AN014: OPERATION OF AUTO-ZERO

ABSTRACT

All GSS sensors are calibrated for accuracy at the factory at multiple different gas concentrations and temperatures. In use, the sensor reference level will change, due to changes in the optical surfaces, accumulation of dirt in the sensor and other degradations. Although the wavelength of the light being emitted by the LED is not affected, the impact of these changes will be to reduce the signal level received by the photodiode in the sensor.

The relationship between CO_2 concentration and measured CO_2 remains linear over time. However, the reference levels may change compared to those stored in the sensor when it was shipped from the factory.

The change in reference level of the sensor can be cancelled out using a process known as zero-setting, sometimes known as baseline correction. This process resets the sensor to a defined concentration level. The sensor zero-point can be reset by the user, or in some circumstances, the sensor can operate fully autonomously and periodically 'auto-zero' without user intervention.

This application note describes how the auto-zero function works in the CozIR family of CO_2 sensors. Each member of the family has an auto-zero function that is enabled by default.

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BASIC PRINCIPLES FOR ALL COZIR® FAMILY SENSORS EXCEPT COZIR®-BLINK
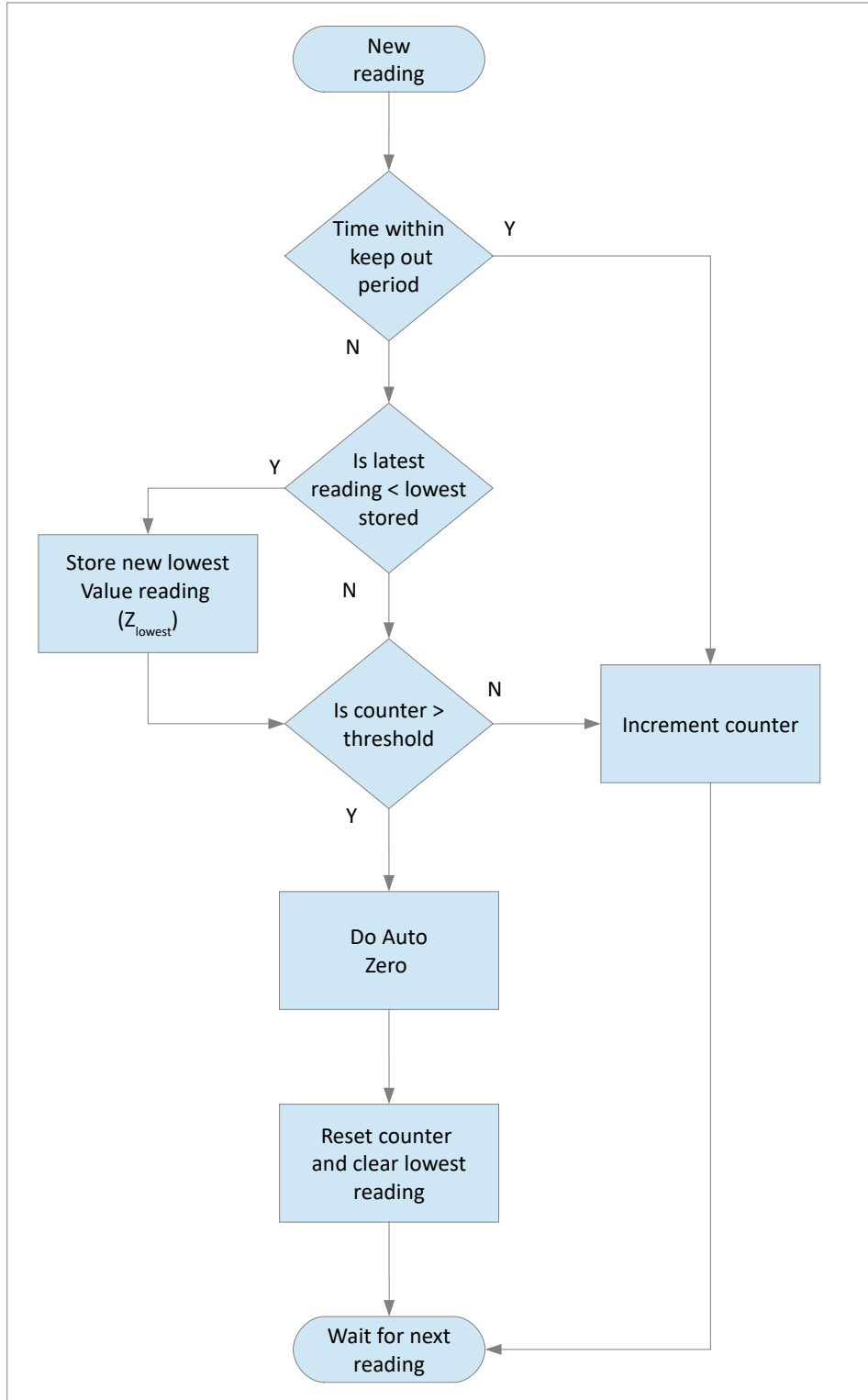
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After the sensor is powered on, it automatically starts taking CO_2 measurements. The sensor can output raw CO_2 measurements and a filtered version of the raw data, referred to in this document as a *reading*. The filter is a customer defined variable but is set to 16 by default.

The exception to this modus operandi is the CozIR®-Blink. It automatically takes a series of measurements, filters them and outputs a single reading. It will not take any more measurements until it is power cycled, where power is switched off and back on again. It will only take one set of measurements per power cycle.

An internal counter keeps track of the number of measurements that have been taken, or as in the case of the CozIR-Blink, the number of power cycles. Once the counter has exceeded the minimum threshold value, an auto-zero sequence is actioned.   The timing of the auto-zero sequence is a variable, with recommended default values for all CozIR family sensors.

All CozIR® ambient sensors have the auto-zero function enabled by default although it can be switched off. The auto-zero function is re-enabled by sending them an auto-zero period value. Assuming the auto-zero function is active, an auto-zero sequence is triggered when the counter equals or exceeds the minimum counter threshold value and the auto-zero value has been reached.

In the CozIR family of sensors, there is a minimum value for the initial auto-zero period, listed below.

UART Mode Minimum Counter Threshold (Excluding CozIR-Blink)

Auto-Zero Period	Minimum Value	Maximum Value	Default Value	Resolution
Initial Auto-Zero	0.1 days	37.9 days	1 days	0.1 day
On-Going Auto-Zero	0.1 days	37.9 days	8 days	0.1 day

I²C Mode Minimum Counter Threshold (Excluding CozIR-Blink)

Auto-Zero Period	Minimum Value	Maximum Value	Default Value	Resolution
Initial Auto-Zero	0 hrs	65535	12096	1
On-Going Auto-Zero	0 hrs	65535	13824	1

In I²C mode, the time-period is calculated as follows.

- On-going Auto-Zero I²C Value = Interval Time x 72 (hours)
- Initial Auto-Zero I²C Value = (Interval Time – Initial Time) x 72 (hours)

All I²C times are expressed in hours.

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CozIR®-Blink Minimum Counter Threshold

For the CozIR®-Blink, the auto-zero minimum threshold value is set to 50 power cycles. If the auto-zero value is set to 50, the auto-zero is done on the 51st power cycle and actioned before the filtered reading is made available by the sensor. It is recommended that the time period between auto-zero events is set to a minimum of several days to ensure consistent performance.

STORING THE LOWEST CO_2 READING IN AUTO-ZERO MEMORY

All GSS sensors keep an internal record of the lowest measured CO_2 reading in internal sensor memory (Z_{lowest}) as long as auto-zero is enabled. The sensor also keeps a record of the last CO_2 reading.

For the CozIR®-Blink, to improve performance, every time the sensor calculates a new reading, the previous and current values are filtered to create a new value (Z_{new}).

$$Znew = \frac{Zcur - Zprev}{2} + Zprev$$

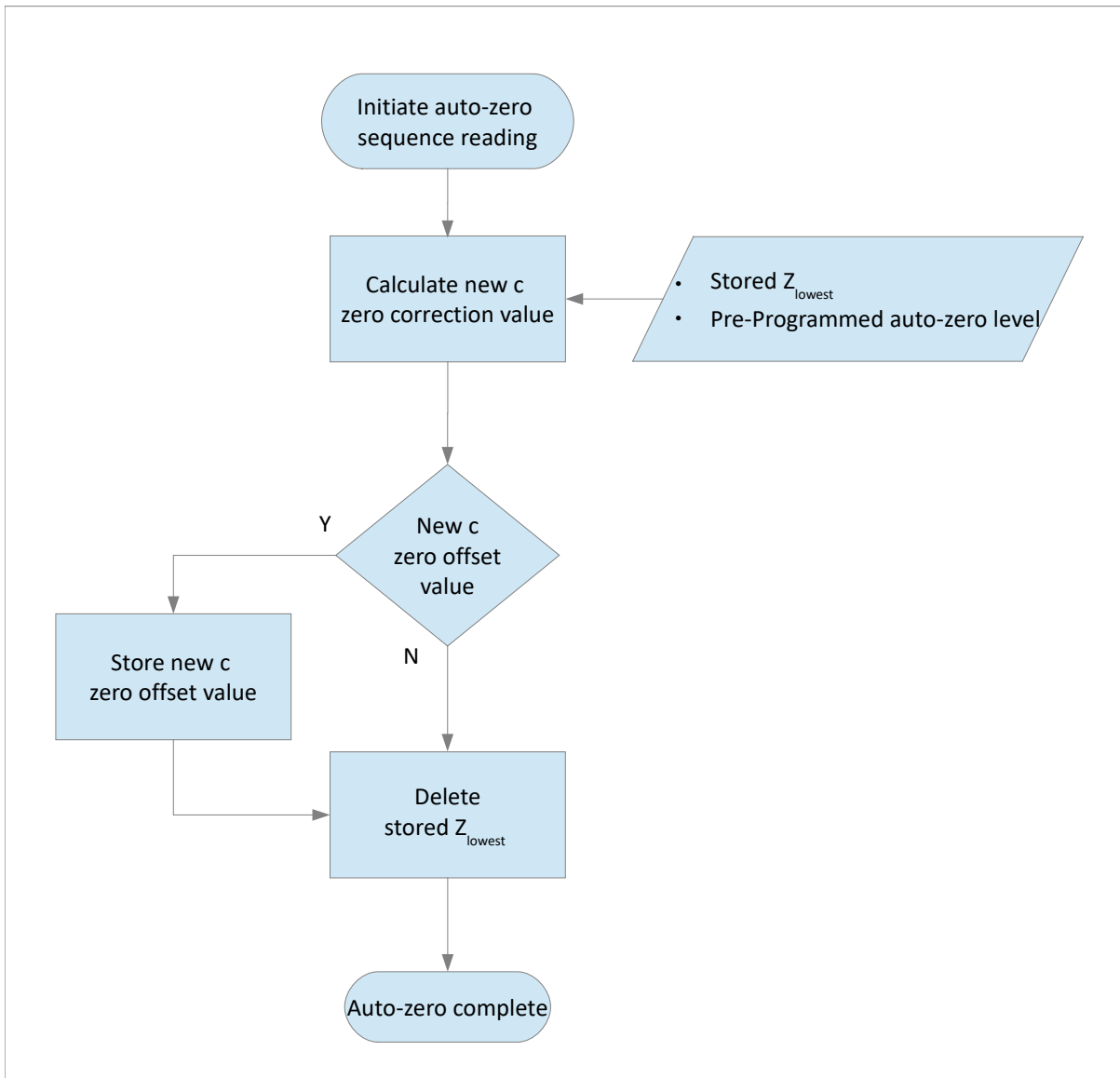If the value of Z_{new} value is lower than the stored Z_{lowest}, Z_{lowest} is updated.

For all CozIR® sensors, the operation of these processes is completely automatic and done on-board the sensor if auto-zero has been enabled. Auto-zero must be enabled before the sensor will start recording the lowest value. Note that except for the CozIR®-Blink, the Z_{lowest} value is not retained after a power down.

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AUTO-ZERO SEQUENCE

When the auto-zero function is run, the sensor will reset the fresh-air zero point using Z_{lowest} and the pre-programmed auto-zero value. The value used by the sensor for this fresh-air zero-point is user programmable. The sensor default value for CO_2 in fresh air is 400ppm.

-

```
        ┌──────────────────────┐
        │  Initiate auto-zero   │
        │  sequence reading     │
        └──────────┬───────────┘
                   │
        ┌──────────▼───────────┐         ╱────────────────────────╲
        │  Calculate new c     │◄────────  • Stored Z_lowest        
        │  zero correction     │         ╲ • Pre-Programmed        ╱
        │  value               │            auto-zero level
        └──────────┬───────────┘
                   │
              ◆◆◆◆◆◆◆
       Y  ◆   New c    ◆
    ┌─────◆ zero offset ◆
    │     ◆   value     ◆
    │        ◆◆◆◆◆◆◆
    │           │ N
┌───▼──────┐    │
│ Store    │    │
│ new c    │    │
│ zero     │    │
│ offset   │    │
│ value    │    │
└───┬──────┘    │
    │    ┌──────▼───────┐
    └───►│   Delete     │
         │ stored       │
         │ Z_lowest     │
         └──────┬───────┘
                │
         ┌──────▼───────┐
         │ Auto-zero    │
         │ complete     │
         └──────────────┘
```

At the appropriate time, or after the pre-programmed power cycle count in the case of the CozIR®-Blink, the sensor will run the auto-zero sequence. The auto-zero sequence is a *mathematical function* designed to re-baseline the sensor. It is not a separate CO_2 measurement sequence. For the purposes of illustration, this application note assumes the relationship between the sensor reading output and the gas concentration input is defined by the linear equation as follows.

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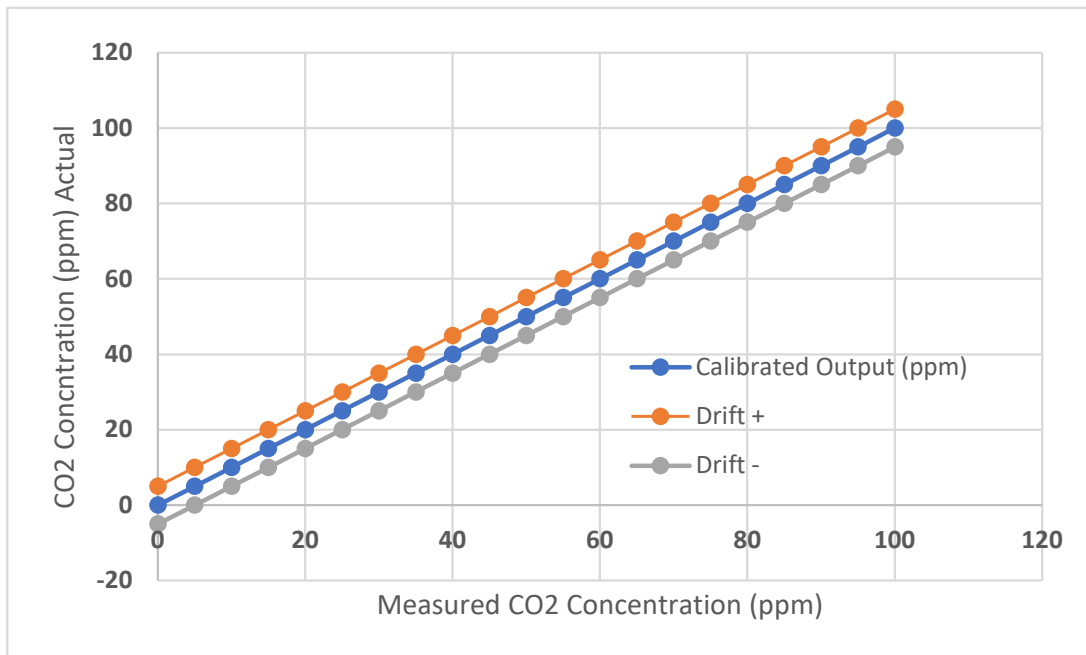
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$$Y = mx + c$$

Where Y = CO_2 reading from the sensor

m = Scaling factor, set at the factory, fixed for the lifetime of the sensor

x = CO_2 gas concentration input

c = Zero offset value

When the sensor leaves the factory, c = 0. However, over time and due to other environmental factors, the sensor can drift and gives rise to a non-zero offset value for c. The purpose of the auto-zero sequence is to re-baseline the sensor and reset c to a defined value.

The actual process is significantly more complex than the illustration but uses the same data inputs, the current zero value, the lowest CO_2 value over the auto-zero period and the assumed lowest gas concentration value seen by the sensor over the period, defaulted to 400ppm.

By way of illustration, assume the Z_{lowest} value stored in auto-zero memory is 450ppm. And assume the pre-programmed auto-zero value is 400ppm. The sensor calculates the difference between the $Z_{lowest,}$ and the stored auto-zero value. In this case, the difference is 50ppm and the new value of c = -50ppm.

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All subsequent on-board sensor measurements will use the new value of c to calculate each new measurement until the next auto-zero event. The stored Z_{lowest} value is then cleared, and the sensor begins the process again of recording the lowest measured CO_2 reading.

SENSOR READINGS AFTER AN AUTO-ZERO SEQUENCE

After an auto-zero sequence, the new zero offset value will be used on the next measurement and all subsequent measurements until the next auto-zero sequence. Due to the operation of the filter, the new auto-zero offset value will only affect the latest measurement in the filter calculations. Even if the auto-zero adjustment is significant, there is typically only a small change observed in the output reading due to the operation of the filter.

For the CozIR®-Blink, no change is made to the current reading after an auto-zero event. The sensor will calculate a single reading, and then run the auto-zero sequence. The new zero offset value will be used on the next set of measurements after a power cycle.

CONCLUSION

The GSS auto-zero sequence is a completely automatic process that does not require any host intervention, timing control or data storage. All parameters for the process are defined as part of the sensor setup configuration and thereafter are stored and calculated on-board the sensor.

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REVISION HISTORY

DATE	RELEASE	DESCRIPTION OF CHANGES	PAGES
07/03/2022	1.0	First revision	All