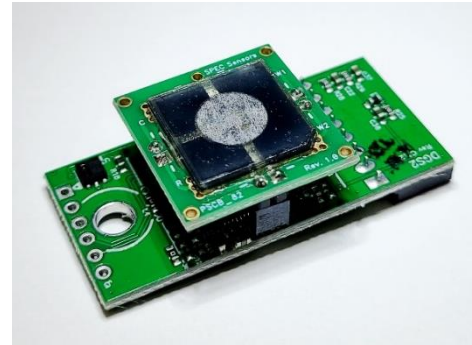


## DGS2 – Digital Gas Sensor

### FEATURES

- Simple digital UART interface
- USB-to-UART adapter included (970- & 975-Series)
- Active and low power modes
- Integrated T & RH sensors
- Calibrated & temperature compensation ready<sup>(4)</sup>
- Robust: up to 10-year estimated lifetime
- Small form factor & Lightweight (< 2 oz.)
- RoHS & REACH compliant



### DESCRIPTION

SPEC Sensors offers an easy way to add small, lightweight, high performance, ultra-low power consumption gas sensing to the Internet of Things. Our Screen Printed ElectroChemical sensor technology (SPEC Sensor™) combined with state-of-the-art electronics and algorithms, enables easy integration of gas sensing into wireless, portable, and networked solutions.

### DGS2 970-SERIES PRODUCT FAMILY

At Standard Conditions: 25 °C, 50% RH and 1 atm					
DGS2 PN	Gas Type	Gas Sensor PN	DGS2 Bias [1] (mV)	DGS2 Range [1] (ppm)	DGS2 Resolution [1,2] (ppm)
97x-100	CO	110-102	+ 10	0 - 400	0.2
97x-110	CO	110-114	+ 10	0 - 20	0.03
97x-200	EtOH	110-202	+ 40	0 - 600	0.3
97x-300	H2S	110-303	+ 10	0 - 10	0.01
97x-400	O3	110-406	- 20	0 - 20	0.02
97x-500	NO2	110-507	- 20	0 - 30	0.03
97x-600	SO2	110-610	0	0 - 40	0.03
97x-800	IAQ	110-801	+ 150	0 - 100 [CO]	0.05
97x-900	RESP	110-901	- 200	0 - 20 [NO2]	0.02
97x-001	H2	110-005	+ 20	0 - 100	0.2
970-010	DGS2 Developer Kit: Includes DGS2 Module + 10 Sensors (one of each Gas Sensor PN)				
981-035	USB-to-UART adapter enables convenient operation of the DGS2				

DGS2 PN	Included Components
970-xxx	Gas Sensor, DGS2 Module & USB-to-UART adapter
972-xxx	Gas Sensor & DGS2 Module
975-xxx	Gas Sensor, DGS2 Module & USB-to-UART adapter & Factory Calibration. <i>Contact SPEC Sensors to customize a calibration for your application.</i>
977-xxx	Gas Sensor, DGS2 Module & Factory Calibration. <i>Contact SPEC Sensors to customize a calibration for your application.</i>

## MEASUREMENT PERFORMANCE CHARACTERISTICS

At Standard Conditions: 25 °C, 50% RH and 1 atm	
Measurement Accuracy [1,4]	± 15%
Measurement Repeatability	< ± 3% or <i>DGS Zero Accuracy</i> , whichever is greater
Response Time [5]	< 15 seconds
Power Consumption	1.32 mW in sleep mode 33 mW in active mode
Expected Operating Life [6]	> 5 years (10 years @ 25 ± 10 °C; 60 ± 30% RH)
Operating Temperature Range [1,5]	-20 to 40 °C (-30 to 55 °C intermittent)
Operating Humidity Range	15 to 95% (0 to 100% non-condensing intermittent)
Mechanical Dimensions	1.75 x 0.82 x 0.35 in. (44.5 x 20.8 x 8.9 mm)
Weight	< 2 Ounces

## ABSOLUTE MAXIMUM SPECIFICATIONS

Parameter	Conditions	Min.	Typ.	Max.	Units
Maximum Concentration	Short term exposure			120	% Range
Storage Temperature	Vapor sealed @ 50% RH	5	20	30	°C
Storage Humidity	Non-condensing, vapor sealed	20	50	80	% RH
Storage Pressure	Vapor sealed	0.8	1	1.2	atm
Storage Time	Vapor sealed	-	12	-	Months
Operating Temperature	< 10 hours	-40	-	50	°C
Operating Humidity	< 10 hours, non-condensing	0	-	100	% RH
Operating Pressure	Transient pulses	-.5	0	.5	atm
Operating Temperature	Continuous	-30	25	50	°C
Operating Humidity	Continuous, non-condensing	10	50	95	% RH
Operating Pressure	Continuous	0.8	1	1.2	atm
ESD Rating	Human Body Model	2		8	kV

## ELECTRICAL SPECIFICATIONS

Parameter	Conditions	Min.	Typ.	Max.	Units
Supply Voltage, V+		2.6	3.3	3.6	V
Supply Current	V+ = 3.3 V, Active Mode V+ = 3.3 V, Sleep Mode		10 0.4		mA
Power Consumption	V+ = 3.3 V, Active Mode V+ = 3.3 V, Sleep Mode		33 1.32		mW

### Notes:

- [1] DGS2 system specifications consider combined electronics, firmware, and sensor performance. DGS2 system specifications may be different than individual sensor specifications.
- [2] Based on standard deviation of noise at zero ppm, 1 Hz measurement, 60 measurements average.
- [3] When zeroed after 24 hours of power-on stabilization.
- [4] Based on *sensor-level* factory calibration. User calibration can improve accuracy. *Module-level* factory calibration of DGS2 can be specified for your application and ordered directly from SPEC Sensors.
- [5] Consult individual sensor datasheets for more details.
- [6] Functional lifetime will vary based on sensor drift as a function of the application environment and accuracy requirements.

## COMMON GAS SENSOR APPLICATIONS

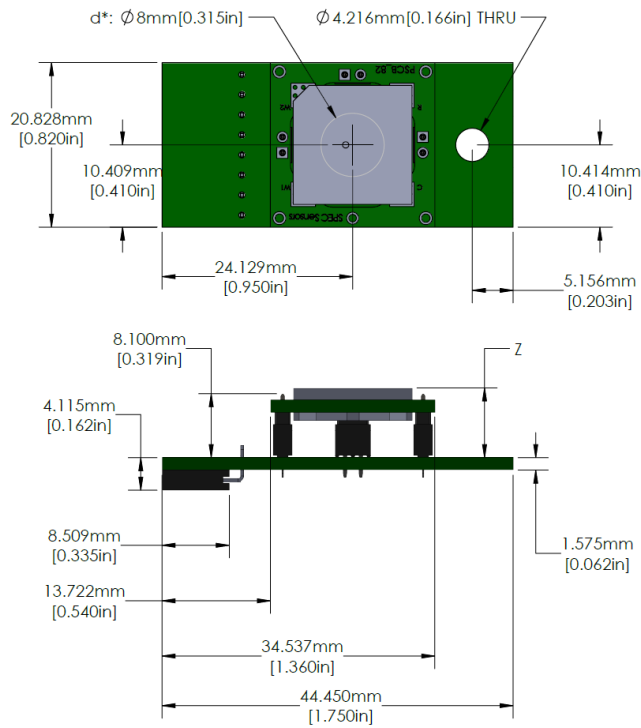
	CO	NO2	O3	SO2	IAQ	RESP	H2S	EtOH	H2
Indoor Air Quality	✓	✓	✓	✓	✓	✓	✓		
Outdoor Air Quality	✓	✓	✓	✓					
Life Safety	✓	✓	✓	✓			✓		✓
Early Fire Detection	✓	✓							
Industrial Safety	✓	✓	✓	✓			✓		✓
Breath Analysis	✓				✓		✓	✓	✓
Alcohol Detection								✓	
Air Purification & Sterilization Control		✓	✓				✓		

## CROSS SENSITIVITY

The following table lists the sensor responses to common interfering gases. For additional cross sensitivity information, please refer to the gas sensor datasheets.

Measured Gas Sensor Response										
Applied Test Gas	Measured (PPM)	CO	EtOH	H2S	O3	NO2	SO2	IAQ	RESP	H2
	Applied (PPM)	110-102	110-202	110-303	110-406	110-507	110-610	110-801	110-901	110-005
CO	400	400	251	1.1	<0.05	<0.02	< 1	100	0	<0.1
EtOH		200	200				< 1	140	1	
H2S	< 1	63	10	10	-12.5	<0.02	500	370	27	
O3	< 1	< 5	-0.9	5	5	< 0.1	-150	-70	80	
NO2	< 1	< 5	-2	5	5	5	-100	-50	10	
SO2	< 1	12	1.7			<0.02	100	70	-7	
H2	17									100
NO		54	1.2			< 0.1		80	0	
Cl2	< 1	-14	-2.2	10	10	< 0.02	-100	-50	6.5	
Isopropyl Alcohol	1.3									
Methane	< 1	< 5	0.1	<0.05					0	
Ammonia	< 1	< 5	0.1						0	
Carbon Dioxide	< 1									
n-Heptane	< 1	-13	<0.05	0.2					0	
Toluene	< 1									
Acetone	< 1									

## PACKAGE OUTLINE DRAWING & DIMENSIONS



DGS2 PN	Gas Type	Gas Sensor PN	Dim. Z (mm)
970-100	CO	110-102	8.7 mm
970-110	CO	110-114	8.5 mm
970-200	EtOH	110-202	7.8 mm
970-300	H <sub>2</sub> S	110-303	7.8 mm
970-400	O <sub>3</sub>	110-406	7.8 mm
970-500	NO <sub>2</sub>	110-507	8.5 mm
970-600	SO <sub>2</sub>	110-610	7.8 mm
970-800	IAQ	110-801	7.8 mm
970-900	RESP	110-901	7.8 mm
970-001	H <sub>2</sub>	110-005	9.0 mm

### Notes:

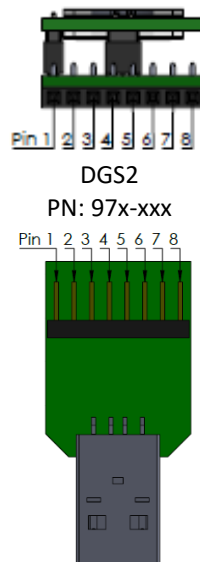
**Tolerances:**  $\pm 0.2$  mm, except Dim Z:  $\pm 0.5$  mm

**d\*:** Features of the gas inlet region may vary with sensor type. See gas sensor datasheets for more details. Do not contact the sensor within this region.

## PINOUT

Electrical connections to the DGS2 are made via a rectangular female socket connector (Sullins Connector Solutions PN: PPPC041LGBN-RC; recommended mate for host board: PN: PBC08SBAN). This connector also provides mechanical rigidity on one end of the board. A through-hole is located on the opposite end of the board to provide additional mechanical connection.

The USB-to-UART adapter (PN: 981-035) includes a DGS2-compatible pin header and a USB-A plug connector.

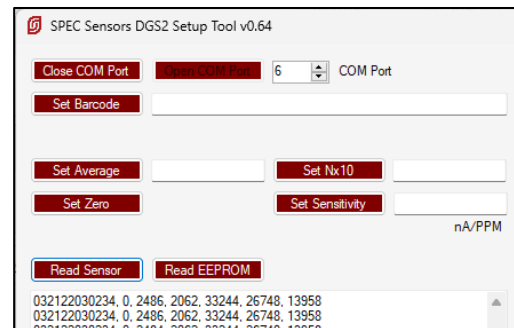


USB-to-UART Adapter  
PN: 981-035

DGS2 Pinout		
Pin #	Function	Description
1	N/C	
2	RXD	DGS2 UART Receive
3	TXD	DGS2 UART Transmit
4	N/C	
5	N/C	
6	GND	Ground
7	N/C	
8	V+	2.6 to 3.6 V

## QUICK START – SPEC SENSORS DGS2 SETUP TOOL

1. **Download and install the “SPEC Sensors DGS2 Setup Tool”**
  - a. The setup tool can be found on the *Documents* page of the spec-sensors.com website.
2. **Connect the DGS2 to the USB-to-UART adapter**
3. **Connect the USB to your computer**
  - a. If device drivers are not automatically downloaded and installed, you can find device drivers for your operating system by searching [www.silabs.com](http://www.silabs.com) for: “CP210x USB to UART Bridge VCP Drivers”.
4. **Determine the COM port associated with the module**
  - a. On Windows operating systems, locate and open the Device Manager.
  - b. The device should be listed under the heading, “Ports (COM & LPT)”, as “Silicon Labs CP210x USB to UART Bridge (COMXX)”, where XX is the unique port number associated with the device.
  - c. Make a note of the unique port number.
5. **Open the “SPEC Sensors DGS2 Setup Tool”**
  - a. Establish a serial connection with the module by entering the COM port number, identified above, in the field next to the Open COM Port button, then press the button.
6. **Single & Continuous Measurements**
  - a. Trigger a single measurement by pressing the ‘Read Sensor’ button.
  - b. Start a  $\approx 1$  Hz continuous measurement by pressing the ‘Continuous Read and Log...’ button.
  - c. Stop the continuous measurement by pressing the button again.
  - d. Refer to **Example Measurement String**, below for more details on the string format.
7. **Initial ZERO (Clean Air) Calibration**
  - a. When first powered on after a long period of unpowered storage, the sensor requires a stabilization period in clean air (See **Normal Sensor Startup**, below).
  - b. Wait at least 1 hour (for best results: 24 hours) in clean air while ensuring power to the DGS2 remains uninterrupted.
  - c. Press ‘Set Zero’ button to initiate the re-zero. Once the re-zero is complete, the change will be reflected in the PPB value of the output string. After re-zeroing, non-zero measurement noise is normal (See the **DGS2 Zero Accuracy** specification).
8. **Pairing Other Sensors**
  - a. Use a barcode scanner to read the encoded label on the **sensor** into the field next to the ‘Set Barcode’ button, then press the button.
  - b. The DGS2 Setup Tool will parse the barcode and sequentially write the barcode value, sensitivity factor, default average value (60), and default  $Nx10$  value (50000) to the DGS2 memory. The DGS2 sets the sensor bias and gain based on the sensor part number encoded in the sensor barcode. If the sensor part number is not recognized, the bias is set to 0 mV and the gain is set to  $512 \cdot 10^3$  V/A.
9. **Other Settings**
  - a. The ‘Read EEPROM’ button prints settings and other information from the DGS2 memory.
  - b. The ‘Set Average’, ‘Set  $Nx10$ ’, and ‘Set Sensitivity’ buttons can be used to change the default settings.
10. **Other Quick Start Options:**
  - a. Use a terminal emulator, such as Tera Term, to establish a serial connection (9600-8-N-1) with the DGS2 via the USB-to-UART adapter. Refer to the *Command Library* for the full set of commands.

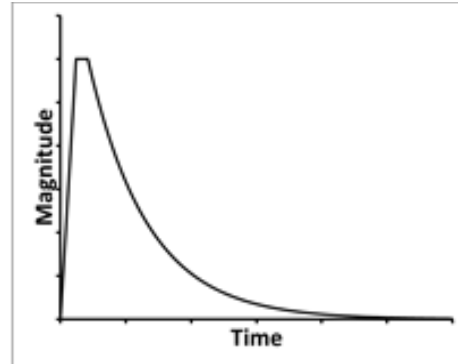


## NORMAL SENSOR STARTUP

The electrochemical sensor output has the normal power-on startup profile pictured here. When powering the sensor, its output magnitude will rapidly increase followed by a gradual decrease. Once this process is complete, the sensor output will be the most accurate and stable. The time, magnitude, and polarity of this response may vary depending on the sensor type and the length of time the sensor has been unpowered.

After storage and/or shipping, the startup duration will be 1 - 24+ hours.

For best performance: a 24+ hour startup duration is recommended. Following startup, the module should remain always on power.



The electrochemical sensor output has the normal power-on startup profile pictured here.

## DGS2 OPERATION

The DGS2 ships from the factory pre-configured for the installed sensor.

*When the DGS2 is connected to V+ and GND:* The module will load the configuration settings and remain in Active Mode. While in Active Mode, the sensor is biased and the module will respond to command characters (See **Command Library**). The module will measure the sensors and populate the average buffers, which are set to 60 measurements by default. Measurement strings returned by 'r' or 'C' commands include the most recent values in the average buffers.

When first powered on after a long period of unpowered storage, the sensor requires a stabilization period in clean air (See **Normal Sensor Startup**, above). Wait at least 1 hour (for best results: 24 hours) in clean air while ensuring power to the DGS2 remains uninterrupted. Type 'Z' to initiate the re-zero. Once the re-zero is complete, the change will be reflected in the PPB value of the output string. After re-zeroing, non-zero measurement noise is normal (See the **DGS2 Zero Accuracy** specification).

## DGS2 COMMAND LIBRARY

The DGS2 ships from the factory pre-configured for the installed sensor. Use the following commands to retrieve data and adjust settings.

**Notes:** Commands are case-sensitive. When entering commands and parameters via a script or software, an inter-character delay may be necessary.

	ASCII character command	Name	Description
Operate	\r [Enter]	Single Measurement	A measurement string is returned. (See <b>Example Measurement String</b> )
	C (uppercase)	Continuous Measurement	Toggles on/off continuous measurement. A measurement string is returned approximately once per second. (See <b>Example Measurement String</b> )
	e	EEPROM Settings	Settings and diagnostic info are returned. (See <b>Example EEPROM Settings Output</b> )
	r	Reset/Restart	Module reset. EEPROM Settings are retained.
Calibration	Z	Zero	Zeros out a ppb measurement offset.
	S (uppercase)	Sensitivity Factor	Enter a new sensitivity factor as a scaled integer: pA/ppm = nA/ppm x 1000. Ex: 3.45 nA/ppm is entered as 3450
	G	Gas Concentration	Enter the known span gas concentration in ppb. The DGS2 will calculate a new sensitivity factor based on this value and the gas sensor value.
Setup	B	Barcode	Enter the encoded data from the sensor barcode to configure the module's default bias and gain settings. The sensitivity factor must be loaded separately using the 'S' command. Or calibrate the module to a known gas concentration using the 'G' command
	A	Average	Set the number of data points included in the moving average: 1 – 256 [default: 60]
Advanced Settings	s (lowercase)	Sleep	Module enters Sleep Mode while maintaining sensor bias. Send any UART character to wake the module and return it to Active Mode, then send a command character.
	P	Potentiostat Settings	Enter new potentiostat settings as the decimal equivalent of the hexadecimal setting. Refer to the AD5940/AD5941 Data Sheet; LPDACDAT0 and LPTIACON0 register settings. A blank value will leave the setting unchanged. (See <b>Advanced Settings and Operation</b> )
	T	Temperature Offset	Enter an offset for the temperature value as a scaled integer: TOff x 1000. Ex: a +0.50 °C offset is entered as 500.
	H	RH Offset	Enter an offset for the RH value as a scaled integer: HOff x 1000. Ex: a -1.23% offset is entered as -1230
	N	Temperature Compensation Factor	Enter a new temperature compensation value 0 - [65535]. (See <b>Calculation &amp; Temperature Compensation</b> )
	O (uppercase)	Open Circuit Zero	Sets a new open-circuit-zero value. **Prior to execution: The sensor must be disconnected from the DGS2. Set A to 1 or wait A cycles after the sensor is disconnected.

## EXAMPLE MEASUREMENT STRING

This is an example of a measurement string, returned by the module after receiving '\r' [Enter]:

```
032122030234, 1588, 2436, 3278, 32291, 26636, 20390<space><cr><ls>
```

The format of the output is:

Measurement Field	Example Measurement Value	Value Range
Sensor SN	032122030234	[XXXXXXXXXXXXXX]
PPB	1588	$[-2^{31}; 2^{31}]$
TEMPERATURE	2436	[-5000:15000]
RELATIVE HUMIDITY	3278	[0:10000]
ADC_G (GAS)	32291	$[0; 2^{16}]$
ADC_T (TEMPERATURE)	26636	$[0; 2^{16}]$
ADC_H (RELATIVE HUMIDITY)	20390	$[0; 2^{16}]$

## EXAMPLE EEPROM SETTINGS OUTPUT

This is an example of the EEPROM Settings output, returned by the module after receiving 'e':

```
*****
FW Date 10FEB23
Sensor Barcode 032122030234 110102 CO 1603 3.62
pA/PPM 3620, Avg 60, Ton 105
Nx10 50000, Toff 0, Hoff 0
LPDACDAT0 128940, LPTIACON0 10048
OC ADC G 32237, T 27516, H 25942
Zero ADC G 32238, T 27524, H 26030
Span ADC G 65535, T 65535, H 65535
Module Barcode 02230655 DGS2 CO
*****
```

The format of the output is:

EEPROM Output Line	Description	Set Command
FW Date 10FEB23	Firmware revision date	Factory Set
Sensor Barcode 032122030234 110102 CO 1603 3.62	Sensor barcode	B
pA/PPM 3620, Avg 60, Ton 105	Sensitivity Factor (pA/ppm) Average Window Size (Avg) Time on Power, seconds (Ton)	S or G A n/a
Nx10 50000, Toff 0, Hoff 0	Temp. Compensation Factor (Nx10) Temperature Offset (Toff) RH Offset (Hoff)	N T H
LPDACDAT0 128940, LPTIACON0 10048	Potentiostat settings	P
OC ADC G 32237, T 27516, H 25942	Open Circuit Zero	O
Zero ADC G 32238, T 27524, H 26030	Zero	Z
Span ADC G 65535, T 65535, H 65535	Custom Sensitivity Span	G
Module Barcode 02230655 DGS2 CO	Module barcode [4] (factory-calibrated DGS2 only, otherwise blank)	Factory Set

### Notes:

[4] Module-level factory calibration of DGS2 can be specified for your application and ordered directly from SPEC Sensors.



## CALCULATION OF GAS CONCENTRATION

The electrochemical sensor utilized in the DGS2 has an output current that is linearly proportional to the gas concentration measured at the gas sensor inlet (at standard temperature and pressure) that is represented by the sensor sensitivity factor ( $S_f$  [nA/ppm]). A transimpedance amplifier (TIA) converts and amplifies the sensor current to a voltage via  $R_{gain}$  [V/A]. The voltage output of the transimpedance amplifier is measured with an ADC.

The system voltage at the output of the TIA amplifier is calculated from the ADC value with the transfer function:

$$V[V] = 1.82[V] \cdot \frac{ADC-2^{15}}{2^{15}} \left[ \frac{cnts}{cnts} \right] \quad \text{Eq. 1}$$

An ideal sensor would generate zero current when there is zero gas present, but practical sensors have a small non-zero baseline current. Additionally, the DGS2 electronics have a small non-zero offset voltage. These are accounted for with  $V_{zero}$  and  $V_{oc}$ , respectively:

$$V_{zero}[V] = 1.82[V] \cdot \frac{ADC_{zero}-2^{15}}{2^{15}} \left[ \frac{cnts}{cnts} \right] \quad \text{Eq. 2}$$

$$V_{oc}[V] = 1.82[V] \cdot \frac{ADC_{oc}-2^{15}}{2^{15}} \left[ \frac{cnts}{cnts} \right] \quad \text{Eq. 3}$$

$V_{oc}$  is a circuit constant that is calculated and saved in the module EEPROM at the factory. It may be recalculated by removing the sensor from the module and sending command 'O'. However, most users do not need to change the factory setting.

$V_{zero}$  is a system constant that is initially calculated and saved in the module EEPROM at the factory but it is imperative that the user re-zeros the system with command 'Z'. The value of the temperature sensor is also saved as  $T_{zero}$ . See document **DGS2 970-Series Addendum: Temperature Compensation** for more details.

The gas concentration is calculated:

$$C[ppb] = \frac{1000 \left[ \frac{ppb}{ppm} \right] \cdot 1 \cdot 10^9 \left[ \frac{nA}{A} \right]}{S_f \left[ \frac{nA}{ppm} \right]} \cdot \left( \frac{V[V]-V_{oc}[V]}{R_{gain} \left[ \frac{V}{A} \right]} - \frac{V_{zero}[V]-V_{oc}[V]}{R_{gain} \left[ \frac{V}{A} \right]} \cdot e^{\frac{T[^\circ C]-T_{zero}[^\circ C]}{N[^\circ C]}} \right) \quad \text{Eq. 4}$$

By default,  $R_{gain}$  is  $85 \cdot 10^3 \left[ \frac{V}{A} \right]$  for the EtOH sensor (110-202) and for all other sensors,  $R_{gain}$  is  $512 \cdot 10^3 \left[ \frac{V}{A} \right]$ .  $N$  is the temperature compensation factor. The value of  $N$  is factory set to a large number ( $2^{16}$ ), effectively turning off temperature compensation by making its effect on the calculation negligible. When  $V_{oc} = V_{zero}$  and/or if  $N \gg T[^\circ C] - T_{zero}[^\circ C]$ , then Eq. 4 simplifies to:

$$C[ppb] = \frac{1000 \left[ \frac{ppb}{ppm} \right] \cdot 1 \cdot 10^9 \left[ \frac{nA}{A} \right]}{S_f \left[ \frac{nA}{ppm} \right]} \cdot \frac{V[V]-V_{zero}[V]}{R_{gain} \left[ \frac{V}{A} \right]} \quad \text{Eq. 5}$$

The user may adjust the value of  $N$  with command 'N'. See document **DGS2 970-Series Addendum: Temperature Compensation** for more details.

## USER CALIBRATION & TEMPERATURE COMPENSATION

The DGS2 ships from the factory pre-configured for the installed sensor. This includes the sensor sensitivity factor ( $S_f$ ), used in the calculation of gas concentration (Eqs. 4 & 5). The user should follow the procedure below to zero the system. *Additionally, temperature compensation is not enabled by default but can be enabled by the user.*

### **Zeroing the System**

When the DGS2 is first powered on after a long period of unpowered storage/shipping, the sensor requires a stabilization period in clean air (See **Normal Sensor Startup**, above). Wait at least 1 hour (for best results: 24 hours) in clean air while ensuring power to the DGS2 remains uninterrupted. Type 'Z' to initiate the re-zero. Once the re-zero is complete, the change will be reflected in the PPB value of the output string. After re-zeroing, non-zero measurement noise is normal (See the **DGS2 Zero Accuracy** specification).

### **Span Calibration**

The sensitivity factor printed on the sensor barcode is pre-configured in the memory of the DGS2 module at the factory. There are two methods available to change the sensitivity factor utilized by the module to calculate the PPB value.

A new sensitivity factor may be saved in the module EEPROM by using command 'S' and entering a new sensitivity value in pA/ppm. The sensor barcode expresses the sensitivity in nA/ppm. For example, if the barcode lists 3.14 [nA/ppm], then enter 3140 when using command 'S'. If the barcode lists -19.45 [nA/ppm], then enter -19450.

The module may also be calibrated while it is exposed to a known and stable concentration of gas. In this case, ensure the gas concentration is known and stable, then use command 'G', then enter the known concentration of gas in ppb. For example, if the gas concentration is 100 ppm, enter 100000.

### **Temperature Compensation**

Temperature compensation is not enabled by default; the temperature compensation value (N) is set to a high value, effectively turning off its effect on the calculation (see Eqs. 4 & 5). Use command 'N' to set a new value. Refer to **DGS2 970-Series Addendum: Temperature Compensation** for nominal values of N for each sensor type and for details on the effect of tuning the value of N to further improve the temperature compensation for individual sensors.

## ADVANCED SETTINGS AND OPERATION

### **Custom Potentiostat Settings**

The DGS2 utilizes the Analog Devices AD5941 Electrochemical Sensor Front End, which includes a low power potentiostat circuit that operates the electrochemical sensor. The DGS2 is configured at the factory for the sensor that is paired with it. Other SPEC Sensors may be paired with a DGS2 module by using the 'B' and 'S' commands or by using the DGS2 Setup Tool.

It is possible to configure non-standard potentiostat settings using command 'P'. In particular, the LPDACDAT0 and LPTIACON0 settings registers can be changed. The LPDACDAT0 register includes settings that control the electrochemical sensor bias. The LPTIACON0 register includes settings that control the potentiostat gain, load resistor, and hardware low-pass filter, among others. Changes to the gain setting will be reflected in the calculation of gas concentration (Eq. 4). It is recommended that the load resistor be set to  $\leq 100 \Omega$ . It is recommended that the

hardware low pass filter resistor be set to either 0  $\Omega$  or 1 M $\Omega$ . Please refer to the AD5940/AD5941 Data Sheet for more details.

LPDACDAT0 and LPTIACON0 are composed as binary register settings and converted to decimal for input via command 'P' on the DGS2. For example, the default settings for the DGS2-CO (970-100) may be interpreted accordingly:

### LPDACDAT0

Decimal (DGS2 Setting)	Hex	Binary (AD5941 Register Setting)
128940	1F7AC	0001 1111 0111 1010 1100

AD5941 LPDACDAT0 Register	DACIN6	DACIN12
Register Settings	0001 1111	0111 1010 1100
Effective Settings	1.265 V	1.255 V
Effective Bias	DACIN6 – DACIN12 = 10 mV	

### LPTIACON0

Decimal (DGS2 Setting)	Hex	Binary (AD5941 Register Setting)
10048	2740	0010 0111 0100 0000

AD5941 LPTIACON0 Register	TIARF	TIARL	TIAGAIN	IBOOST	HALFPWR	PAPDEN	TIAPDEN
Register Settings	001	001	11010	00	0	0	0
Effective Settings	0 $\Omega$	10 $\Omega$	512k $\Omega$	Normal Mode		Power-up	

The default settings for the standard DGS2 970-Series sensors are listed in the following table:

DGS2 PN	Gas Type	Gas Sensor PN	LPDACDAT0 (decimal)	Vw (V)	Vr (V)	Bias (mV)	LPTIACON0 (decimal)	Gain (V/A)
970-100	CO	110-102	128940	1.265	1.255	+ 10	10048	512·10 <sup>3</sup>
970-110	CO	110-114	128940	1.265	1.255	+ 10	10048	512·10 <sup>3</sup>
970-200	EtOH	110-202	128885	1.265	1.225	+ 40	9792	85·10 <sup>3</sup>
970-300	H2S	110-303	128940	1.265	1.255	+ 10	10048	512·10 <sup>3</sup>
970-400	O3	110-406	128997	1.265	1.285	- 20	10048	512·10 <sup>3</sup>
970-500	NO2	110-507	128997	1.265	1.285	- 20	10048	512·10 <sup>3</sup>
970-600	SO2	110-610	128959	1.265	1.265	0	10048	512·10 <sup>3</sup>
970-800	IAQ	110-801	128680	1.265	1.115	+ 150	10048	512·10 <sup>3</sup>
970-900	RESP	110-901	129332	1.265	1.465	- 200	10048	512·10 <sup>3</sup>
970-001	H2	110-005	128992	1.265	1.245	+ 20	10048	512·10 <sup>3</sup>

## **Sleep Mode, Firmware Average, & Hardware Filter**

When the DGS2 is in Active Mode, the module will measure the sensors and populate the average buffers approximately 1/second. Measurement strings returned by the '\r' or 'C' commands include the most recent values in the average buffers. The default moving average window of 60 measurements is a good compromise between response time and noise reduction. If the application requires a different setting, the size of the moving average window can be adjusted with command 'A'.

When the DGS2 is in Sleep Mode, the sensor bias is maintained but the sensor output is not measured and the average buffers are cleared. When the module returns to Active Mode, the average buffers are rebuilt, starting with a window size of 1 and increasing until the Average Window Size setting (Avg) is reached. Therefore, it is recommended that when Sleep Mode is utilized, the Average Window Size is reduced to 1.

Reducing the Average Window Size to 1 will impact the noise performance of the system. To improve the noise performance in this use case, a low-pass hardware filter, built in to the AD5941 potentiostat chip, may be activated by changing the LPTIACON0 register setting. In particular, the TIARF setting bits of the LPTIACON0 register should be changed from default value of 0b 001 to 0b 111. This will replace a 0 Ω short with a 1 MΩ resistor in a low-pass filter network with a 4.7 μF capacitor, at the output of the sensor signal chain, just before the ADC.

## **Temperature and Relative Humidity Sensors & Offsets**

The ADC measurements for the temperature and relative humidity sensor are passed through to the measurement string of the DGS2 as ADC\_T and ADC\_H, respectively. These values together with their respective user-adjustable offsets are used to calculate Temperature (°C) and Relative Humidity (%) fields in the measurement string:

$$T[°C] = -46.85 + 175.72 \cdot \frac{ADC_{TEMP}}{2^{16}} + \frac{T_{offset}}{1000} \quad \text{Eq. 6}$$

$$RH[\%] = -6 + 125 \cdot \frac{ADC_{RH}}{2^{16}} + \frac{H_{offset}}{1000} \quad \text{Eq. 7}$$

The result of Eq. 6 is utilized in the temperature compensation of the gas sensor, given in Eq. 4. Commands 'T' and 'H' allow the user to add an offset to the temperature and relative humidity values.

## **IMPORTANT PRECAUTIONS**

All sensor designs are made for air monitoring @ 1 atm +/- 0.2 atm. Because applications of use and device implementation are outside our control, SPEC Sensors cannot guarantee performance in a given device or application, and disclaims any and all liability therefore. **Customers should test under their own conditions to ensure the sensors are suitable for their requirements.**

Contact the factory to discuss specific concerns that might damage the sensor performance or life.

- Condensation and Water [1]
- High Temperature Operation (> 40C) for more than 1 month
- Low Humidity Operation (< 15% RH) for more than 3 months
- Highly contaminated air over a prolonged period
- High levels of particles or soot (unless proper filtering is provided) [2]
- High Altitudes
- Low oxygen levels

[1] Use of porous PTFE membrane or filter cap may address this concern)

[2] Use of replaceable filter recommended where dust and particulate is expected.

## SENSOR STORAGE, HANDLING AND SOLDERING

This information embodies various general recommendations concerning the storage, handling, and manual soldering conditions for SPEC SENSORS products. It is only applicable for products guaranteed by SPEC SENSORS stated in SPEC SENSORS Sensor Specification Sheet. Moreover, SPEC SENSORS' products are NOT warranted and should NOT be used in high temperature soldering (reflow) or pre-tinning baths.

### Sensor & Module Handling

Handle sensors with care. Take precautions, including but not limited to the following:

- A. DO NOT apply excessive pressure to the top or bottom of the sensor module.
- B. Whenever possible, handle or make contact with the sensor module from the sides of the PCB or substrate.
- C. Light vacuum pressure is possible during handling, DO NOT apply vacuum over gas sensor port.
- D. If the sealed sensor package is opened, DO NOT re-seal using vacuum or nitrogen gas. DO NOT reseal with desiccant.
- E. DO NOT obstruct the gas sensor port by making direct contact with any tape, apparatus, weights, etc.
- F. DO NOT use silicone or other conformal coatings around the sensor or gas port-holes.
- G. Operators are requested to wear powder free antistatic gloves.

### Manufacturing Assembly Floor Environment

SPEC SENSORS recommends that the manufacturing assembly floor environment be maintained at controlled conditions:

- A. Temperature: 18 - 26°C
- B. Relative Humidity: 40 to 60%
- C. Pressure: 1.0 ± 0.2 atm

### Sensor & Module Storage Conditions

SPEC SENSORS recommends that sensor components should be stored in the factory-sealed bag at the following conditions:

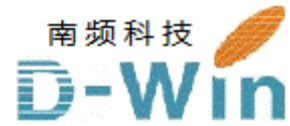
- A. Temperature: 5 to 25 °C
- B. Relative Humidity: 20 to 80%
- C. Pressure: 1.0 ± 0.2 atm
- D. Storage Time: 12 months

When moving from Storage Conditions to the Manufacturing Assembly Floor Environment, the sensors should be allowed to equilibrate at the new conditions for at least 24 hours prior to testing.

### Module Attach Soldering Process

Hand solder only. Keep the soldering iron or solder process tool away from the sensor. The sensor should not see pre-heat temperatures above 70 °C. There have been suggested cases where a heat sink cover over the sensor may be applicable to protect the sensor during processing. No Application notes to this approach available. To be used as reference only.

- A. DO NOT heat sensor above 70 °C.
- B. Hand or peripheral process type approach.
- C. Use solder wire alloy with the lowest possible eutectic temperature.
- D. Use lowest possible soldering iron temperature.
- E. Contact the host board with the soldering iron at a 45° angle on the solder pad.
- F. Keep the soldering iron away from the top and bottom of the sensor module.
- G. DO NOT place in reflow, wave or IR reflow type processes.
- H. DO NOT place mounted board in a wash.



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