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CAMBRIDGE CMOS SENSORS

Applications Note
AN1008

NDIR Gas Detection

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The monitoring of gaseous emissions can be undertaken for a range of environmental reasons. It is also a legal requirement in most countries, and this has generated a large demand for inexpensive, portable, and versatile analysers for the measurement of gaseous emissions. CCMOSS IR emitters can be used in low cost, low power, Non-Dispersive Infra-Red (NDIR) gas detection systems and offer a number of advantages over traditional microbulb technology.

- **Low cost** devices fabricated using standard CMOS technology for high volume applications.
- **Small footprint** SMD packaging options to improve circuit integration.
- **Lower power consumption** compared to microbulb technology (typically 200 mW vs. 1 W)
- **Fast heating time** (20 ms) for fast operation.
- **Broadband infrared output** (2 – 14 µm) to increase the range of gases which can be detected.
- **Lifetime** @ 450°C (> 10 years)

NDIR Principles

NDIR gas detection can be used to detect a large range of molecules including CO_2, CO, CH_4, NO, N_2 and O. When infrared radiation passes through a gas, some of the absorbed optical energy creates transitions between the vibrational-rotational energy levels within the gas molecules. This process creates 'absorption lines' in the infrared spectrum (generally between 2.5 to 16 µm). The characteristics of the absorption spectra depend on the number and masses of atoms in the molecules, as well as the nature of the various chemical bonds. A common gas to detect is CO_2 which has absorption lines at 2.7, 4.26 and 14.9 µm wavelengths.

Single Channel NDIR Systems

There are two main types of NDIR detection systems which use single or dual channels, as shown in Figure 1. Single channel NDIR systems are the most common and consist of a broadband infrared source, such as a MEMS IR emitter, which is used to transmit infrared radiation through the gas sample contained within a cell where the gas is allowed to diffuse in and out of. An optical bandpass filter is used to select the gas absorption wavelength of interest. An infrared detector, such as a thermopile, can be used detect the resulting IR signal. When the gas concentration is low there is limited interaction between the optical signal and the gas and the signal level on the detector is therefore high. If the gas is introduced, absorption occurs and the detected signal level drops. The transmitted optical intensity is described by the Lambert and Beer law, where I_o is the initial intensity, k is the gas specific absorption coefficient, c is the gas concentration and l is the length of the absorption path.

$$I = I_o e^{-kcl}$$

The infrared source can be a simple infrared lamp, MEMS infrared source, a blackbody radiation source or an infrared diode or laser. The choice depends on a number of parameters, including the spectral characteristics, cost, response time and optical power. The key advantages with using a CCMOSS MEMS IR source are its low power consumption, low cost and fast heating/cooling times.

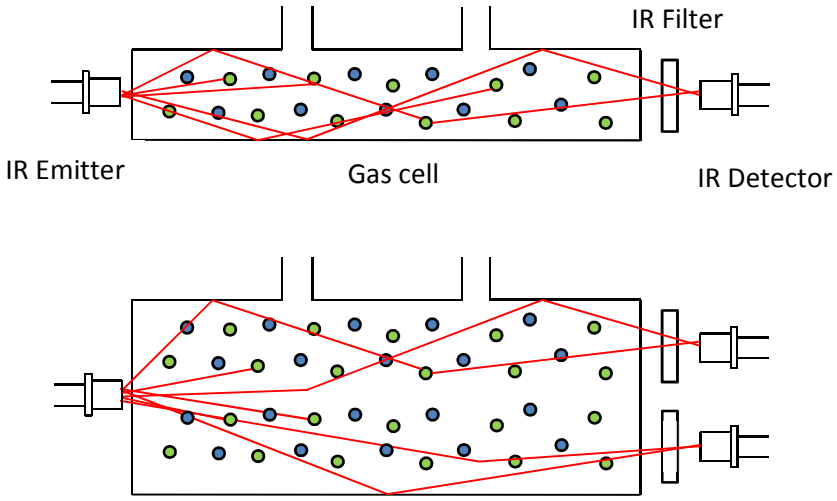

Figure 1: Single and dual wavelength NDIR gas detection systems.

Dual Channel NDIR Systems

A dual channel NDIR system can be used to compensate for the effect of system drift, including drift caused by temperature changes and variations in IR emission from the source. In a dual channel system, a second 'reference' filter and optical detector are used with a detection wavelength well away from the gas absorption wavelength of interest. Dual channel filters and detectors can be integrated within the package of a single device. With this type of system, the ratio of the two detected IR signals will be proportional to the gas concentration but independent of any system drift. Although a dual channel system has some advantages, it is more expensive and complex to implement and often has a poorer sensitivity.

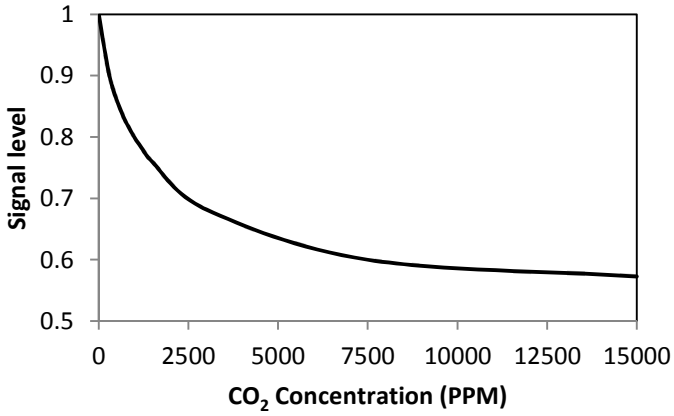

Figure 2: Optical signal level measured at various CO_2 gas concentrations (0 to 15,000 PPM) using a CCMOSS NDIR system.

Maximising the Absorption Path

In many instances it is necessary to maximise the length of the absorption path to enhance gas detection at low concentrations. An increase in path length can be achieved by reflecting the IR rays off surfaces using mirrors, as shown in Figure 3. Multipass or long path absorption cells with a high number of reflections allow very low concentrations of gas to be measured.

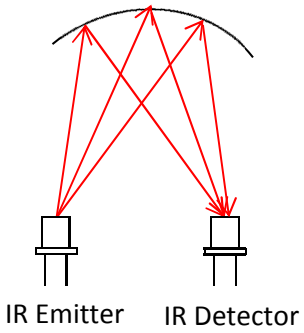

Figure 3: Parabolic mirror arrangement which can be used to increase the path length in a gas cell.

Optical Filtering

The choice of optical band pass filter is critical to the operation of the NDIR system and should be selected according to the gas to be measured and its absorption spectra. For example, CO_2 has a strong absorption peak at 4.26 µm and many hydrocarbons compounds have absorption peaks over the 3.3 - 3.5 µm waveband. When multiple gases are present, overlapping infrared absorption spectra can cause cross-interference which should be taken into account. For instance, CO_2 and H_2O often initiate cross sensitivity in the infrared spectrum. For fixed wavelength NDIR detection systems, the optical filter is normally integrated into the package of the IR detector which is normally either a thermopile or pyro-detector.

NDIR System Components

A block diagram showing the main components of an NDIR system is given in Figure 4. The IR source is pulsed on and off by the microprocessor and driver circuit. This allows background fluctuations in IR radiation measured during the off-period to be subtracted. Pulsing at higher frequencies can be used to reduce the effect of 1/f noise. CCMOSS MEMS IR emitters can be pulsed at high frequency using width modulation (PWM) or a voltage/current regulator (see Application Note AN1001). A thermopile or pyrodetector is used to detect and produce a signal that is proportional to the amount of IR energy absorbed by the gas of interest. As the energy of the narrow band IR radiation detected is small, the signal from the detector will typically be in the 10s µV range and will have to be heavy amplified before it is digitised. Signal processing, including to noise filtering, is normally performed by the microprocessor.

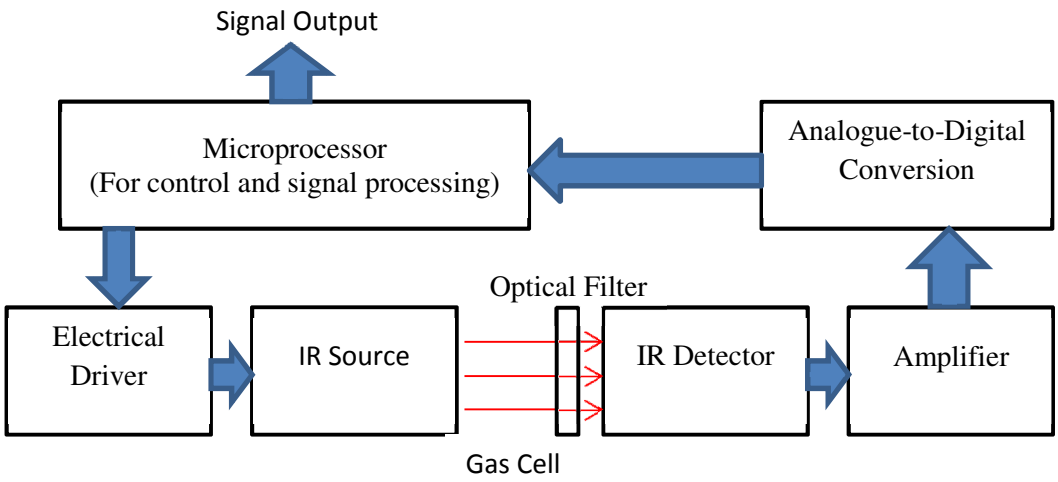

Figure 4: Main NDIR system components.

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