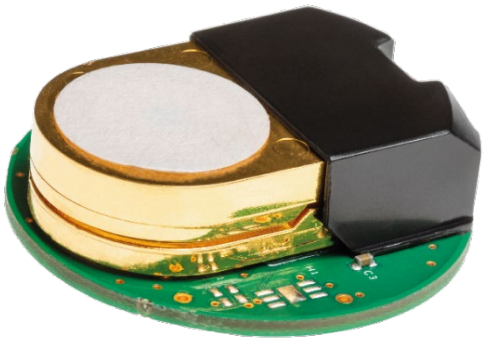
# AN006: $CO_2$ Sensor Analogue Output Voltage

**ABSTRACT**

GSS sensors are designed to measure $CO_2$ levels in variety of applications.

Typically, measurement data is accessed through either a UART or $I^2C$ digital interface. In some circumstances, this interface mode may not be suitable.



In such cases, some GSS sensors come with a true analogue $CO_2$ level indicator output, where the analogue signal level voltage is directly proportional to the $CO_2$ gas level.

This application note describes how the GSS voltage level indicator functions and how to ensure the user maximises the performance of the sensor using this indication method.

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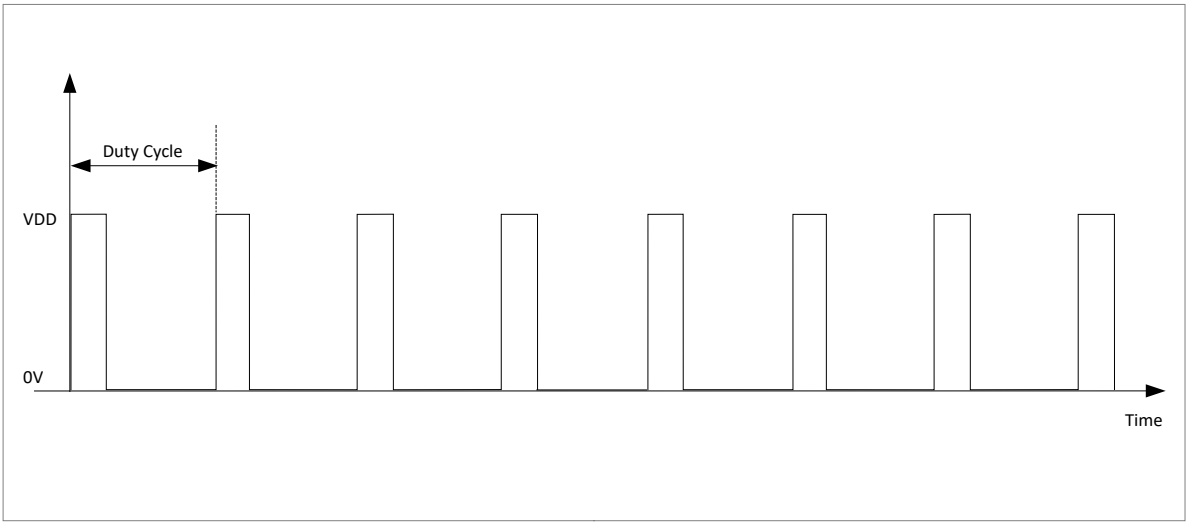
## METHOD OF OPERATION

The user can specify an analogue $CO_2$ level indication option on a number of GSS $CO_2$ sensors. If specified as an option on the sensor, the output voltage level will be directly proportional to the measured gas level.

The on-board sensor microprocessor generates a PWM output with a duty cycle proportional to the $CO_2$ signal level. There are a number of methods to use the PWM output. In some circumstances, the digital PWM signal can be used directly. This method is not supported by GSS sensors as it offers little advantage over and above the UART or $I^2C$ interface.

All GSS sensors provide a genuine analogue signal level output. The PWM signal could be filtered using a simple RC network, or filtered and buffered before being made available to the user. In normal circumstances, in order to maintain a constant output signal, the PWM signal must be run continuously, consuming unnecessary power.




However, in all GSS sensors where there is an analogue output $CO_2$ signal level option, GSS has chosen to implement a more sophisticated analogue output option, that saves power and does not need any external components.

The on-board PWM output is switched on in synchronisation with the sampling period. The digital PWM signal is filtered to create an analogue output, and the signal sampled by the sample and hold circuit. Once the signal is sampled by the sample and hold circuit, the PWM output from the microprocessor is stopped. This reduces noise in the sensor increasing measurement accuracy, and dramatically reduces sensor power consumption. Power consumption can be reduced by as much as 50% compared to a continuously running PWM output.

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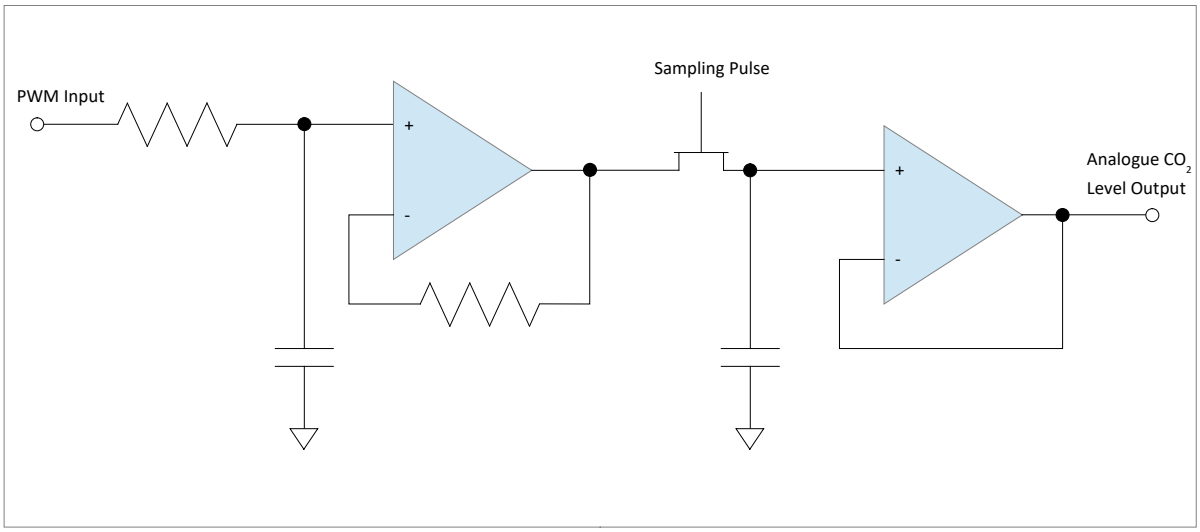


## ANALOGUE $CO_2$ SIGNAL LEVEL

The voltage range of the $CO_2$ level output from the sensor is determined by the sensor supply voltage. The sensor supply voltage defines the PWM signal levels. All voltage outputs are relative to the sensor input supply voltage. For example, if the supply voltage is 3.4V, then the full-scale output from the voltage pin will also be 3.4V, the half scale voltage will be 1.7V etc.

To convert a voltage into a $CO_2$ concentration, use the following formula.

$$Concentration\ (ppm) = \frac{Vout}{Vsupply} * Full\ Scale\ Range\ of\ Sensor\ (ppm)$$

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### $CO_2$ ANALOGUE OUTPUT PERFORMANCE CHARACTERISTICS

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| Output voltage range[1, 2] | ANALOGUE_OUTPUT | | 0 | | VDD | V |
| Repeatability | | @25°C | | ±0.1 | | °% |
| Response time | | From 0ppm to $T_{90}$ default settings | | 0.5 | | secs |

**Notes**

The output $CO_2$ accuracy is degraded where ANALOGUE_OUTPUT <50mV, or >VDD–50mV
ANALOGUE_OUTPUT accuracy specified with a resistive loading @ >100Kohm

The $CO_2$ sensor voltage output pin has an internal resistance of approximately 150Ω. The internal capacitance between the voltage output pin and ground is 220nF. This gives the output a single order high frequency roll-off at about 4.8kHz.

To avoid loading issues affecting the measurement, it is essential to ensure the load connected to the voltage output pin is greater than 10kΩ and preferably greater than 100kΩ. A low value external load resistance will introduce reading errors as illustrated in the table below.

| EXTERNAL LOAD RESISTANCE (OHMS) | $CO_2$ MEASUREMENT ERROR |
|---|---|
| 4k7 | 3% |
| 10k | 1.5% |
| 100k | 0.1% |
| 500k | 0.03% |

The $CO_2$ analogue signal level accuracy is also affected by op-amp DC offsets and op-amp signal headroom. At low $CO_2$ concentrations, the DC offset of approximately 14mV will increasingly affect the signal level accuracy. At high $CO_2$ concentrations, the $CO_2$ analogue signal level is unable to generate a voltage of more than VDD-50mV. The user is advised to take care when interpreting $CO_2$ analogue signals below 50mV and or where the signal level is >VDD-50mV.

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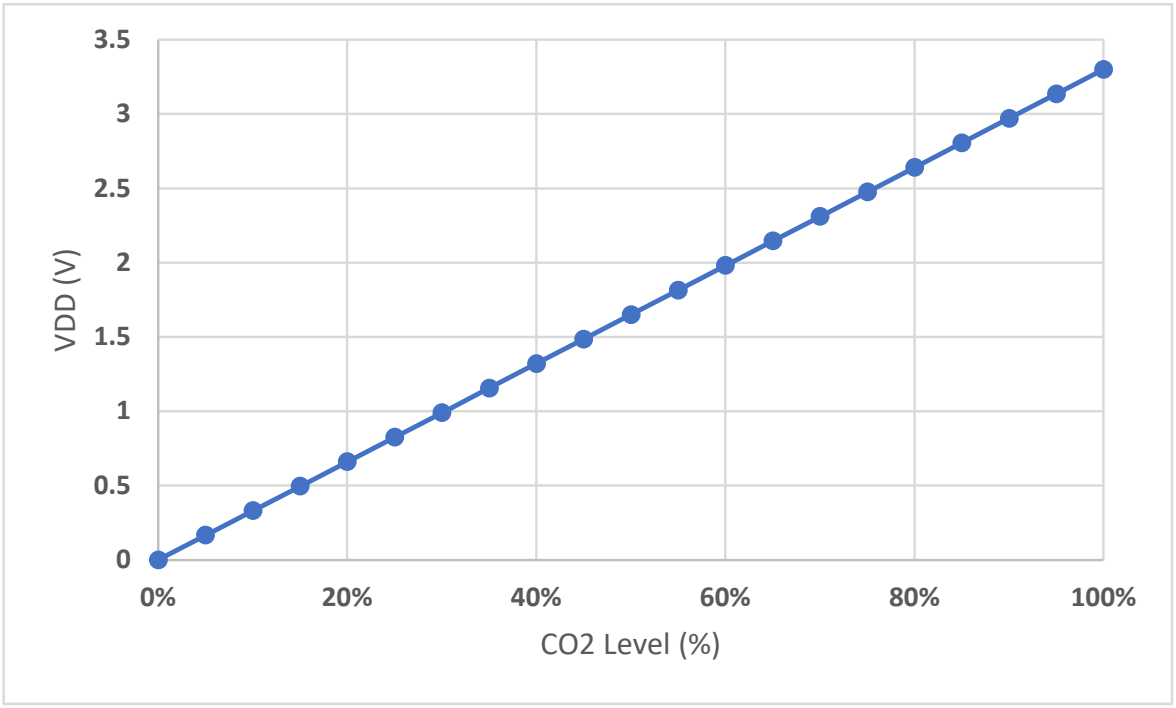
Although great care has been taken to minimise sensor noise, there may be some high frequency noise present on the analogue voltage output. The typical noise present on the voltage output is as follows with the voltage output at half full scale:

140µVrms measured in a 20kHz bandwidth.
450µVrms measured in a 10MHz bandwidth.

In a 10MHz bandwidth, the highest noise voltage amplitude is at least 70dB below the desired DC output voltage.

**OUTPUT LINEARITY**

The output voltage is linearly dependent on the $CO_2$ concentration measured by the sensor. However, as noted in the $CO_2$ analogue output performance characteristics, the accuracy of the reading will be compromised close to zero and near to full scale.



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## SPECIFYING A VOLTAGE OUTPUT OPTION

The ordering guide for the CozIR®-A is shown below, but an analogue $CO_2$ signal output is available on several other GSS sensors. Refer to the specific sensor data sheet ordering information to determine if the option is available.

The full-scale analogue output signal range always matches the selected measurement range of the sensor. This means when the output signal level is full scale, the $CO_2$ level will be at full scale.

**COZIR-A-X-XXXX-X**

| X | Measurement Range |
|---|---|
| 2000 | 2,000ppm |
| 5000 | 5,000ppm |
| 1 | 10,000ppm (1%) |

| X | Pin Position |
|---|---|
| RA | Right Angled |
| Blank | Standard |

| X | Temperature Range |
|---|---|
| E | Extended, -25 to 55°C |
| Blank | 0 to 50°C |

| X | Temperature and RH |
|---|---|
| H | Included |
| Blank | Not included |

| X | $CO_2$ Voltage Output |
|---|---|
| V | Included |
| Blank | Not included |

| X | Casing |
|---|---|
| U | Uncased |
| X | Cased |

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**REVISION HISTORY**

| DATE | RELEASE | DESCRIPTION OF CHANGES | PAGES |
|---|---|---|---|
| 13/05/2020 | 1.0 | First revision | All |
| 18/05/2020 | 1.1 | Re-write | All |
| 24/02/2022 | 1.2 | Order Information | P.7 |

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