Whitepaper
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Meeting stringent CO2 building code requirements with Infineon's XENSIV™ PAS CO2 Sensor

The smallest sensor to meet California's Building Code Title 24 requirements

Abstract

As today's world is struggling to come to grips with a worldwide pandemic and the rapid spread of viruses, accurate and reliable indoor air quality monitoring has become a crucial part of existing and newly updated building codes.

This white paper discusses carbon dioxide (CO_2) monitoring requirements as covered by California's Title 24 standard (one of the strictest building code standards in the U.S.), its associated demands for CO_2 sensors, and how Infineon's XENSIV™ PAS CO2 sensor became fully compliant with California's Title 24, making it the ideal candidate for precise and dependable air quality monitoring.

by
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1 Introduction

For over 40 years, California has been setting and continuously improving energy efficiency standards and code regulations for any and all structures in the state. California Code of Regulations Title 24, also referred to as California Building Standards Code (CBSC), is a collection of standards that help new, existing and remodeled properties (residential and public) safeguard the health and welfare of its occupants. Note that cities and counties that are obligated by state law to enforce the CBSC published in Title 24 of the California Code Regulation (CCR) as it applies to buildings are not subject to enforcement by state agencies. Title 24, Part 6 refers to the energy efficiency standards for residential and non-residential buildings as well as additions, alterations, and new construction.

Title 24 has been established based on a set of different criteria, such as the standards adopted by states based on national model codes, which were adapted to meet California's conditions/requirements, and standards passed by the legislature that address requirements tailored to the needs of California.

The CBSC is a compilation of three types of building standards developed by various state agencies. Title 24 consists of 12 parts related to administrative, building, fire, residential, electrical, plumbing, mechanical, historical, green, existing codes, and referenced standard codes as well as energy codes. Part 6, also known as the California Energy Code, covers the requirements for Ventilation and Indoor Air Quality in section 120.1. Under this provision, CO_2 sensors must be installed in each room to meet set criteria of no less than 1 sensor per 10,000 square ft floor space. Infineon's cost-efficient, miniaturized, plug-and-play Photoacoustic Spectroscopy (PAS) CO_2 sensor is well-suited to ensure building designers and all new construction are up to code.

Provisions for CO_2-based Demand Controlled Ventilation (DCV) have been part of California's building code (Title 24) since 1996 and became mandatory (for certain high-density applications) in 2005. CO_2 DCV is addressed in Title 24, section 120.1 (d).

In 2016, the Building Energy Efficiency Standards (BEES) outlined the need for air quality monitoring in areas that host an occupancy density greater than or equal to 25 people per 1,000 sqft. The demand for controlled ventilation in these areas calls for a CO_2 concentration of 600ppm or less[1]. *

Table 1 illustrates ventilation airflow speed based on CO_2 concentration levels, assuming a confined area of 1,000 sqft with an occupancy rate of 10 people.

[1] NOTE: This requirement does not apply to healthcare, medical or social services buildings/areas, classrooms, offices or call centers that are multi-zone systems and continuously occupied during usual business hours.

Table 1 CO_2 concentration vs. ventilation, CFM/person (cubic feet per minute per person). Source: Air Test Technologies

Ventilation Status	CFM/person	CO_2 concentration (ppm)
Under ventilated	5	2,500
	10	1,500
Ideally ventilated	15	1,100
	20	900
Over ventilated	25	800
	30	750
	35	700
	40	650
	50	600
	100	500
	Outside air	400

As of January 1, 2020, all new buildings and altered/remodeled residential properties in California must also meet Title 24 compliance standards, which means every construction/building company must submit an official Title 24 report for approval. This report is a collection of forms that verify a building plan meets instated code regulations and energy efficiency standards. If a new or remodeling plan does not meet or exceed the required Title 24 standards, the construction company/contractor must alter them until compliance is achieved. Should a construction company put up a new structure (residential or public) or make alterations to an existing building that does not meet Title 24 standards, they could be fined by the state.

Under Title 24 DCV, suitable CO_2 sensors must meet the following requirements:

- Be certified by the manufacturer to meet an accuracy of ±75 ppm or less at 600 ppm and 1,000 ppm (e.g., maximum allowable CO_2 density for classrooms) concentration when measured at sea level and an ambient temperature of 25°C.
- Be factory calibrated and certified by the manufacturer to require calibration no more than once every 5 years.
- CO_2 levels outside the specified levels require the system to be able to provide a signal, which resets the air quality to a healthy level as required by Title 24 specifications; in other words, the monitoring sensor must be able to provide a signal that activates a ventilation system, which in turn provides the needed air exchange to achieve 600 ppm or better CO_2 level in the monitored space.
- CO_2 sensors must be able to cover up to 10,000 sqft floor space with a minimum of one sensor for this space and with an installation height of 3 ft to 6 ft above occupant head levels.

2 Meet all Title 24 requirements with Infineon's XENSIV™ PAS CO2 sensor

With the stringent requirements of Title 24 in mind, Infineon conducted an in-depth analysis of their XENSIV™ PAS CO2 sensor specifications to determine whether the sensor meets all of the Title 24 requirements for California. Table 2 showcases critical findings related to the air quality accuracy for rooms/spaces of 1,000 sqft to 10,000 sqft.

Table 2 Title 24 expectations for air quality accuracy

Title 24 requirements	XENSIV™ PAS CO2 Spec (@ 1 meas/200 s)		Competitor	
	Zero Hour	5 years	Zero Hour	5 years
600 ppm ±75 ppm	±48 ppm	±57 ppm (meets Title 24)	±70 ppm	±118 ppm (does not meet Title 24)
1000 ppm ±75 ppm	±60 ppm	±75 ppm (meets Title 24)	±90 ppm	±170 ppm (does not meet Title 24)

Compared to other manufacturers on the market who claim Title 24 compliance, Infineon's XENSIV™ PAS CO2 actually does meet the criteria. The PAS CO2 gas sensor offers the best specifications available, easy-to-use handling (e.g., assembly process), and crucial CO_2 accuracy of ±75 ppm with no need for manual calibration for 5 years.

It should be noted that competitors' sensors depict two drift specifications: 0.5 percent (typ.) and 2 percent (max.):

- Considering 0.5 percent drift per year for the competitor's sensors, after 5 years, the total drift translates to 2.5 percent. At 600 ppm, the positive drift number will be +75 ppm +15 ppm = 90 ppm. With that, the competitor specifications range outside of the Title 24 requirements.
- At 2 percent drift per year, its total drift after 5 years results in 10 percent. At 600 ppm, the positive drift number will be +75ppm +60ppm = 135ppm, which puts the competitor's sensor well outside the Title 24 requirements.

Any microcontroller used in an end application associated with sensors and ventilation systems can be triggered by a sensor to produce an I/O signal that will engage air conditioning and/or ventilation to ensure the monitored space offers acceptable air quality. Figure 1 is an example of an indoor HVAC unit with a CO_2 sensor that can be used to control ventilation through an indoor fan in order to lower the CO_2 level of the room.

Studies on the accuracy of deployed CO_2 sensors used for DCV in California indicate that a substantial fraction of CO_2 sensors has errors greater than what is specified in Title 24. 47 percent of sensors had errors greater than 75 ppm at a concentration of 760 ppm, and 40 percent of sensors had errors greater than 75 ppm at a concentration of 1,010 ppm (Fisk/Sullivan/Faulkner/Eliseeva, 2010). A significant fraction of sensors have much larger errors (e.g., larger than 300 ppm). These concentrations of 760 ppm and 1,010 ppm are typical of the setpoint concentrations at which DCV systems increase outdoor air ventilation rates. Although the information from the aforementioned studies is 10 years old, based on these studies, many existing CO_2 sensors still do not meet current accuracy requirements for effective DCV implementations.

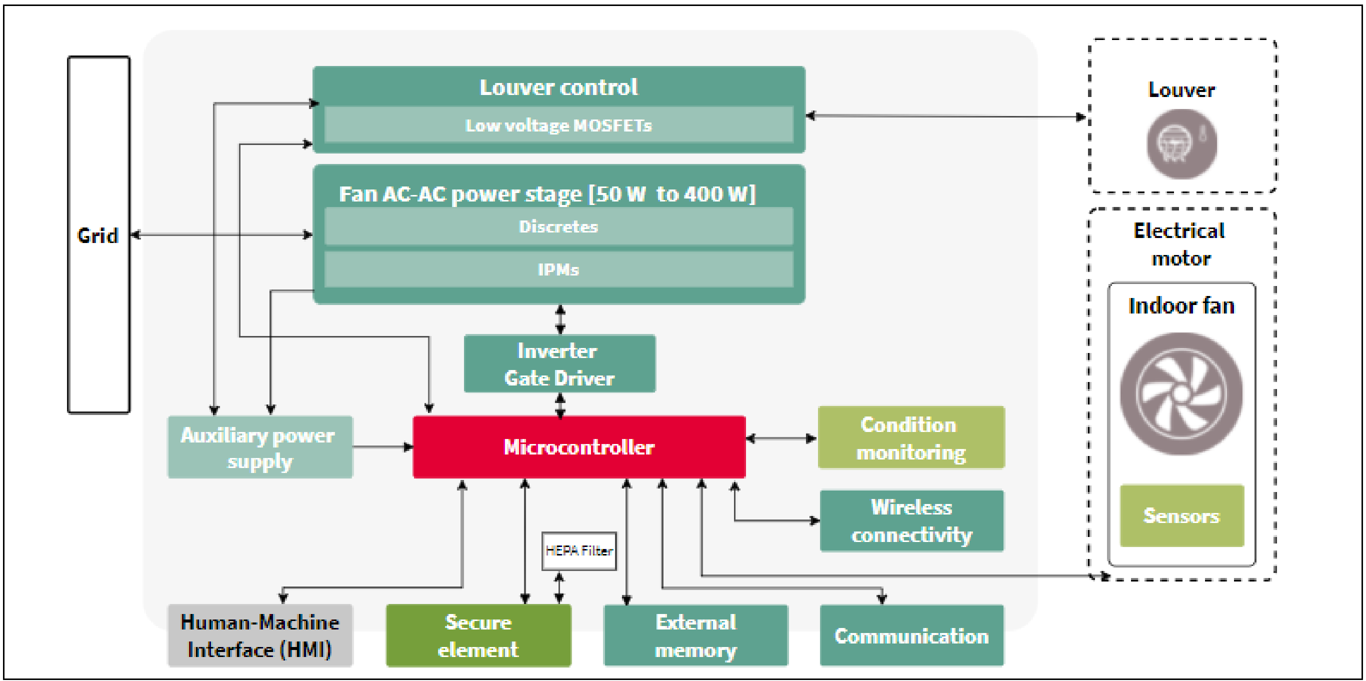

Figure 1 Indoor HVAC example with CO_2 sensor to monitor air quality in a room

Infineon's XENSIV™ PAS CO2 sensor is a game-changer in this field. Based on Photoacoustic Spectroscopy (PAS) technology, the PAS CO2 sensor guarantees high performance (±30 ppm ±3 percent of reading) in an exceptionally small form factor (14 mm x 13.8 mm x 7.5 mm). Its plug & play capabilities set an affordable new standard for high-volume applications. For more details, visit www.infineon.com/CO2.

The following figures (2 through 4) showcase air quality monitoring in home and office settings, as one would experience for single- and/or multi-person environments. Data in these figures were generated utilizing the XENSIV™ PAS CO2 Sensor2Go Evaluation platform. Click here for more detailed information regarding this evaluation kit.

Figure 2 shows CO_2 monitoring in a poorly ventilated space (air conditioning system turned off) during the day, with only 1 occupant present and the patio door open (see first dip in the curve), which made the CO_2 level drop significantly. The person in the room was approximately 1 ft to 2 ft away from the sensor at all times, working on a laptop with a regular breathing pattern. The back-end part of the curve indicates the occupant leaving the room, which causes the curve to retract from higher levels of CO_2 to a healthier (green) air quality in the room.

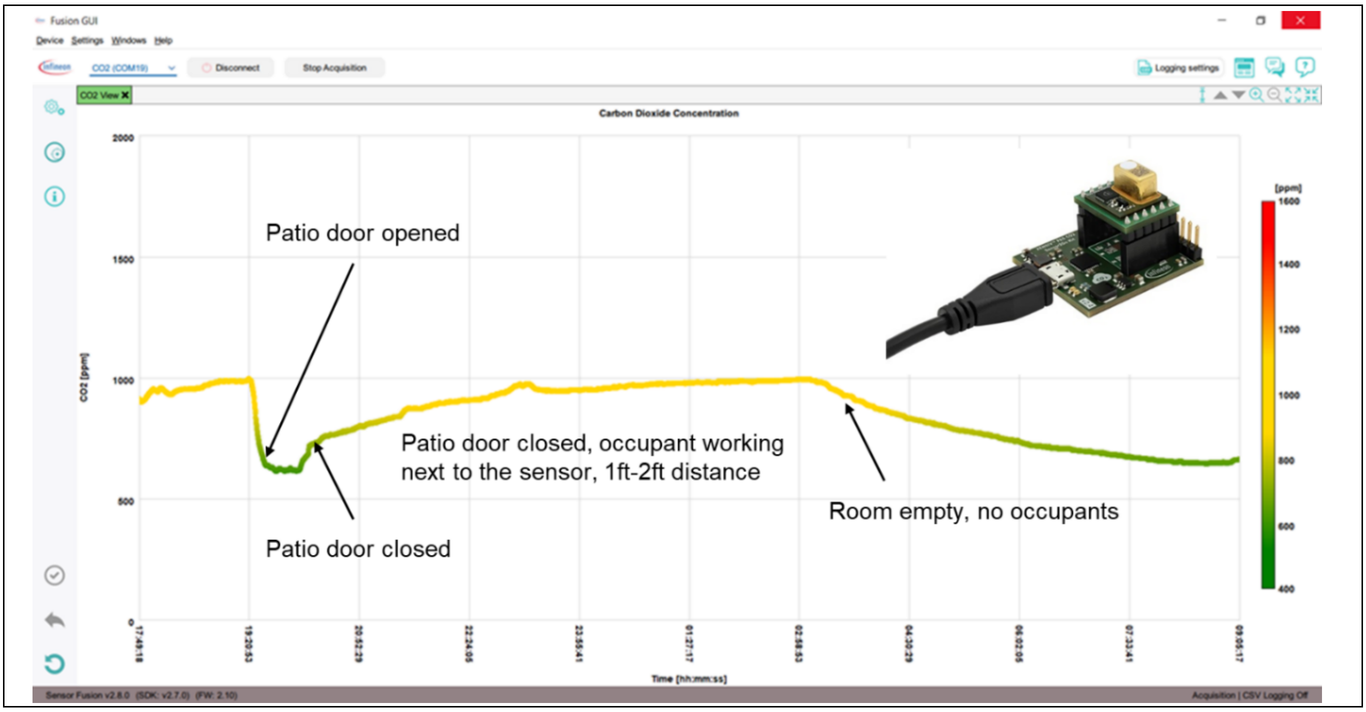

Figure 2 CO₂ monitoring in a home setting, 26 ft x 21 ft space, with 1 occupant

Figure 3 displays CO_2 monitoring in an office setting with up to 3 occupants (masked and talking) present at all times in a 20 ft x 14 ft fully air-conditioned room. The starting air quality is at a lower level (fully air-conditioned and ventilated throughout the day) than Figure 2 but clearly shows an increase in CO_2 level when multiple individuals occupy the room. Note that during these readings, Infineon conducted tests that required opening the door regularly, which contributed to the higher quality of air even with three people occupying the room.

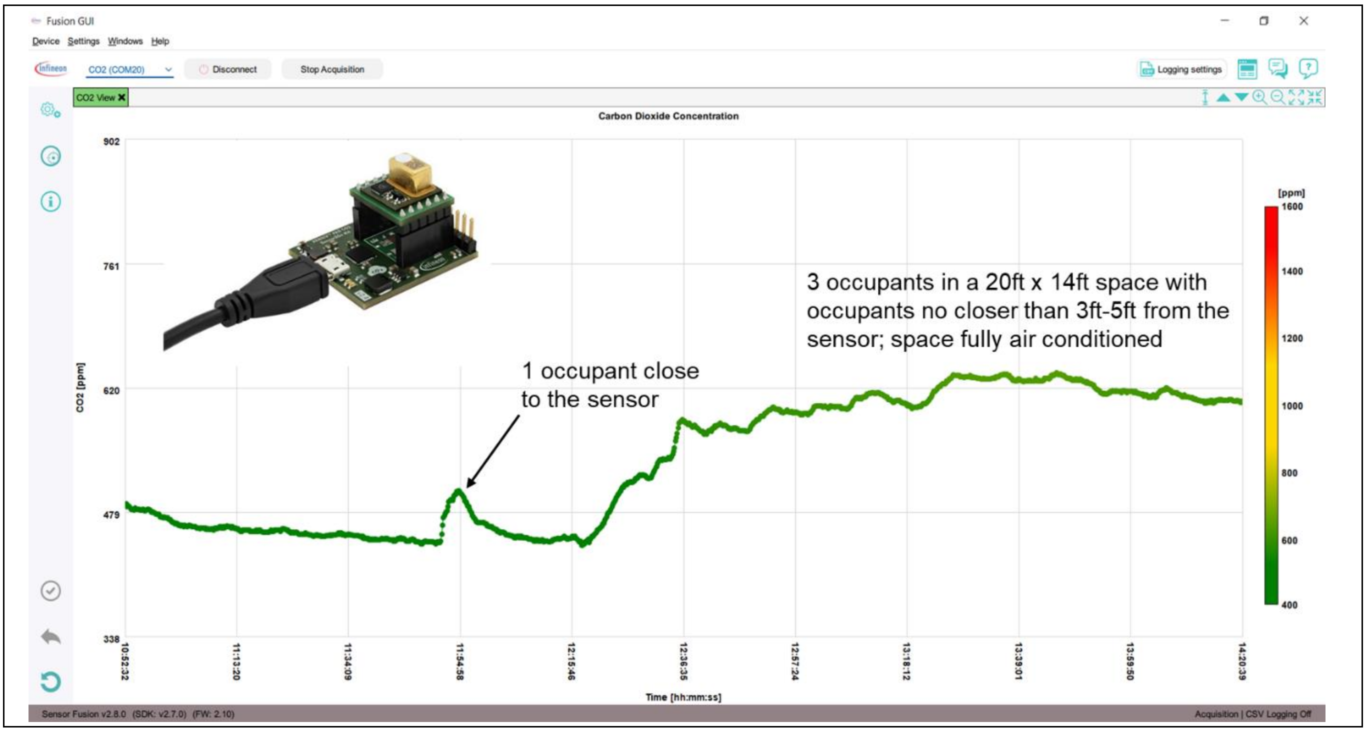

Figure 3 CO₂ monitoring in an office setting, 20 ft x 14 ft space, with 3 occupants

Figure 4 shows more detailed measurements (than Figure 2 and Figure 3) using multiple conference rooms of various sizes, well-ventilated labs, and open cubicle spaces with occupancies of 5-18 individuals (fully masked) over the course of 6-7 hours. However, one can clearly see the CO_2 content increasing when presenters took their masks off for more than 5 minutes or when more people started joining in the limited meeting space. Readings were taken every minute with swift updates to the graph, as depicted in Figure 4. This kind of monitoring becomes very important in smaller settings with increased occupancy and clearly shows the need for enhanced airflow.

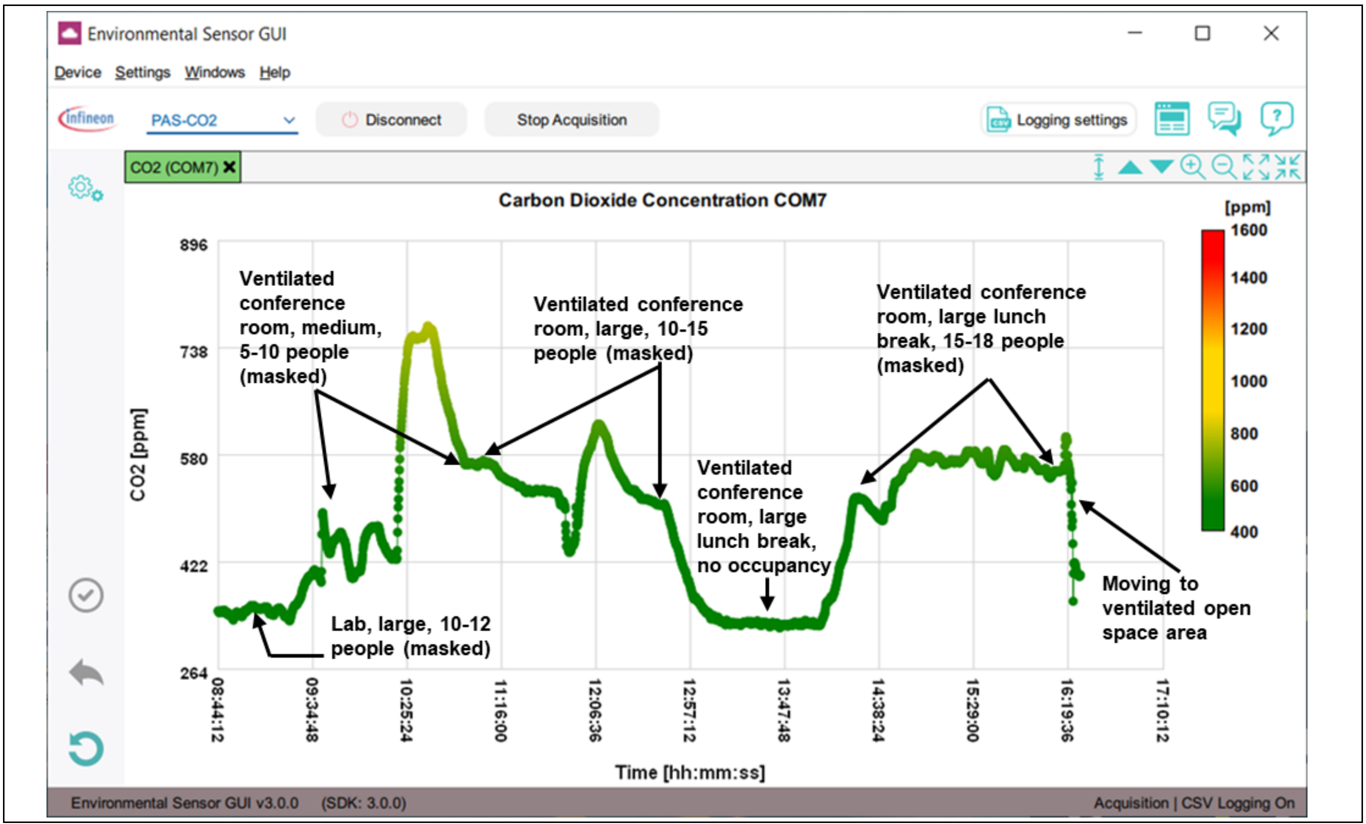

Figure 4 **CO_2 monitoring in different office settings with up to 18 occupants**

The data in Figure 5 was taken at a local bowling alley with about 35-40 masked persons occupying a rather large space. Most individuals gathered around the seating area near the bowling lanes. The typical bowling lane measures about 60 ft in length and 3.5 ft in width. The bowling venue where these measurements were taken included 10 lanes plus a spacious seating/resting and entertainment area behind the lanes. The total monitored space for these measurements included at a minimum 80-100 ft in length and 60-70 ft in width, making the area around 4,800 sqft to 7,000 sqft.

The peaks in the CO_2 levels (see specified areas in Figure 5) indicate close proximity of one or more persons to the sensor, as the sensor was placed on the back/arm-rests of the seating/resting area closest to the bowling lanes.

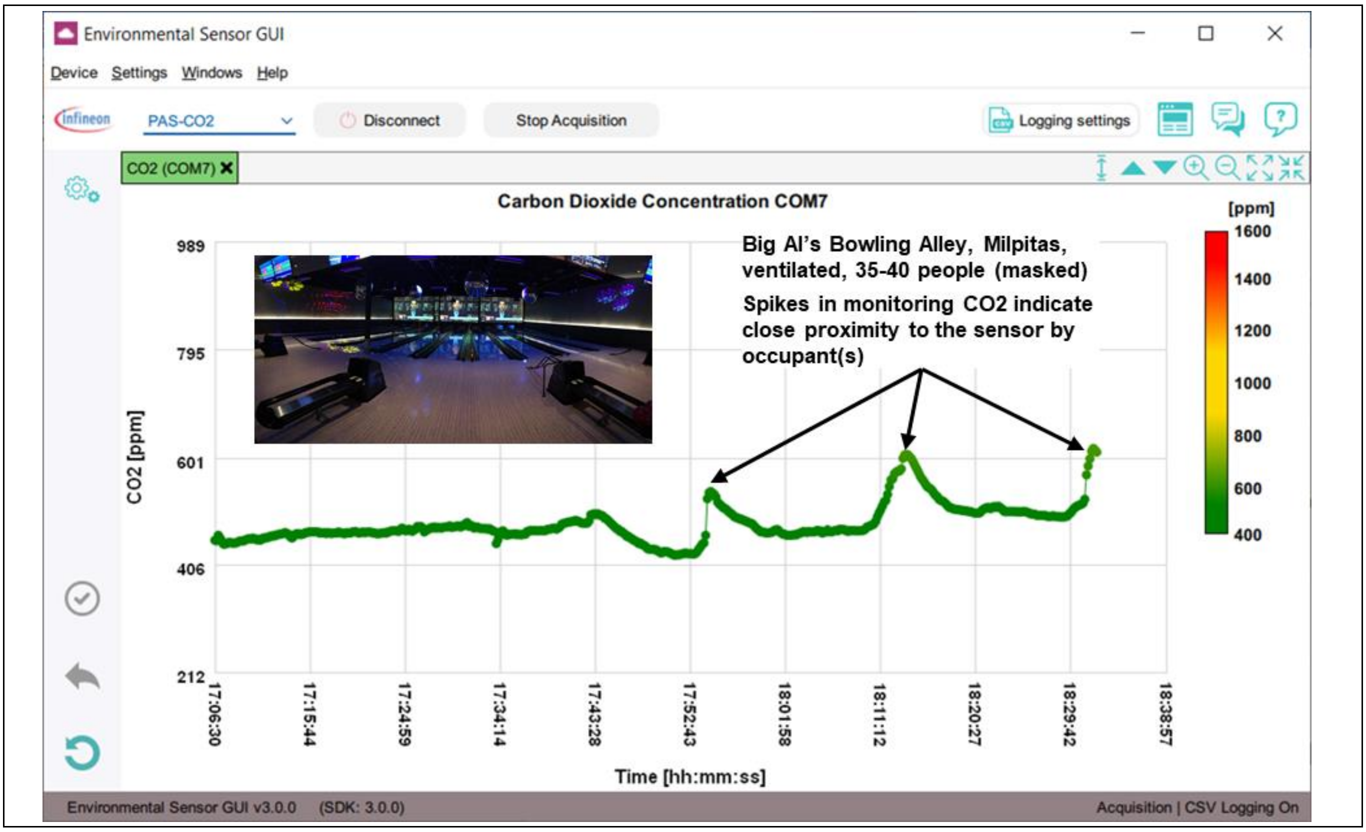

Figure 5 **CO_2 monitoring @ Big Al's Bowling Alley in Milpitas, CA (space size estimated 4,800-7,000 sqft with an occupancy of 35-40 masked individuals)**

3 Conclusion

The California Energy Code (Title 24, Part 6) has stringent performance requirements for DCV, which emphasizes both HVAC energy savings and indoor air quality. Infineon’s PAS CO2 is the only gas sensor on the market today that meets all of California’s Title 24 mandatory building code requirements.

Monitoring your home, office, or public space with Infineon’s XENSIV™ PAS CO2 sensor will not only assist with the optimization of the air quality in that environment, but it will also improve building energy consumption, reduce its carbon footprint, as well as increase occupant productivity (lower CO_2 levels enhance concentration, focus, and cognitive abilities).

Measure what matters with Infineon’s XENSIV™ PAS CO2 sensor for improved health, productivity, and overall well-being. To find out more, make sure to visit www.infineon.com/xensiv

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