CO_2 Sensors: Using LEDs opens up new possibilities

Gas Sensing Solutions is pioneering a new generation of compact, low power, faster responding CO_2 sensors by using the innovative approach of specially developed LEDs. This means that mains power is no longer required for CO_2 sensors, opening up a world of new applications and solutions.

Why monitor CO_2?

To most people, carbon dioxide (CO_2) is just a harmless gas that you cannot smell or see. However, increasing levels result in yawning and dizziness. The normal level of CO_2 is around 400 parts per million (ppm).

In a closed room with several people inside, the level can rapidly rise to 2,000 ppm and even higher. The stuffy feeling making you yawn is, in fact, not the lack of 'fresh air' or oxygen, but your body reacting to high levels of CO_2.

Even higher levels of CO_2 can have effects on health at 15,000 ppm, with high concentrations of 80,000 ppm and above causing dizziness, headaches, unconsciousness and possibly permanent medical issues[1]. Dangerously, along this path, is a narcotic stage so that people don't even realise that they are in danger.

A spacecraft is a perfect example of an environment where CO_2 build up can have serious consequences. The problem that Apollo 13 faced was not a lack of oxygen but CO_2 build-up. The CO_2 scrubber in the main spacecraft, which removed CO_2 from the air, had been damaged.

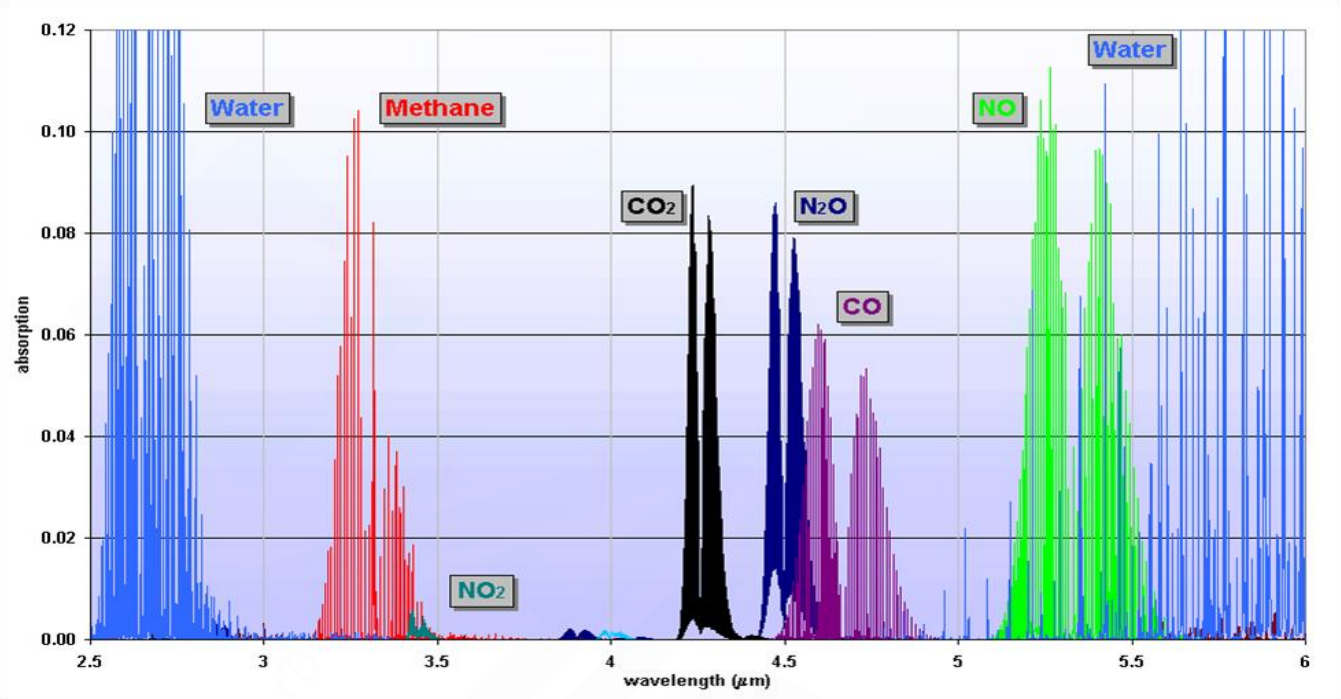
How to detect CO_2?

How do you detect a colourless, odourless gas? Humans are very bad at detecting rising CO_2 levels because you exhale at around 50,000 ppm (5% CO_2). This makes it hard for the body to easily detect changes in the levels of CO_2 in the incoming air.

1

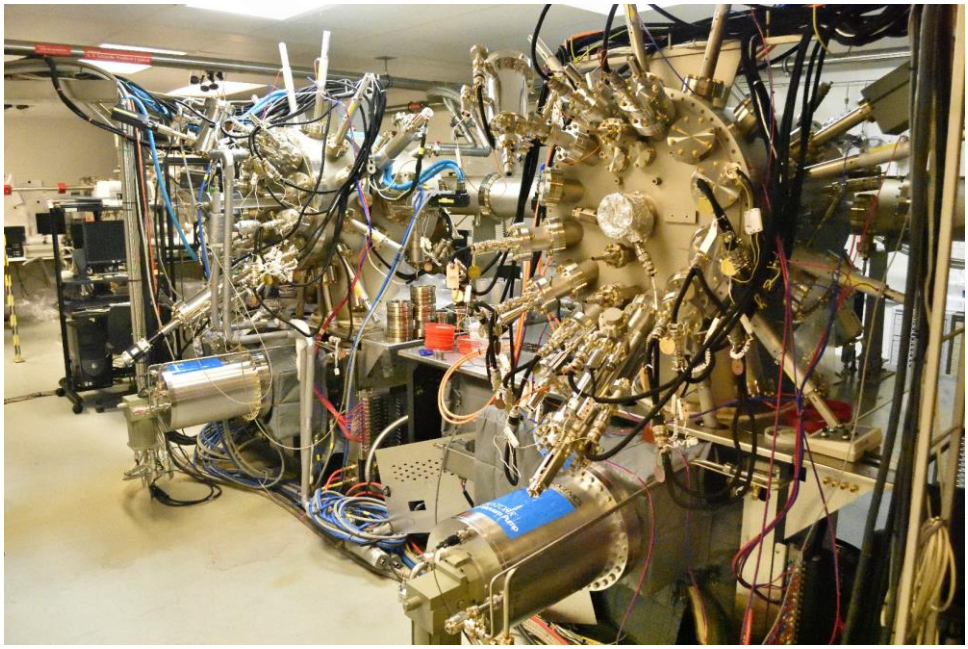
Singel 3 | B-2550 Kontich | Belgium | Tel. +32 (0)3 458 30 33
info@alcom.be | www.alcom.be
Rivium 1e straat 52 | 2909 LE Capelle aan den IJssel | The Netherlands
Tel. +31 (0)10 288 25 00 | info@alcom.nl | www.alcom.nl

Miners solved this CO_2 detection problem by taking canaries in a cage down the mines. The canaries would be affected first, falling off their perches and so giving an early warning to the miners. The Davey Lamp then mainly replaced canaries; amazingly canaries were still used in British mines until 1986. Many modern CO_2 detectors now use Non-Dispersive InfraRed (NDIR) technology that works by shining infrared (IR) light through the sample gas. CO_2 molecules absorb in the mid range of infrared — 4.2 to 4.4 micron wavelengths — so the more of these wavelengths that are absorbed, the more CO_2 is present.



Traditionally the source of this IR is a filament, similar to what would be found in an old-fashioned light bulb, or a micro-heater. These are slow to reach a stable state, wasting energy while doing so and also wasting energy by producing wavelengths that have to be filtered out. As a result, they need to be mains powered.

Gas Sensing Solutions has removed the need for mains power by pioneering the use of LEDs. These intrinsically use much less power and reach a stable condition in a fraction of a second, again cutting the power need. Also, rather than wastefully producing a whole range of wavelengths, GSS uses LEDs that have been tuned to only produce the specific wavelengths needed for CO_2 detection, further cutting power consumption.



The GSS epitaxy machines

As there were no commercial manufacturers of mid-range IR LEDs, GSS solved this problem by manufacturing its own LEDs and matching photodiodes that are specifically tuned to 4.2 to 4.4 micron wavelengths. GSS invested in its own epitaxy machines so that it could control the manufacturing of these key components in house - an approach that provides the company with a barrier to entry for rivals trying to make LEDs. Unique processes have been developed and refined within the company to create proprietary solutions.

Sensor solutions for any range of CO_2 concentrations

GSS has developed two forms of optical path for the IR according to the concentration level of the CO_2 to be measured. For low CO_2 concentrations of 0-5%, a long optical path is needed to give the CO_2 molecules sufficient opportunity to absorb the IR light. For this, the company has a horseshoe light path (Figure 1). If concentrations are high, for example right up to 100%, then a short light path is needed, and the company has a dome-shaped reflector for this (Figure 2). Being able to provide rapid accurate readings from a small, battery-powered sensor in the really high concentration range is something few, if any, rivals can do.

Figure 1 The GSS horseshoe design gives a long optical path for measuring low concentration of CO2

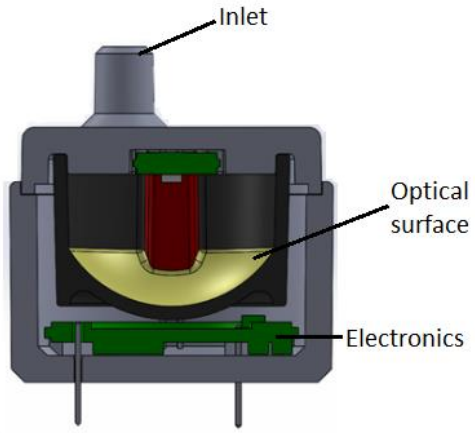


Figure 2 The GSS dome design gives a short optical path for high CO2 concentrations up to 100%

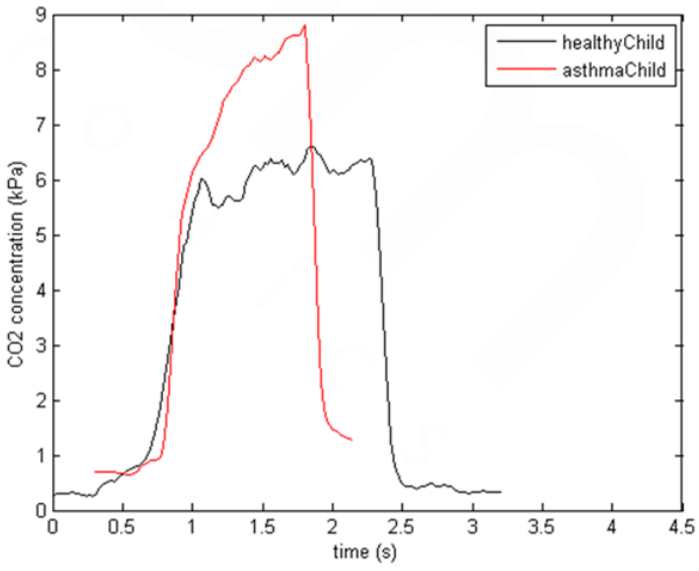
Up to 10-year battery life

By using LEDs, GSS CO_2 sensors use significantly less power – often up to 50 times less than competitors that must use mains power. As a result, GSS CO_2 sensors are the perfect solution for battery-powered applications.

The life of the battery depends on the frequency of the readings. Thus for HVAC applications where a reading is only needed every few minutes, a battery can last for ten years. High frequency readings, such as for healthcare applications requiring many readings a second, will mean that the battery life reduces yet can still achieve weeks of use.

Medical Application

The changing CO_2 content of a breath creates a waveform shape of the inhalation and exhalation. This has been established as an indicator for several medical conditions and is called capnography. However, the equipment needed to detect this is large, expensive, and mains-powered. This restricts its use to mainly monitoring anaesthesia in operating theatres and critical care.



GSS has changed this with its innovative CO_2 sensor technology. As the LED can turn on and off almost instantaneously, readings can be taken at more than 50 times a second. Also, the LED requires very little power, enabling battery-powered CO_2 sensing devices to be created with long battery lives.

This breakthrough in CO_2 sensing is being commercialised for the medical market by GSS' sister company, Cambridge Respiratory Innovations Limited (CRiL). GSS has exclusively developed an ultra-fast, compact version of its SprintIR®6S CO_2 sensor for CRiL to provide the level of accuracy needed to produce detailed

waveforms and to work in the challenging medical environment. This has enabled CRiL to produce a hand-held personal respiratory monitor, called N-Tidal™, which analyses CO_2 levels in normal tidal breathing.

The key part of the solution is the gas sample size. If you take too large a gas sample from the breath, it is effectively sucking the breath out of the patient—you don't want a patient going blue! Therefore the sample size has to be very small – something GSS has engineered into its SprintIR®6S. The dome-shaped gas detection chamber only needs 2ml per sample and requires so little power that it can be battery-powered. The small sample size also means that the response time is much faster, as the sample gas can be changed much quicker.

This opens up a whole new field of application solutions that was not possible before. Handheld, battery-powered breath analysis devices can now be made at a fraction of the cost of the previous generation of mains-powered machines. As a result, patients could now be provided with devices for home use, giving much better monitoring of their condition on an hour-by-hour, day by day basis, rather than just when in the laboratory or visiting hospital. And, as this new generation of breath analysis devices with LED CO_2 sensors is likely to be priced in the few hundreds, rather than many thousands of dollars range, home fitness use is also a possibility.

N-Tidal will be used to create a personalised respiratory management system for each patient. Not only could this provide live, accurate status reports within a couple of minutes but, even more excitingly, it could predict impending issues so that preventative treatment, such as self medication, could be taken before problems become acute. Several clinical trials are currently in progress, and CRiL believes N-Tidal has the potential to save the UK NHS more than £100 million a year by providing advance warnings of a respiratory deterioration, enabling early medical intervention and reducing avoidable hospitalisations.

Air Quality Monitoring application

Everyone is familiar with air conditioning, but mainly for heating or cooling and changing the air. Now people are realizing that CO_2 levels need to be kept low for good health – just a percent or so above normal levels can cause drowsiness.

Following the awareness of the harmful effects of high levels on CO_2 on health, HVAC or Indoor Air Quality (IAQ) systems are increasingly incorporating CO_2 monitors so that the air change is controlled by the need to reduce the CO_2 levels. There are several driving forces behind this. Firstly, the need to meet legislation designed to ensure a healthy working environment. The US Occupational Safety and Health Administration (OSHA) has set a Permissible Exposure Limit (PEL) for CO_2 of 5,000 parts per million (ppm) (or 0.5 %) over an 8-hour workday. They report that exposure to levels of CO_2 above this can cause problems with concentration, an increased heart rate, breathing issues, headaches and dizziness. Secondly, the need to save money, as changing the air in a building has an energy cost - especially if incoming air also has to be heated or cooled. This is particularly relevant at night-time and weekends, when buildings may not be fully

occupied. Fewer people means less CO_2 being produced so that the rate of air change can be reduced accordingly to save money. The EnOcean Alliance estimates that making a building a 'Smart building' can result in an energy reduction of between 30% and 40%, which helps achieve zero carbon consumption targets, and saves money. This is supported by a report by the Minnesota Department of Commerce that improvements in Demand Control Ventilation (DCV) can have a payback of between four to eight years. DCV uses CO_2 or occupancy sensors to estimate the number of people in an area and supply only as much ventilation air as is needed at a given time. This is particularly appropriate for areas of widely varying occupancy such as meeting rooms, auditoriums, etc.

Normally CO_2 monitors have to be mains powered, because their sensors have high power demands, resulting in significant costs for wiring and installation. Gas Sensing Solutions has a unique solution that is revolutionising the Smart Air Quality Control market by cutting out these costs. Its low power LED-based CO_2 sensors need so little energy to take a reading in a fraction of a second that they can be powered by batteries. As a result, HVAC CO_2 detectors can be designed using, for example, the GSS CozIR®LP. This ultra low power CO_2 sensor can be battery powered for up to 10 years from a small battery or solar panel, with enough power left over for a wireless control connection.

The GSS CozIR®LP sensor

The installation costs of a CO_2 monitoring system with battery-powered detectors is significantly less than with mains-powered ones, as they are simply attached to the walls where needed. Thus, for installations in new buildings, there are no cabling or ducting costs, plus no installation costs – which can be significant as each metre of cable can take an average of around three minutes to install, according to the German Electrician Union. This soon adds up, especially with the trend for buildings with high ceilings, which needs more cable. For existing buildings, the savings of an easy to install battery-powered set of detectors are even greater – there's no disruption, no mess and no redecoration. What's more, these 'fit and forget' battery-powered monitors provide a future-proof solution that can be easily adapted as room use changes, with no rewiring costs, mess or disruption. It's no surprise then that a recent survey by ON World found that nearly all respondents were planning to use wireless sensing/control systems in future.

Industrial CO2 Monitoring Applications

Modified Atmosphere Packaging (MAP) is used to prolong the shelf life of fruits, vegetables and salads with a specific level of CO_2 to keep the produce fresher for longer. The optimal level varies widely according to the product. On the production line, sample packs are taken at regular intervals and the CO_2 levels checked by inserting a hollow needle into the pack and drawing out a sample of the gases for analysis. However, standard CO_2 sensors take several minutes to stabilise on a reading -- during which time many bags can progress along a high-

The GSS SprintIR6S can provide 20 measurements in a heartbeat

speed line. The longer the read time, the more bags are made with potentially the wrong CO_2 level, which wastes product and money. In addition, packages that ship with the wrong CO_2 levels can spoil before the use by date, resulting in claims against the producer by the supermarkets.

The SCS 354 Dual Gas Analyser measures CO_2 levels from 0-20% and O_2 from 0-25%

Storage Control Systems (SCS) wanted to create a portable gas analyser that would provide an accurate CO_2 reading in seconds, and only need a small sample volume. The sensor that they had been using in their products has a very high power consumption and was not fast enough in providing a reading for this application.

To achieve the performance specifications of the new class of analyser that they wanted to create for MAP applications, the company used a SprintIR® CO_2 sensor from GSS. The SprintIR® sensor can provide 20 readings per second from only a 3ml sample due to its patented design. As the LED-based sensor requires so little power, SCS was able to create a portable, battery-powered analyser.

On the other hand, a leak in CO_2 handling facilities can rapidly take a normal level of around 400 parts per million up to levels where dizziness and disorientation can happen. An all-too-often example of this problem is found in restaurants, microbreweries, and bars where the cellar is used to store the CO_2 cylinders used to carbonate drinks. A CO_2 leak collects in the cellar and builds up to levels that could potentially knock out someone going down there. Indeed, this can often claim several victims as more people go down to investigate what happened. Wall-mounted, battery-powered CO_2 monitors with an alarm provides a vital Health and Safety warning, which is simple, easy to retrofit and reconfigurable.

This can also take the form of a small, battery-powered CO_2 monitor that clips onto clothing to provide an alarm if CO_2 levels become high. For example, NASA has developed such personal CO_2 monitors for the crew on the International Space Station using GSS sensors that, thanks to the low power demand of the sensor, have an operational life of many weeks.

Three Critical Decisions

Lastly, when deciding which is the appropriate sensor to use for a given application, one has to decide the CO_2 concentration range to be measured over, the power budget, and the frequency of readings required, as there are usually trade-offs to be made. For example, frequent readings will rapidly drain a battery but, for some applications, that might not be an issue if the portable device is rechargeable. Whereas taking a reading every few minutes means that the battery life is measured in years.

Alcom electronics
Singel 3 | B-2550 Kontich | Belgium | Tel. +32 (0)3 458 30 33
info@alcom.be | www.alcom.be
Rivium 1e straat 52 | 2909 LE Capelle aan den IJssel | The Netherlands
Tel. +31 (0)10 288 25 00 | info@alcom.nl | www.alcom.nl