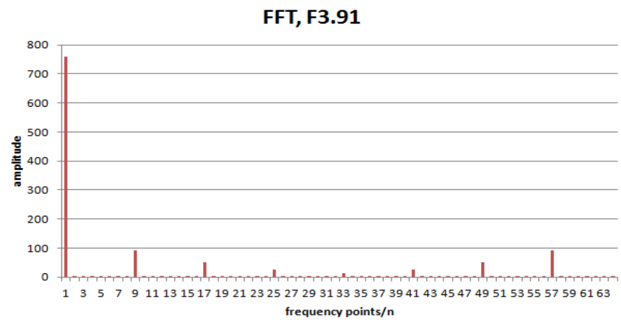

fig. 6 FFT of the reference channel

In general there are two possible ways to evaluate the data. Either to take the ratio or the difference of gas sensitive and reference channel.

Temperature Characteristics – Accuracy Improvement

Depending on the required precision it might be necessary to characterize your customized setup vs. operating temperature to make your own correction factors for best temperature compensation.

Test setups which exceed the “normal” atmospheric pressure-variation should be investigated similar to take physical effects of extinction vs. pressure into account.

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