CO_2 Sensor Module – RX-9

EXSEN EXSEN Inc.

Product Overview

Carbon dioxide gas sensor: RX-9

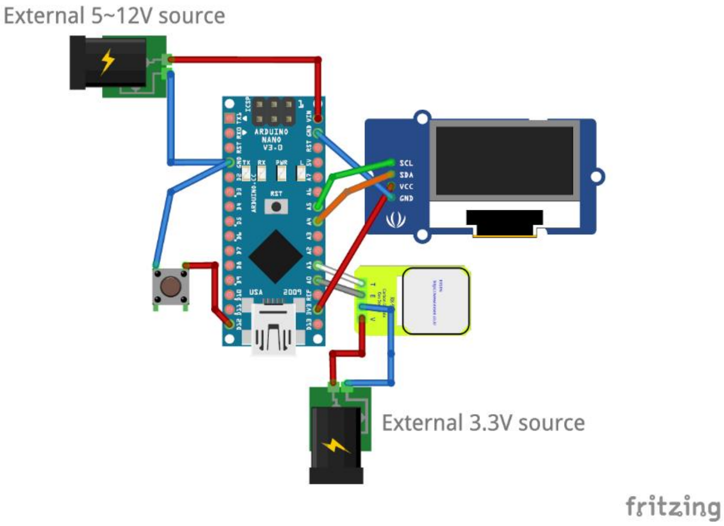

Figure 2 Arduino wiring

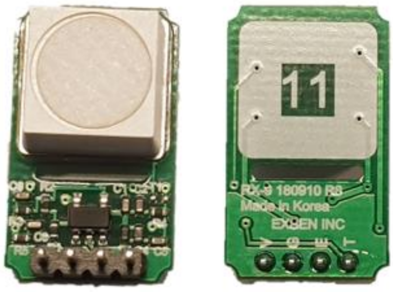

Figure 1 RX-9, RX-9 Simple

Do you want to add carbon dioxide gas sensor functionality to your project or system very cheaply? The RX-9 can help you realize the CO2 sensor's functionality at a very low cost.

Carbon dioxide is a key determinant of indoor air quality. Generally, carbon dioxide is associated with the freshness of the indoor air quality in three criteria of the indoor air quality: comfort, cleanliness, freshness. It is the same reason as feeling refreshing in the forest.

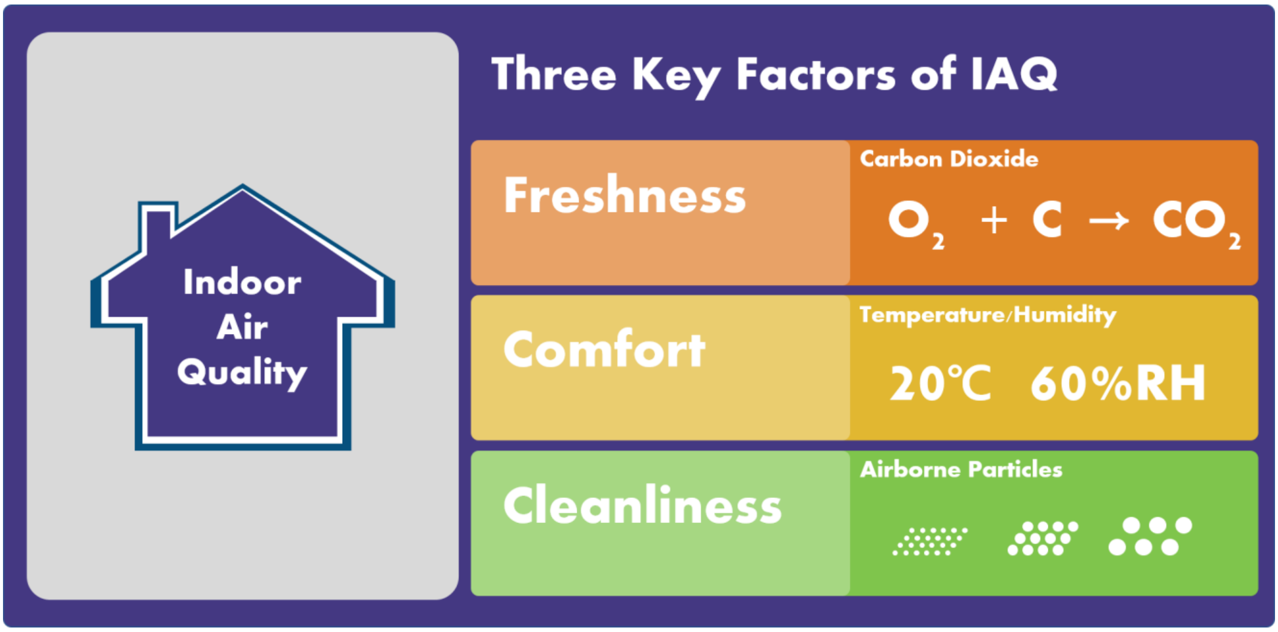

Figure 3 Three key factors of IAQ

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In recent years, studies on the relationship between learning and activity levels of brain and carbon dioxide concentration have been carried out, and the importance of carbon dioxide concentration in indoor air quality has been emphasized. The results of this study (“A study of CO2 influence on student activity in classroom”[1]) are summarized the concentration of carbon dioxide in the classroom is related to the test score. If concentration of carbon dioxide is higher, test score is lower. Considering that carbon dioxide consumes oxygen in the body and is a by-product, it can be easily deduced from the relationship that the carbon dioxide concentration is high, that is, if it is thought that oxygen is insufficient to affect the brain, which has been experimentally verified.

In addition, it can be applied to prevent drowsiness inside the vehicle because it can cause accidents due to the increase of carbon dioxide concentration in the vehicle (oxygen shortage) even when driving for a long time. Normally driver can sleepy when indoor carbon dioxide concentration is more than 1,000 ppm. However, in the summer / winter, when the air circulation system of the vehicle is operated in inner circulation mode, 1,000 ppm is easily reached, and 5,000 ppm is easily reached in 30 minutes.

Therefore, the application of the carbon dioxide sensor as an auxiliary function for preventing the driver from knowing It is actively being done. And already in the market there is a product that uses carbon dioxide sensor as a indicator of drowsiness on dashcam.

The RX-9 is a sensor that implements the market's accuracy, price competitiveness, miniaturization and long life. It is the best price competitiveness, minimum size (20 mm x 12 mm) It has a life span of about 10 years.

In addition, the RX-9 offers two modes. The RX-9 Simple is suitable if the concentration of carbon dioxide you want to display in the system you want to implement is step or color, and you can use the RX-9 if you need the concentration output (ppm).

Most sensors undergo a calibration process to display the correct value and store the calibration information in memory to display the correct value. Some of the sensors provided by EXSEN have memory calibration information as mentioned above, but some products do not provide memory devices like RX-9 series (RX-9, RX-9 Simple).In order to provide calibration information among RX-9 series, it is RX-9 that has separate calibration information on the back of RX-9, and RX-9 Simple without additional calibration information.

The RX-9 incorporates the information of the QR code attached to the rear side in the calculation algorithm of the MCU connected to the RX-9, so that the accuracy is maintained even in the case of ppm output. The QR code data must be matched between the system and RX-9 at 1: 1 when the product is manufactured.

Figure 4 how to calibrate RX-9

[1] A study of CO2 influence on student activity in classroom, Revista Romana de inginerie Civila, Volumul 4(2013), Numarul 2

The RX-9 Simple is implemented with simple code without the hassle of QR code matching. Because it is implemented without calibration information, it is more suitable to use for step (color) output than for ppm output.

Arduino Wiring

Arduino Nano/Uno compatible

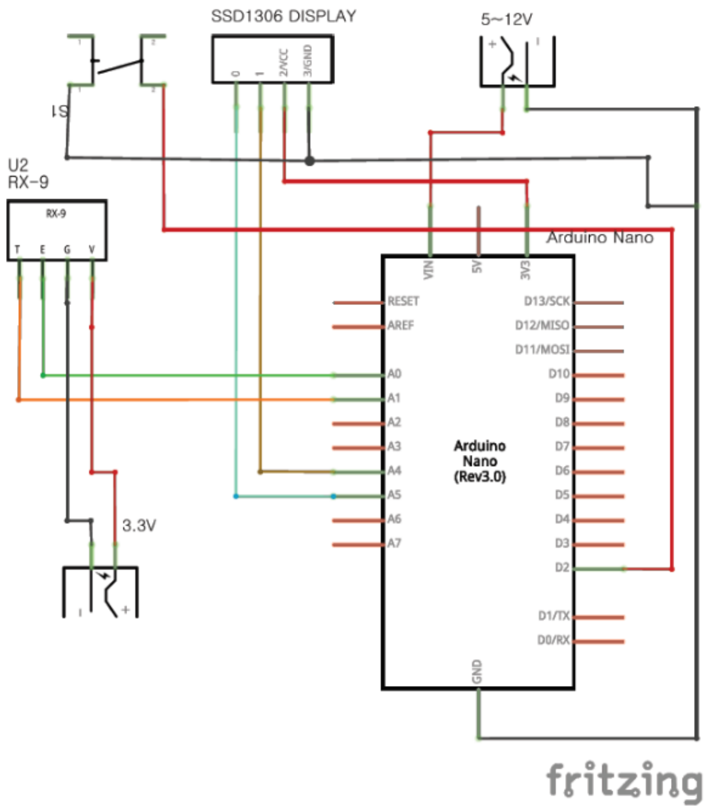

Figure 5 Schematics of Arduino with RX-9

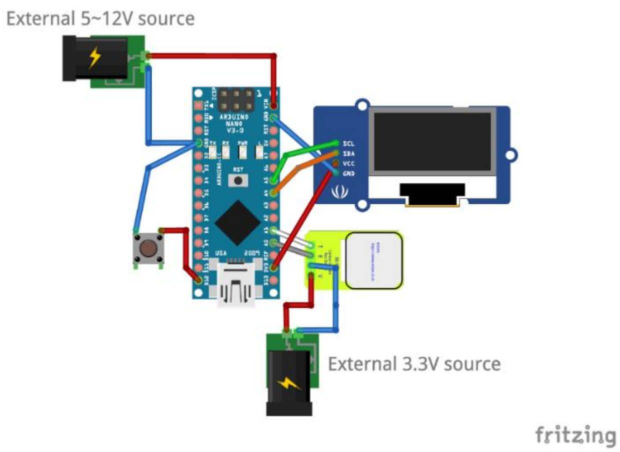

Figure 6 Arduino wiring

Arduino nano to RX-9

- RX-9 E -- Nano A0
- RX-9 T -- Nano A1
- RX-9 V -- Power Supply(3.3V) 3.3V +
- RX-9 G -- Power Supply(3.3V) GND –

Arduino nano to SSD1306

- SSD1306 SDA -- NANO A4
- SSD1306 SCL -- NANO A5
- SSD1306 VCC -- NANO 3.3V
- SSD1306 GND -- NANO GND

Arduino nano to SW

- SW 1) -- NANO D2
- SW 2) -- NANO GND

Arduino nano to Power Supply(5~12V)

- NANO Vin – Power Supply(5~12V) +
- NANO GND – Power Supply(5~12V) -

Caution

Do not connect 3.3V of Arduino to RX-9 VCC. RX-9 need over 100 mA @3.3V. Arduino can’t supply 100 mA to RX-9. So Use External 3.3V source or convert Voltage from 5V of Arduino to 3.3V with DC/DC regulator.

RX-9 Sensing Theory, Calculation Equation of CO2 concentration

Linearity by CO2 concentration

First, I will explain the simple RX-9 Simple. The RX-9 Simple is a step-marking sensor that provides an alarm for a specific concentration without ppm output. The RX-9 Simple is intended for low-cost, moderate-accuracy, and easy-to-use calibration data. The following is the measured data of the EMF signal of RX-9 according to CO2 concentration.

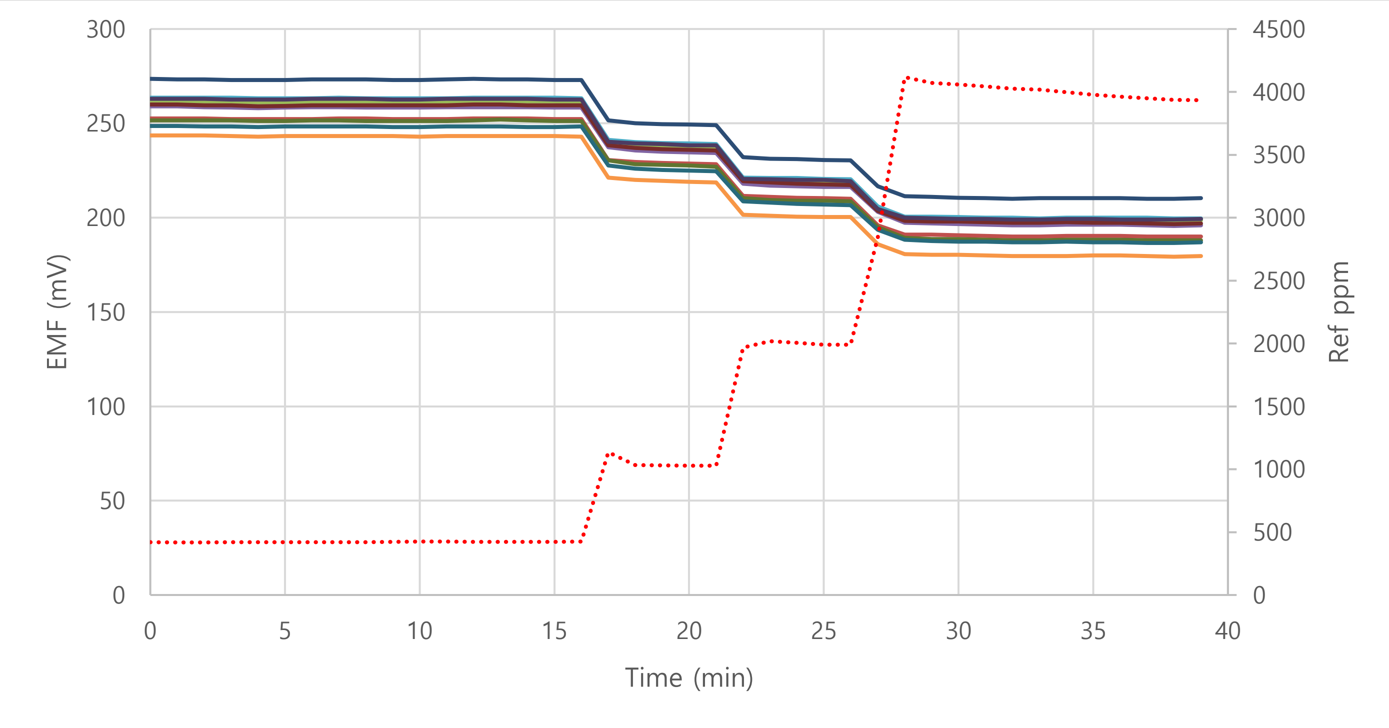

Figure 7 Graph of RX-9 EMF data compare with Ref

As you can see, you can see the change in the actual carbon dioxide concentration and the resulting change in the output signal of the RX-9.

The red dotted line graph is the CO_2 concentration data of the Ref instrument, and the other graph is the original signal (EMF) data of the RX-9 sensor. The EMF value of RX-9 decreases in the direction opposite to the increase of the carbon dioxide concentration, and the stairs are formed according to the concentration.

Notice that the staircase is formed, and the stairs are not tilted very much and are kept almost parallel to the x axis. If this is parallel to the concentration maintenance interval, it is a good sensor.

But there is a problem. Deviation between sensors is a problem. If you only want to create one sensor, you can use the above graph to create a sensor with correct values without calibration data (although the data above is the calibration data), but in the above case, Accuracy is too low. The concept of the RX-9 Simple is to produce a product with the correct accuracy without calibration data, which is likely to be in violation of the "correct accuracy" of the original production intent. So, let's extract the elements with small deviation between products from the above data. Let’s express the y-axis unit of the above graph as a ratio of the concentration-maintaining interval to the value at the 15-minute point as 100%.

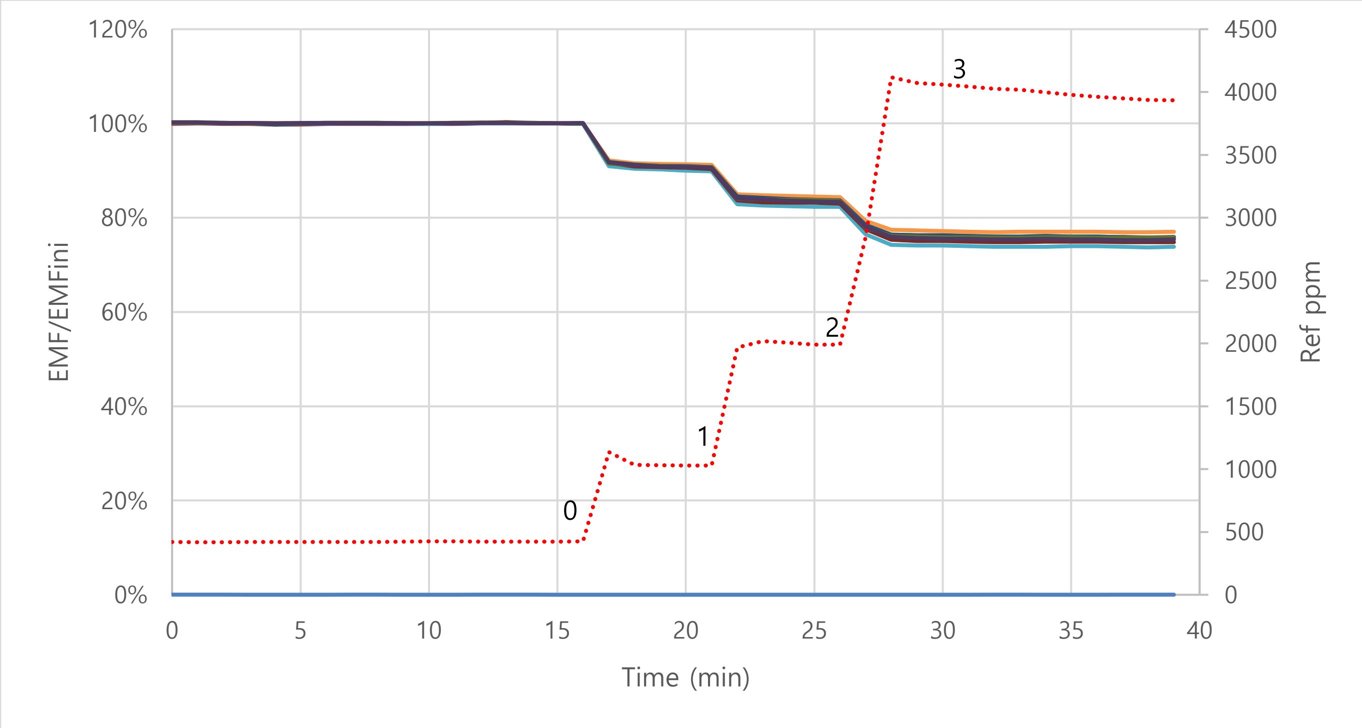

Figure 8 Graph of EMF/EMFini compare with Ref

If you keep the y axis as a percentage, can you see that the deviation between the sensors is reduced? Fortunately, the RX-9 sensor is a similar sensor with varying proportions of the original signal, even if the deviation is large. Deviations of this magnitude can produce products with reasonable accuracy.

Since RX-9 Simple is a sensor for step display, we will explain the case of displaying 0 ~ 3 step as follows.

- Step 0: 400~1000 ppm
- Step 1: 1000~2000 ppm
- Step 2: 2,000~4,000 ppm
- Step 3: >4,000 ppm

The steps are divided for illustrative purposes, and can be divided slightly more, or change the display reference concentration. the step is divided by the current output EMF divided by the lowest EMF of 0 level. Let's use the table to represent the graph in more detail.

STEP	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	Min	Max	AVG
0	100%												
1	90.49%	90.71%	90.71%	90.67%	89.85%	91.21%	90.76%	90.33%	90.75%	90.56%	89.85%	91.21%	90.60%
2	83.23%	83.72%	83.74%	83.57%	82.33%	84.36%	83.71%	83.01%	83.51%	83.31%	82.33%	84.36%	83.45%
3	75.31%	75.92%	75.88%	75.87%	73.82%	76.92%	76.00%	74.81%	75.78%	75.40%	73.82%	76.92%	75.57%

Figure 9 data of EMF/EMFini

- STEP 1 Averaged value: 90.60%
- STEP 2 Averaged value: 83.45%

- STEP 3 Averaged value: 75.57%

The min value and the max value of each step are distinguished without overlapping with other sections, showing a meaningful difference in values. Let's consider the standard value of 1,000 ppm as the first step. Based on the measured min value of 89.85%, only one sensor with the greatest change in carbon dioxide concentration will display the first step, and if the max value of 91.21%, all sensors will display the first step . Based on the average, some will display level 1 and some will not. There are many more things to worry about, but I'll draw a flowchart based on the average value.

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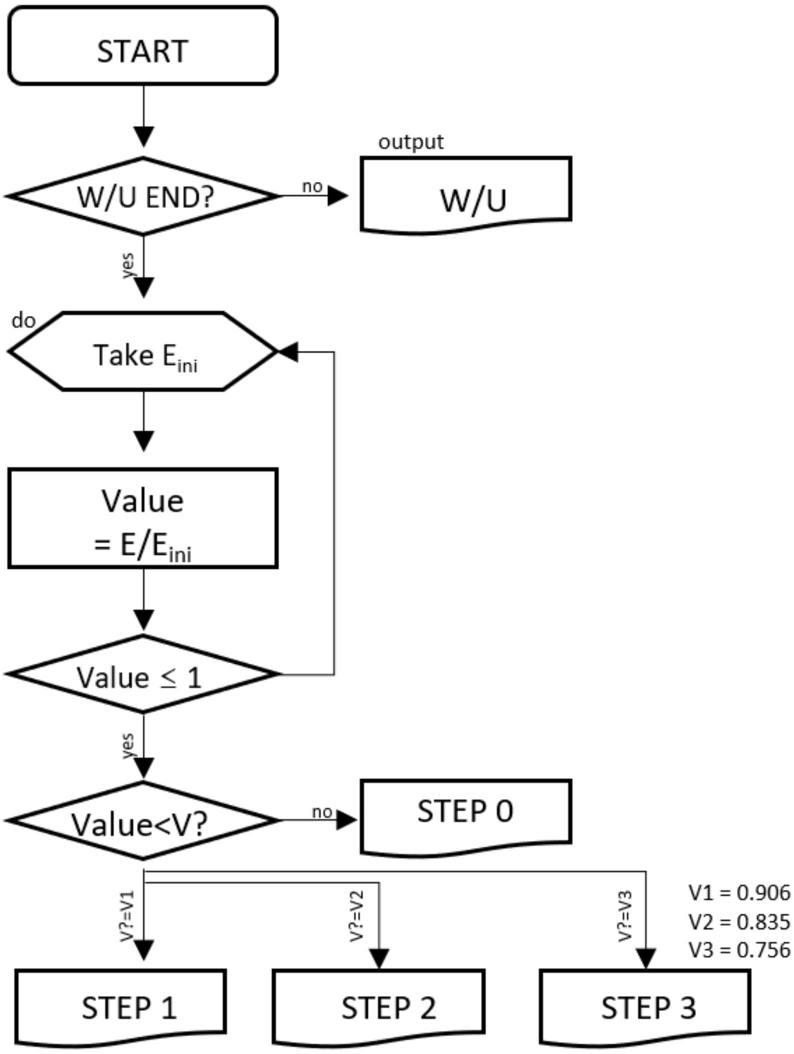


Figure 10 Flow chart of RX-9 Simple operation

- Power on the RX-9 Simple.
- W / U stands for warm-up. A stabilization time is required to select a small reference value, such as divided by 15 minutes in the graph above. Default is 3 minutes - When the W / U is finished, the current EMF value is selected as the Eini value. - Computes the Value value. E is the EMF value currently output.
- If Value ≤ 1, compare Value with V1, V2, V3. - If Value> 1, the stabilization time was not enough yet, or the ambient air at the time of selecting the Eini value was not clean enough. Again, the value of Value is calculated.
- Value ≥V1 Output: Step 0 - Value <V1 Output: Step 1 - Value <V2 Output: Step 2 - Value <V3 output: Step 3 - V1, V2, V3 are based on the average of each step calculated above.

I've summarized the RX-9 Simple in a more complex sequence than I thought. Coding as above will update the Eini value every time the sensor is turned on, so the Eini value will change each time. However, if the system remembers the Eini value, ignore the third step (Take Eini) in the flowchart and use the 1 - 2 - 4 ... You can proceed to step. This will prevent the sensor output from always starting from STEP 0, while selecting the Eini value immediately after the W/U and display the step to the actual ambient CO2 concentration after sensor restart.

However, this method is not always right. Because the sensor changes in the direction of decreasing the EMF value at the same carbon dioxide concentration as you use it, you need to change the Eini value as well. This is because the output of sensor (EMF) decreases as time elapses. The algorithm that helps to calibrate this change is called ABC LOGIC, which I will explain below.

The RX-9 is now explained. The RX-9 is a concept that allows 'ppm output' rather than 'reasonable accuracy' to 'low price', 'reasonable accuracy' and 'easy without calibration data'. Let's implement 'ppm output is possible' by using the same data of RX-9 Simple. We change the x axis of the graph used above to the output ppm of the ref sensor, let the y axis be EMF / EMFini and the x axis log scale.

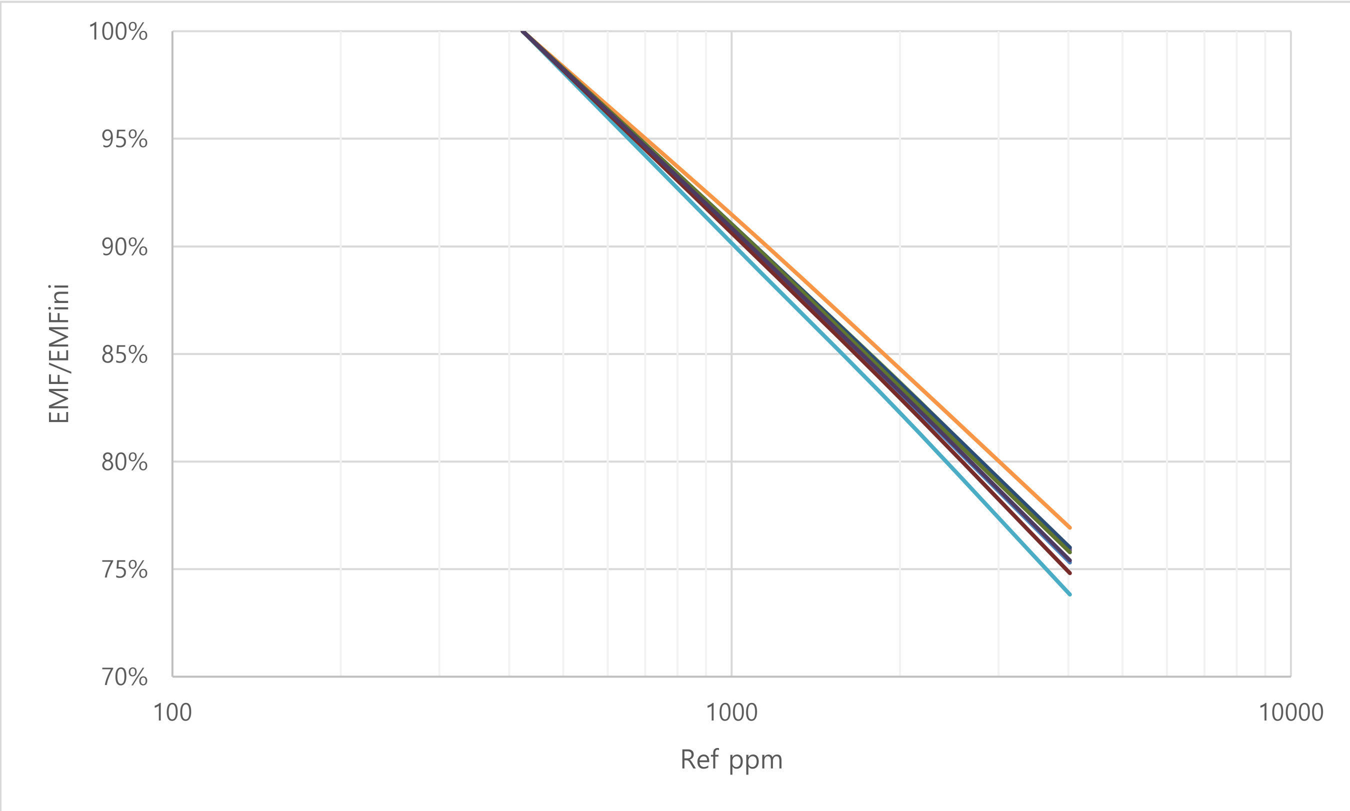


Figure 11 EMF/EMFini by Ref

Anybody who wants a sensor has a linear graph. It is ideal to have a linearity about the concentration of gas you are trying to detect. For a sensor that does not have linearity, divide the circle into several segments to ensure linearity, and divide the circle by division. It is very troublesome.

Fortunately, we have linear, so we will extract calibration data from this graph. Calibration data consists of the y-intercept and slope of the graph above. For convenience, y intercept is cal_A and slope is cal_B. One of the values already obtained (# 5) is as follows.

cal_A: 1.703

cal_B: 0.2677

The number will be calculated longer but will count as four significant figures. Please note that the x axis is a log scale and that the exponentiation formula appears.

$$\text{Concentration of } CO_2 = 10^{\frac{cal\_A - \frac{EMF}{EMF\_ini}}{cal\_B}}$$

Let's check it according to the formula above. cal_A = 1.703, cal_B = 0.2677, and EMF / EMF ini = 85%.

This is how the Excel calculation formula works.

Concentration of CO2 = power(10,(1.703-85%)/0.2677) = 1536

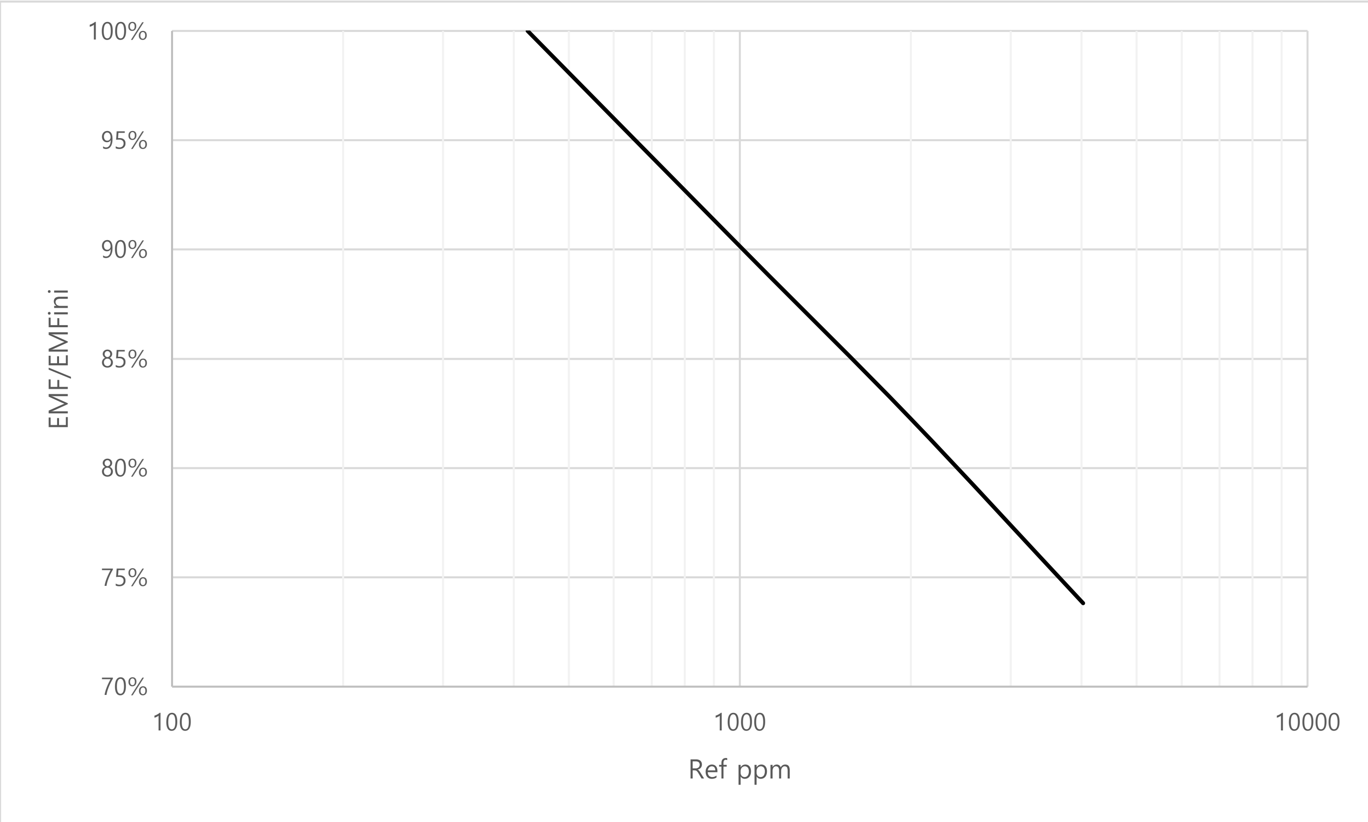


Figure 12 Graph of Example, EMF/EMFini by Ref

This simple calculation of CO2 concentration and the graph of the sample used for actual calculation are as follows.

In this graph, you can see that the calculation is correct even if you look for a value of 85%. Calibration data (cal_A and cal_B) are provided as above to display ppm in RX-9. You can calculate the carbon dioxide concentration by substituting the supplied cal_A and cal_B into the above formula. The ability to directly calculate the concentration of a sensor is a meaningful undertaking for engineers or related professionals who are familiar with and understand the principles. These calculations are meaningful calculations that can be applied not only to carbon dioxide sensors but also to other related fields.

ABC(Auto Baseline Calibration) Algorithm

An algorithm for long-time use of the sensor, thanks to the Earth atmosphere.

There are algorithms that any manufacturer of carbon dioxide sensors uses. It is also known as ABC logic and ABC algorithm. ABC is an algorithm that automatically corrects something, as you can see by looking at the full name Prior to describing the ABC algorithm, let's look at the graph first.

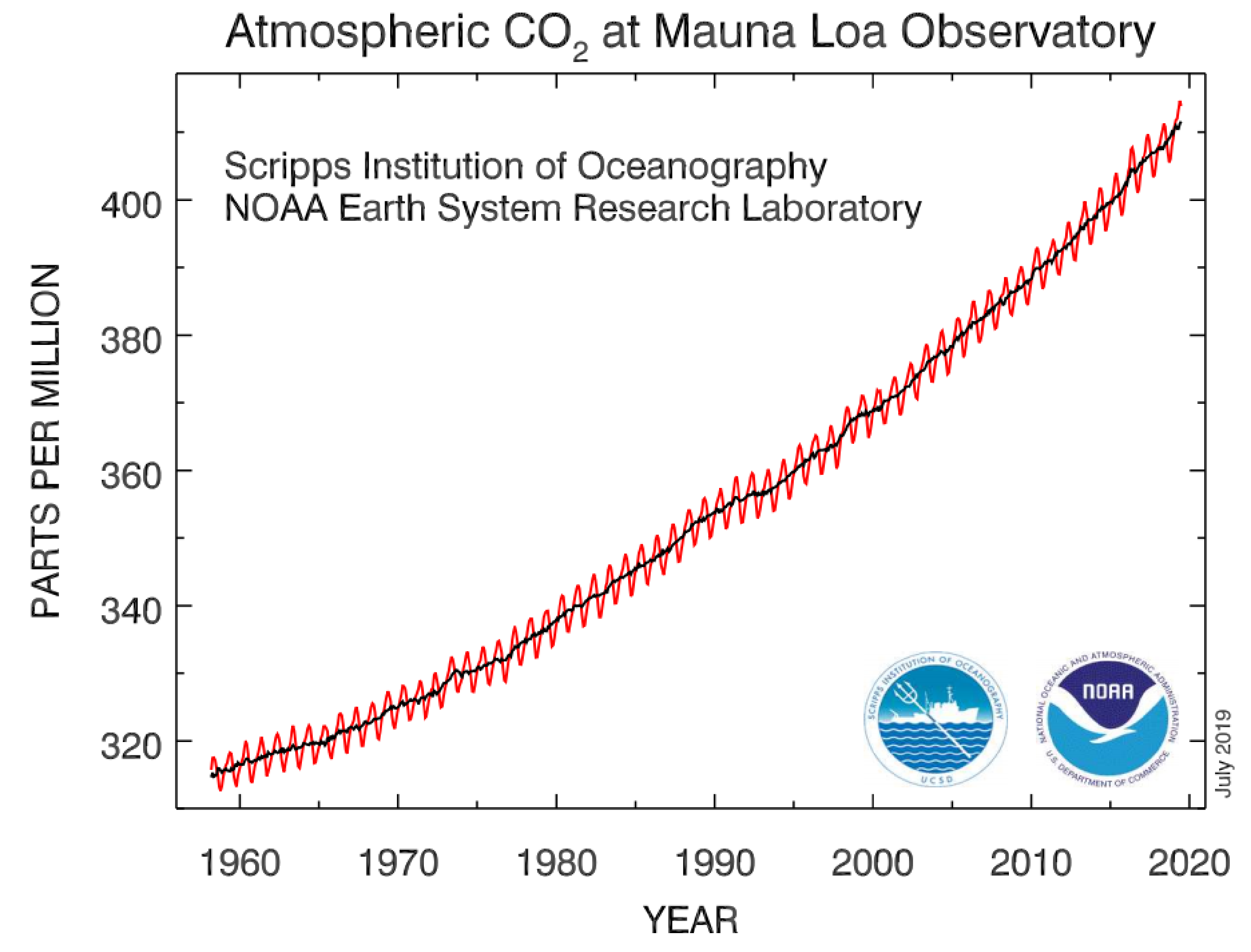


Figure 13 Atmospheric CO_2 at Mauna Loa Observatory[2]

It is concentration trend of accumulated carbon dioxide gas until recently. It tends to increase by about 10 ppm in about five years. The CO2 concentration of the Global Greenhouse Gas Reference Network, which provides the graph above, is 413.92 ppm as of June 2019. For reference, the CO2 concentration was 410.79 ppm as of June 2018. In the graph above, the red line refers to the change in carbon dioxide concentration by season, and the black color is the average value. The ABC algorithm is calculated based on this data. Here are some conditions.

1. CO2 concentrations in the Earth's atmosphere are equator / polar.
2. Seasonal variation is about ± 5 ppm, which is ignored in the ABC algorithm.

[2] Global Greenhouse Gas Reference Network, https://www.esrl.noaa.gov/gmd/ccgg/trends/

3. Concentrations below the reference concentration on Earth are either non-naturally occurring concentrations or are transient. In other words, the lowest concentration of carbon dioxide that can be measured on the earth's surface is now 413.92 ppm (as of June 2019). The CO2 concentration in the earth's atmosphere increases with the passage of time after the sensor is manufactured, or it is updated separately at specific intervals. Ignore it in this algorithm.
4. The sensor will be exposed to the global atmospheric concentration once within a certain period.

Apply the algorithm on the above four conditions. The algorithm is simple. The lowest value measured within a certain period of the sensor is the carbon dioxide concentration of the Earth's atmosphere. This is shown in the flowchart below.

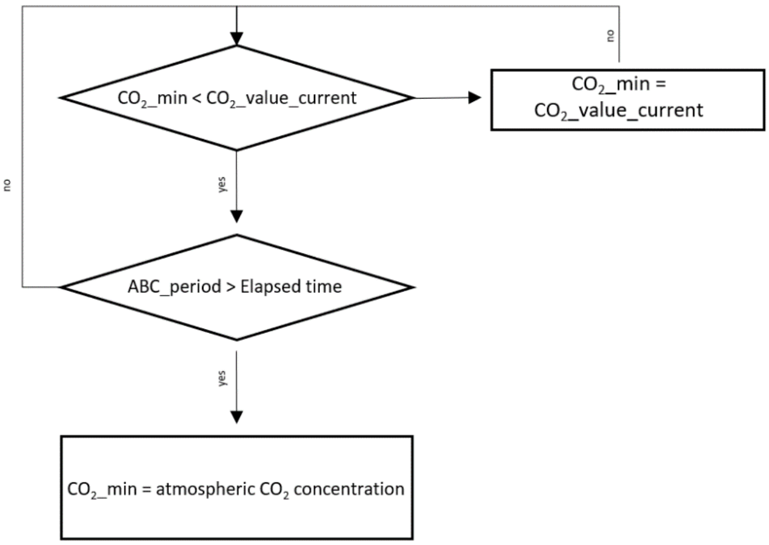
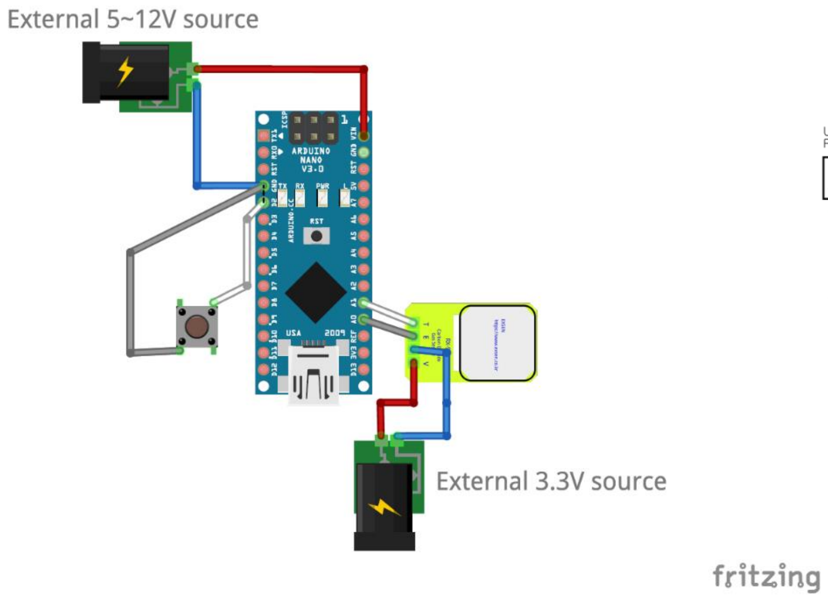


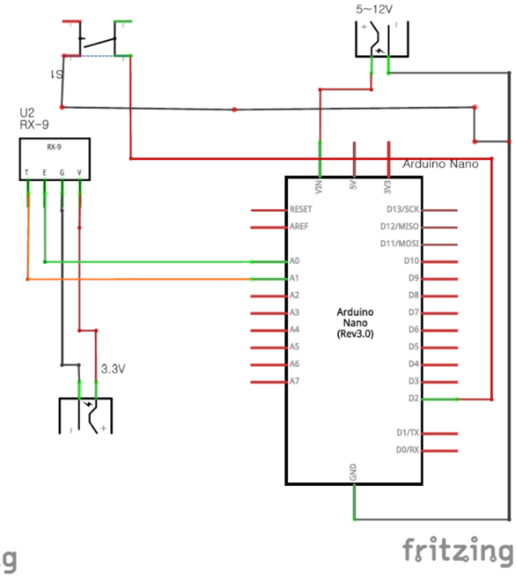
Figure 14 Flow chart of ABC alrorithm

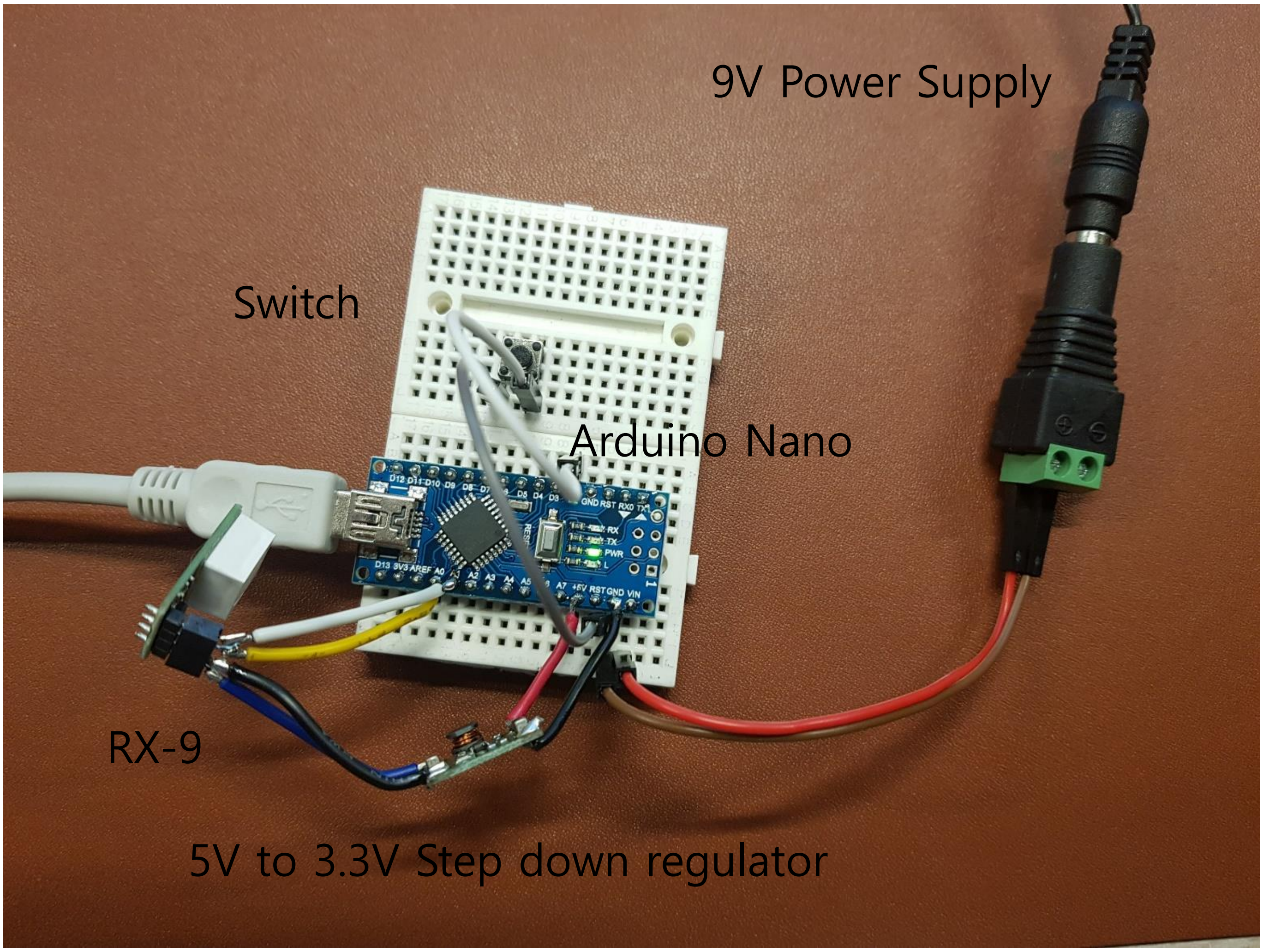
- If the lowest value (CO2_min) measured within a certain period is less than the currently measured CO2 value (CO2_value_current), check whether it is a certain period or not
- If the minimum value is greater than the currently measured CO2 value, the minimum value is updated to the currently measured CO2 value
- If a certain period has been reached, the lowest value (CO2_min) of the measured values within a certain period is updated to the same value as the concentration of the Earth's atmosphere.

The ABC algorithm is an algorithm that is used to compensate for the degree of sensor degradation that all sensors must exposed. Even if the output of the sensor is shaken due to the degradation of the sensor or the physical / chemical shock due to the application of such an algorithm, the sensor will be adjusted to the lowest concentration according to the concentration of the earth's atmosphere after a certain period of time. This algorithm can compensate damage without factory calibration.

Arduino Code Test Hardware







RX-9 Simple Arduino Code (step)

RX-9 Simple Code

Sample Code: https://github.com/EXSEN/RX-9, RX-9_SIMPLE_1CH_CODE.ino

RX-9 Simple Arduino Code (step, LED)

RX-9 Simple and LED Color display

Sample Code: https://github.com/EXSEN/RX-9, RX-9_SIMPLE_1CH_LED_CODE.ino

RX-9 Arduino Code (ppm)

RX-9 ppm output code

Sample Code: https://github.com/EXSEN/RX-9, RX-9_PPM_1CH_CODE.ino

RX-9 Arduino Code (ppm, ABC Algorithm)

RX-9 ppm + ABC algorithm

Sample Code: https://github.com/EXSEN/RX-9, RX-9_PPM_1CH_ABC_CODE.ino

RX-9 Arduino Code (ppm, ABC Algorithm, T/C)

RX-9 ppm + ABC + Temperature Compensation

Sample Code: https://github.com/EXSEN/RX-9, RX-9_PPM_2CH_ABC_CODE.ino