ECOSENSE SENSOR MODULES FOR DISSOLVED H2 IN TRANSFORMER OIL - OPERATING NOTES

1. Product Introduction

This technical specification is applicable to the below sensor modules for dissolved H2 gas in transformer oil. These modules combine gas sensor and special oil chamber, integrating gas separation and gas detection, greatly reducing the development cost of gas online monitoring equipment. The modules continuously monitor the concentration of dissolved gas in insulating oil, in real time, and are designed for use in online monitoring devices for dissolved gas in transformer oil, which are based on the principle of photoacoustic spectroscopy.

ECOSENSE Dissolved H2 Gas Module
for mount directly on transformer valve
Part Numbers: 2112B6001A / 2112B6001B

ECOSENSE Dissolved H2 Gas Module
for mount directly in oil phase
Part Number: 2112B6001C

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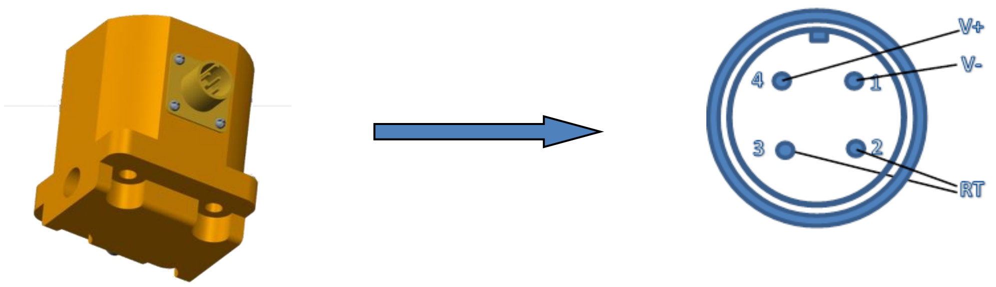
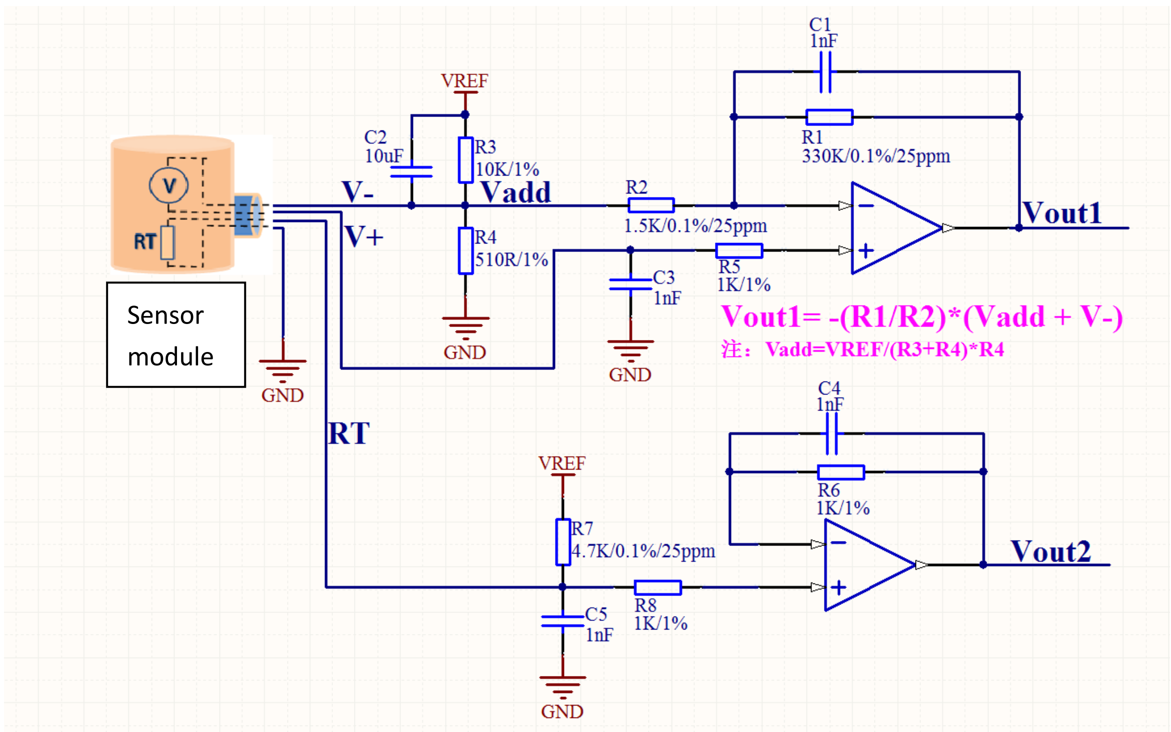
2. Sensor Conditioning Circuit





The sensor module consists of a miniature fuel cell and a thermostat, which outputs a voltage signal and a resistor signal, respectively, which are both conditioned.

1. Voltage signal conditioning:

As shown in the circuit above, in order to detect the negative voltage signal that may occur at the zero point, a voltage divider using resistors R3 and R4 can be added to raise the voltage signal of the sensor, and when the reference voltage (VREF) is 2.5V, the voltage partial Vadd is around 120mV. The elevation voltage is subject to the fact that it does not affect the op amp output and AD acquisition, and generally the voltage can be raised by more than 1mV, and it is recommended to raise it by about 100mV.

For the highest signal conditioning accuracy, signal conditioning is performed using amplification circuits. The negative signal V- plus the raised voltage leads to the op amp, together with the resistors R1 and R2, to form a reverse amplification circuit, and the signal output value can be calculated according to the formula in the figure. This design approach has an extremely high input impedance that can ignore the output impedance of the sensor itself. **According to the calculation of the sensor's full-scale signal (V-) of 1~2mv, please refer to your own analog conversion chip type to adjust the magnification.**

In actual use, if the sensor leads are not well shielded, the capacitor C3 must be wired, and be sure to use a capacitor made of COG material or a material with a lower leakage current. Connecting this capacitor will reduce signal jitter caused by interference, but it will lose a little accuracy.

This circuit must be based on an operational amplifier with an offset voltage below 10uV, such as the AD8572. If you want to reduce costs, you can also choose a normal op amp, but with a slight loss of accuracy. At the same time, precision amplification resistors are required. If the signal voltage value is collected using a differential method (signal output to reference voltage), the accuracy of the reference can also be reduced.

Offset voltage parameters of the AD8572:

FEATURES
Low Offset Voltage: 1 μV
Input Offset Drift: 0.005 μV/°C

2. Resistance signal conditioning

The temperature sensor in the sensor uses NTC resistor with an initial resistance value of 3K and a parameter of b25/50=3950k , and its resistance value is as follows:

T/℃	R(ohm)
0	10110
25	3000
45	1298
70	527

For the specific formula of resistance conversion temperature, please refer to the program code in this article!

Resistive signals can be detected using a constant current source or by resistor voltage division. Considering the high rate of resistance change of this temperature sensor, the requirements for voltage and resistance can be slightly reduced. The design in the demonstration uses a 2.5V reference voltage and a precision resistor for simple voltage division.

3. Voltage Calibration

The sensor requires the circuit board to directly measure the signal voltage value output by the sensor, and use the voltage value to calculate the sensor measurement result, and the sensor signal is uV-level, so it is very important for hardware calibration. Two calibration methods are currently available, and users can also design their own calibration methods.

1. Self-made uV-level signal generator, using battery power, calibrating the hardware, the calibration point range is 0~2000uV.

2. Use a potentiometer and calibrate it with Agilent's six-and-a-half-digit multimeter.

Note: Do not make your own simple voltage source, calibrate with a multimeter, or the result could be very inaccurate!

4. Data Calculation

At a minimum, the math header file needs to be included:

```
#include "math.h"
#include "string.h"
#include"stdio.h"
typedef struct
{

Sensor calibration information
u16 module_info_sn;
        s16 module_info_p1;
        s16 module_info_p2;
        s16 module_info_p3;
        u16 module_info_n1;
        u16 module_info_n2;
        u16 module_info_check;
s16 voltage_value[2];                   //uV
        s32 voltage_caiyang[2];
        u16 resistance_value[2];    //Ω
        s32 resistance_caiyang[2];
} struct_set_data;
typedef struct
{
      float    H2_uV;         //uV
        float H2_value_inter;//PPM
      float R_h2;//℃
      float T_h2;//℃
}struct_cal_inter;
```

Store calibration values

```
struct_set_data    set_data    ;
```

Store the calculated results

```
struct_cal_inter       cal_inter;
```

Initialize the settings in the calculation

```
u8 CALIBRATION_init(void)
{
/*
1	Sensor Serial Number	The factory number of the sensor can be found in the Random Sensor Calibration Certificate
	0	65500	10000

2	Parameter P1	sensor parameters, see Random "Sensor Calibration Certificate"	-32767	32767	-1664

3	Parameters P2	Sensor parameters, see Random "Sensor Calibration Certificate"	-32767	32767	166

4	Parameter P3	sensor parameters, see Random "Sensor Calibration Certificate"	-32767	32767	400

5	Parameter N1	sensor parameters, see Random "Sensor Calibration Certificate"	0	9999	1102

6	Parameters N2	Sensor parameters, see Random "Sensor Calibration Certificate"	0	9999	3255

7	Check sums	and sensor checksums can be found in the Random Sensor Calibration Certificate	0	9999	1203
*/
	set_data.module_info_sn=10000;
		set_data.module_info_p1=-1664;
		set_data.module_info_p2=166;
		set_data.module_info_p3=400;
		set_data.module_info_n1=1102;
		set_data.module_info_n2=3255;
		set_data.module_info_check=1203;
```

The voltage value of the voltage channel is 0uV and the sampling value of 1000uV is 4434575. Please modify this setting according to the AD actually used on your circuit. (Both can be set to negative values)

```
		set_data.voltage_value[0]=0;//uV
		set_data.voltage_value[1]=1000;//uV
		set_data.voltage_caiyang[0]=0;
		set_data.voltage_caiyang[1]=4434575;
```

The resistance value of the resistor channel corresponds to the AD sampling value. The sampling value corresponding to 1000 ohms is 1796491, and the corresponding sampling value of 10000 ohms is 6965986. Please modify this setting according to the AD conversion chip you are actually using

```
        set_data.resistance_value[0]=1000;//Ω
        set_data.resistance_value[1]=10000;//Ω
        set_data.resistance_caiyang[0]=1796491;
        set_data.resistance_caiyang[1]=6965986;
}
float CAL_h2_ppm (void)
{
    float   p1,p2,p3,b,r;
  float   v0,v1,v2;
    float   sensor_temp,y;
    float n1,n2,t;
    p1=(float)set_data.module_info_p1/100;
    p2=(float)set_data.module_info_p2/1000;
    p2 = p2*p2*p2;
    p3 = (float)set_data.module_info_p3/100;

    r = cal_inter.R_h2/1000.0;  //komhs

    if(r<0.35) r=0.35;
    if(r>10.0) r=10.0;

    b = 10.0/r;
    v0 = p1 + (p2*exp(p3*log(b)));
    v1 = cal_inter.H2_uV;
    v2 = v1 - v0;

    if (v2 < -1000)   v2 = -1000;
    if (v2 > 10000)   v2 = 10000;

    sensor_temp = cal_inter.T_h2; //电阻为 0.35k----10k,温度 0----82
    if(sensor_temp < 0.0) sensor_temp = 0.0;
    if(sensor_temp > 82.0) sensor_temp = 82.0;
```

```
    n1=(float)set_data.module_info_n1/100;//N1
        n2=(float)set_data.module_info_n2;//N2
        t=273.2+sensor_temp;
        y=v2*exp(n2/t)/exp(n1);

    return (y);
}
s32 Misc_ad_date_read(u8 data)
{
Please modify this function to add your own AD underlying driver code
if(data==1 )    return 10000;
if(data==2 )    return 20000;

}
Data calculation function, call this function to complete the calculation process
u8 CAL_sensor(void)
{
s32 cy;
float a,a1,a2,r1,r2,r;

   Calculate the gas sensor voltage signal
   if((set_data.voltage_value[0]<set_data.voltage_value[1])
&&(set_data.voltage_caiyang[0]<set_data.voltage_caiyang[1]) )
    {
        cy=Misc_ad_date_read(1);
        a=cy-set_data.voltage_caiyang[0];
        a=a/(set_data.voltage_caiyang[1]-set_data.voltage_caiyang[0]);
        a=a*(set_data.voltage_value[1]-set_data.voltage_value[0])+set_data.voltage_value[0];
        cal_inter.H2_uV=a;
    }
```

Calculate the gas resistance

```
    if((set_data.resistance_value[0]<set_data.resistance_value[1])
&&(set_data.resistance_caiyang[0]<set_data.resistance_caiyang[1]) )
     {
          cy=Misc_ad_date_read(2);
              a1=set_data.resistance_caiyang[0];
              a2=set_data.resistance_caiyang[1];
              r1=set_data.resistance_value[0];
              r2=set_data.resistance_value[1];
         r=(a2-a1)*r1*r2/(a1*r2-a2*r1);
              a1=(r1/(r+r1))/a1;
               cal_inter.R_h2=(r*cy*a1)/(1.0-cy*a1);

     }
```

Calculate the temperature of the gas

```
        if(cal_inter.R_h2 > 115800.0)    cal_inter.R_h2 = 115800.0;
     if(cal_inter.R_h2 < 5.0)       cal_inter.R_h2 = 5.0;
     a =cal_inter.R_h2+0.5;           //ohms

     a = (-0.1241)*(exp(3*log(log(a)))) + 4.7187*(exp(2*log(log(a))))-74.172*log(a) + 380.0;
     if(a>120) a=120;
     cal_inter.T_h2=a;

cal_inter.H2_value_inter=CAL_h2_ppm();

return 1;
}
int main(void){
     CALIBRATION_init();
     while(1)
     {
         CAL_sensor();
    }

}
```

5. Calculation of PPM

The sensor can directly generate two kinds of signal: one is temperature in KΩ and the other is voltage in uV.

1. Definition of symbols:

R: temperature in KΩ

t: temperature in ℃

V: voltage collected on-line in uV

V0: zero voltage (in clean air) of the sensor at current temperature in uV

C: current concentration in PPM

2. The sensor can collect temperature (in KΩ) and voltage (in uV) at the same time.

3. Calculation of temperature in ℃:

Transfer temperature from KΩ into ℃ as follows:

t= - 0.1241 * LN(R*1000) * LN(R*1000) * LN(R*1000) + 4.7186 * LN(R*1000) * LN(R*1000) - 74.172 * LN(R*1000) +380

Note: R refers to the temperature in **KΩ**

4. Calculation of the zero voltage (V1) at current temperature:

Calculate V1 as follows:

V1= （P1/100）+ (P2/1000)^3 * (10/R) ^ (P3/100)

Note: P1, P2, P3 refers to parameters of the sensor

5. Calculation of the current concentration (C) in PPM:

Calculate C as follows:

C = (V – V1) * EXP [N2 / (273.2 + t) - N1/100]

Note: N1, N2, refers to parameters of the sensor

t refers to the temperature calculated above in ℃

Notes: the range of voltage is between -2000uV and 20000uV

the range of temperature in **KΩ** is between 0.5 and 120