SPONSORED COVER STORY

New PAS CO2 5V Sensor Solution for Smart Buildings: Optimizing Energy Efficiency While Ensuring a Healthy Indoor Environment

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Buildings are a significant consumer of energy and a major contributor to global carbon emissions, requiring substantial amounts of energy for heating, ventilation and air conditioning (HVAC). To mitigate climate change, it is therefore essential to reduce their environmental footprint by optimizing their operating efficiency. Infineon is committed to reducing carbon emissions and has introduced a new sensor solution that enhances energy efficiency while maintaining a healthy indoor environment. The XENSIV™ PAS CO2 5V sensor is a key milestone in Infineon's effort to drive decarbonization. By enabling smart buildings to optimize HVAC energy consumption while maintaining a healthy indoor environment through proper ventilation, this solution takes a significant step toward a more sustainable future.

The fight against climate change has intensified in recent years, with decarbonization becoming a central goal for governments, industries and organizations around the world. Many countries have committed to reducing their carbon emissions to meet international climate targets, and the built environment plays a critical role in achieving these goals. In fact, buildings are responsible for a staggering 40% of global carbon emissions, making them a prime target for innovative solutions.

By adopting advanced energy management systems and more efficient construction practices, the carbon footprint of the built environment can be significantly reduced. Demand-controlled ventilation (DCV) systems, enabled by CO_2 sensors, play a pivotal role in achieving sustainability goals while ensuring people's well-being and comfort. CO_2 sensors continuously monitor indoor air quality, providing real-time data on CO_2 levels. This information enables HVAC devices to optimize ventilation rates based on actual occupancy and demand. By precisely controlling airflow, DCV systems increase operational efficiency, reduce energy consumption and minimize the carbon footprint of buildings. By doing so, CO_2 sensors not only support global sustainability efforts but also improve the well-being and productivity of building occupants by providing a comfortable, safe and healthy environment.

ONGOING CHALLENGES IN SENSOR TECHNOLOGY

Despite advances in sensor technology, several challenges persist, hindering the widespread adoption and effectiveness of CO_2 sensors. Conventional, low-cost electrochemical or equivalent CO_2 (eCO_2) sensor solutions often struggle with accuracy, yielding unreliable data that can lead to inefficient building operations and compromised indoor air quality. Sensors also need to be robust and reliable in diverse environmental conditions, yet some still require frequent calibration and maintenance, adding to the overall cost of ownership. Finally, the bulkiness of non-dispersive infrared (NDIR) sensors can also pose a challenge in applications where space is limited, such as in IoT and consumer devices.

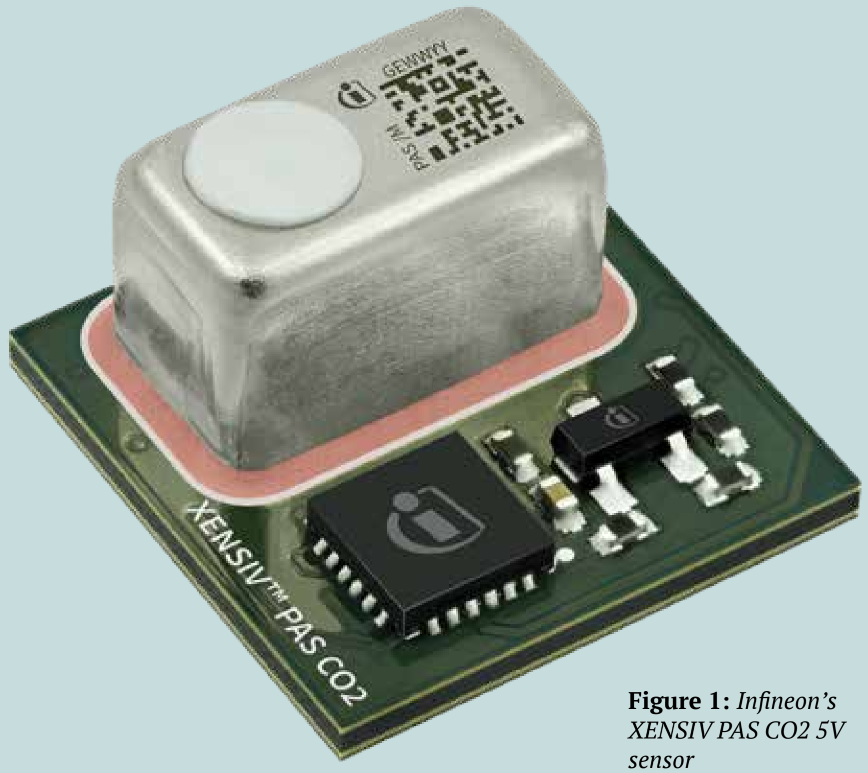


Figure 1: *Infineon's XENSIV PAS CO2 5V sensor*

ADDRESSING THESE CHALLENGES WITH THE XENSIV™ PAS CO2 5V SENSOR

To address the limitations of conventional CO_2 sensors, Infineon Technologies has developed the XENSIV PAS CO2 5V sensor, a cutting-edge CO_2 sensor solution based on the photoacoustic spectroscopy (PAS) principle and designed to overcome the accuracy, reliability and cost challenges associated with existing technologies. This innovative sensor provides a more precise, reliable and cost-effective solution for CO_2 monitoring, enabling improved indoor air quality and energy efficiency in various applications, such as HVAC systems as well as IoT and consumer applications. The main objectives of this CO_2 sensor are to improve the performance, reduce the size and simplify the integration, thereby facilitating its widespread adoption.

OVERVIEW OF TECHNICAL CHALLENGES

Currently, various CO_2 sensor technologies are available in the market. However, they have several shortcomings that limit their use in improving the efficiency of smart buildings. A few examples are outlined below:

- **NDIR sensors:** While NDIR sensors offer some advantages, such as high accuracy, long lifespan and low drift, making them suitable for applications requiring reliability and precision, they also have some drawbacks. The need for recalibration after shipment adds complexity to the installation process; their bulky design makes them unsuitable for space-constrained applications; and their incompatibility with high-volume surface-mount-technology assembly processes limits their scalability in mass production. Furthermore, their high cost further restricts their adoption.
- **Electrochemical CO_2 sensors:** Although these sensors are more affordable, they come with many tradeoffs. Due to their limited lifespan, they must be replaced frequently, which increases long-term costs and maintenance needs. Moreover, regular recalibration is required to ensure accuracy, a process that can be both time-consuming and inconvenient. They are also sensitive to temperature and humidity changes, affecting their performance under varying conditions. Additionally, their slow response time reduces their effectiveness, especially in dynamic environments where quick adjustments are critical.
- **eCO_2 sensors:** eCO_2 sensors are less expensive than real CO_2 detectors, but they only provide indirect measurements of CO_2, making them less accurate than direct measurement methods. Moreover, their lack of specificity can result in sensitivity to a wide range of volatile organic compounds, including detergents and other chemicals, potentially leading to false alarms. Additionally, they are sensitive to changes in temperature and humidity, just like electrochemical sensors.

MARKET REQUIREMENTS POSE ADDITIONAL CHALLENGES

Beyond the technical challenges, sensor system developers face growing market demands: HVAC systems, smart thermostats and room controllers require increasingly energy-efficient, cost-effective and sustainable solutions that prioritize occupant comfort. As building energy efficiency regulations become more stringent, the need for advanced CO_2 sensing technologies that meet these evolving requirements while remaining affordable and reliable is growing. In this regard, Infineon's XENSIV PAS CO2 5V offers designers a valuable and comprehensive solution that meets the needs of modern HVAC systems.

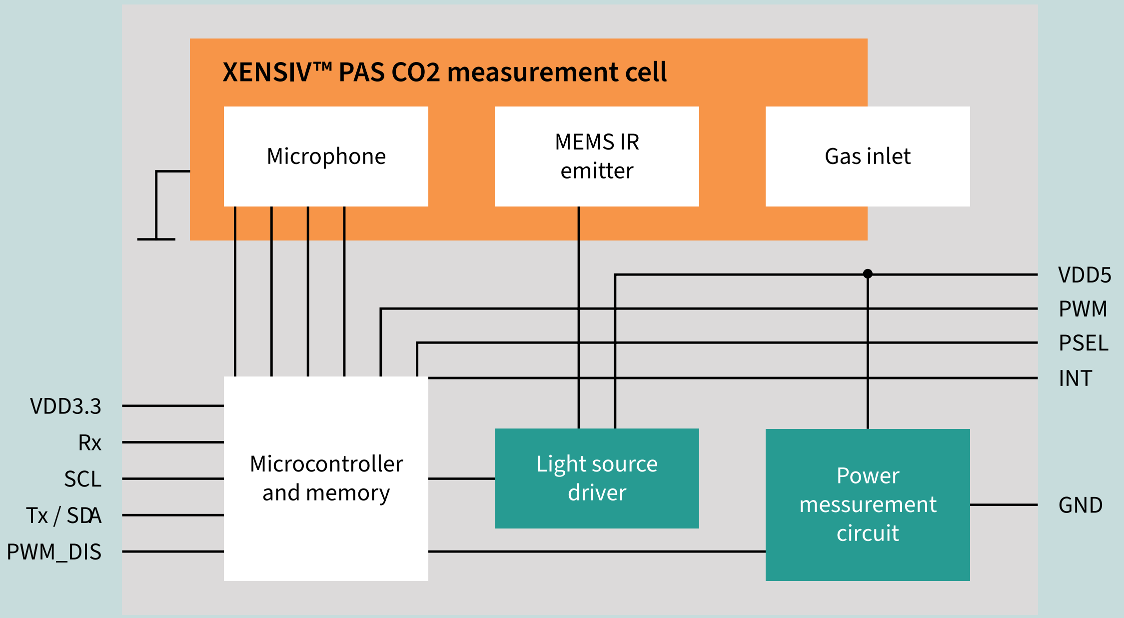
INFINEON'S SENSOR SOLUTION

The XENSIV PAS CO2 5V sensor (**Figure 1**) leverages photoacoustic spectroscopy to overcome the limitations of conventional CO_2 sensor solutions while meeting industry requirements. By addressing key trends, such as miniaturization, performance and ease of mounting, this CO_2 sensor is an ideal solution for precise indoor air quality monitoring and energy-efficient HVAC management.

The XENSIV PAS CO2 5V leverages PAS technology to overcome the limitations of conventional CO_2 sensors.

Infineon's XENSIV PAS CO2 5V sensor boasts a remarkably compact design, measuring only 14 × 13.8 × 7.5 mm³, making it 4× smaller and 3× lighter than comparable NDIR sensors. This significant reduction in size and weight enables a 75% decrease in space requirements, making it an ideal solution for applications where space is limited. In addition to its compact design, the sensor provides accurate CO_2 measurements with an accuracy of ±50 ppm ±5% over a range of 400 to 3,000 ppm. By fulfilling the performance requirements of the WELL™ building standard, the XENSIV PAS CO2 5V sensor contributes to optimal indoor air quality and energy efficiency through demand-controlled ventilation, which in turn results in enhanced real estate value.

The sensor is powered by a 5-V supply, ensuring compatibility with standard power sources and simplifying installation. With a



PIN	Symbol	Type	Description
1	VDD3.3	Power supply (3.3 V)	3.3 V digital power supply
2	Rx	Input /Output	UART receiver pin (3.3 comain)
3	SCL	Input /Output	I²C clock pin (3.3 V domain)
4	Tx / SDA	Output	UART transmitter pin (3.3 V domain) / I²C data pin (3.3 V domain)
5	PWM_DIS	Input	PWM disable input pin (3.3 V domain)
6	GND	Ground	Ground
7	INT	Output	Interrupt output pin (3.3 V domain)
8	PSEL	Input	Communication interface select input pin (3.3 V domain)
9	PWM	Output	PWM output pin (3.3 V domain)
10	VDD5	Power supply (5 V)	5 V power supply for the IR emitter

Figure 2: *Block diagram and pin configuration of the XENSIV PAS CO2 5V sensor*

qualified lifespan of 10 years in typical indoor environments, it offers a fast response time of 55 seconds, providing consistent performance even in rapidly changing conditions. This enhances efficiency in various applications and enables faster data acquisition in dynamic environments. The sensor's dust-tight design, certified to ISO 20653:2013-02, extends its lifespan in dusty environments and minimizes maintenance requirement as well. Furthermore, the UART, I²C and PWM interfaces support seamless integration with microcontrollers and other digital systems, streamlining the design and development process.

All key components of the XENSIV PAS CO2 5V sensor (**Figure 2**) are designed in-house according to Infineon's high-quality standards. This includes a dedicated microcontroller that runs advanced compensation algorithms to provide direct and reliable parts-per-million readings of real CO_2 levels. The available configuration options make it one of the most versatile plug-and-play CO_2 sensors on the market. These options include a dedicated automatic baseline offset calibration, ambient pressure compensation, signal alarm, sample rate and early measurement notification, which are particularly useful for power management. Supplied in tape and reel, the SMD package allows easy assembly even in high-speed, high-volume production.

UNDERSTANDING PAS TECHNOLOGY

CO_2 measurements using photoacoustic spectroscopy (**Figure 3**) start with pulses of light emitted by an infrared source. This light passes through an optical filter specifically tuned to the absorption wavelength of CO_2, which is 4.2 µm. When the filtered light enters the measurement chamber, it is absorbed by the CO_2 molecules in the chamber. This causes the molecules to vibrate, creating a pressure wave with each pulse of light—a phenomenon known as the photo-

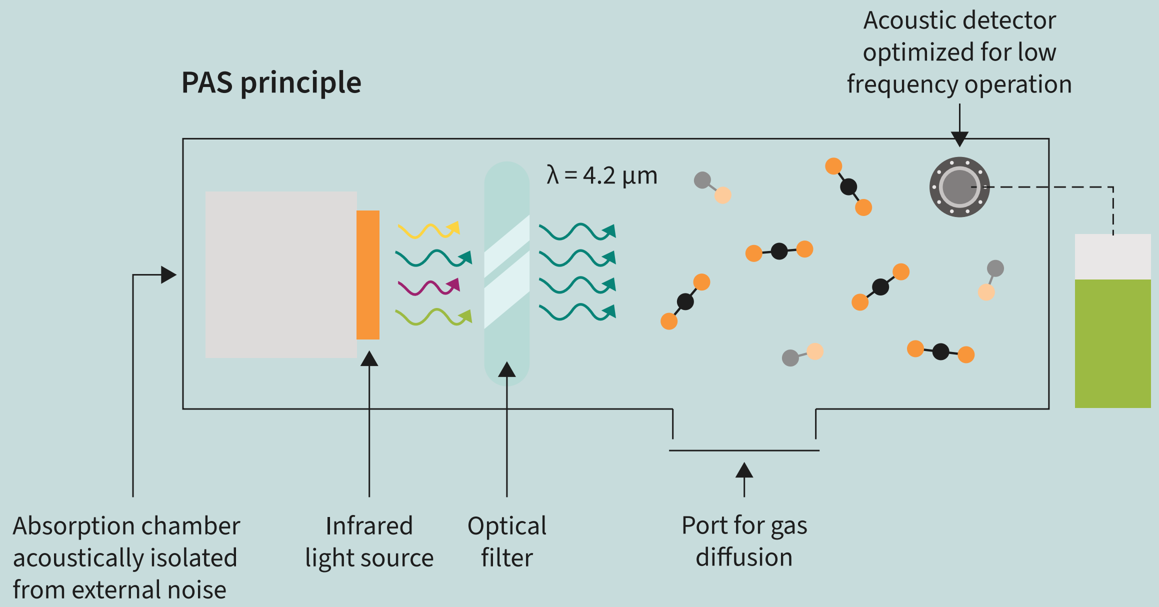


Figure 3: *In the PAS principle, infrared light at the CO_2 absorption wavelength is absorbed by CO_2 molecules, creating pressure waves.*

acoustic effect.

These pressure waves, which are essentially sound waves, are then detected by an acoustic detector optimized for low frequencies. The absorption chamber, where this process occurs, is acoustically shielded from external noise, ensuring that the detection is accurate and unaffected by surrounding environmental factors. Finally, the data from the acoustic detector is processed by a microcontroller, which converts the information into a CO_2 concentration value, providing a reliable measurement of the CO_2 level in the indoor environment.

POSSIBLE APPLICATIONS OF THE NEW SENSOR

Key applications include DCV for HVAC systems, room controllers and thermostats in commercial and residential buildings. In these applications, the new XENSIV PAS CO2 5V sensor provides real-time CO_2 concentration measurements and enables constant air quality monitoring. If CO_2 levels exceed predefined thresholds, the sensor automatically adjusts HVAC systems or triggers an alarm to preserve occupant comfort and prevent energy waste.

Beyond HVAC systems, room controllers and thermostats, the CO_2 sensor offers significant value in IoT and consumer devices, such as smart lighting systems, air purifiers, conferencing systems and smart speakers. The sensor's ability to log historical data is particularly beneficial in these applications, as it enables the analysis of long-term trends and effective air quality management over time. Furthermore, the sensor's adaptive capabilities allow it to optimize energy savings and enhance user experience by responding to room utilization and occupancy patterns. In addition to building automation, the XENSIV PAS CO2 5V sensor finds applications in emerging areas, such as smart horticulture for optimized plant growth and yield and smart refrigeration for preserving food freshness and safety.

WELL™ Building Standard

The WELL Building Standard is an international standard focused on promoting human health and well-being in buildings. Based on scientific research, it evaluates buildings in 10 categories: air quality, water, nourishment, light, movement, thermal comfort, sound, materials, mind and community. WELL-certified buildings create healthy, productive environments that improve the physical and mental well-being of their occupants. The standard is a performance-based system, and each WELL project is verified through on-site testing of the building's performance. Based on the number of points achieved, a project is rated at one of four WELL levels—Bronze, Silver, Gold and Platinum—depending on how well it meets the criteria.

SUMMARY

Recent breakthroughs in CO_2 sensor technology, particularly the introduction of photoacoustic spectroscopy, have substantially enhanced the reliability, accuracy and cost-effectiveness of CO_2 monitoring. Consequently, the XENSIV PAS CO2 5V sensor has emerged as a cutting-edge solution that optimizes energy efficiency in smart buildings while ensuring the well-being of occupants. This innovative sensor offers a unique value proposition, combining a 5-V supply voltage, small size and high-quality data output, making it an ideal choice for a wide range of HVAC as well as IoT and consumer applications. Moreover, the CO_2 sensor meets the performance requirements of the WELL green building standard, further underscoring its potential to create healthier and more sustainable indoor environments. To facilitate rapid development and prototyping, Infineon also offers 5-V Sensor2Go kits and mini boards, providing developers with a convenient and flexible way to integrate the PAS CO2 5V sensor into their designs.

Building on this success, Infineon is now extending the benefits of PAS technology to new use cases, including a series of groundbreaking refrigerant leakage sensor solutions, targeting the detection of propane and other A2L refrigerants. This expansion of its environmental sensing portfolio marks a significant step forward in Infineon's journey to become a leader in the PAS-enabled gas sensing segment. ■