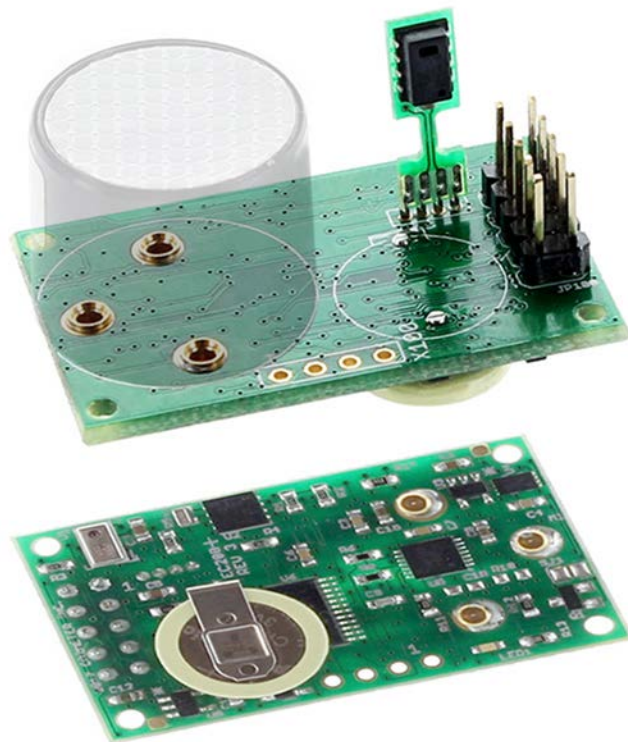


EC200 Electrochemical Sensor Controller Manual

Revision R



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Document History

Date	Revision	Description
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18 February, 2015	B	Version 2 Firmware
11 May, 2017	C	Version 3 Firmware
12 September, 2017	D	Final Draft for Review
10 October, 2017	E	Publish
13 October, 2017	F	Added dimensional drawing
14 February, 2018	G	Firmware EC200v3b008. Add # command, Add J for AUX voltage logging. Scaling for PWM and Analog outputs. Clarification and elaboration.
20 February, 2018	H	Detail on Parameter 3
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June 20 2018	P tmp	Rev 3B19 validate calibration procedure.
July 9 2019	Q draft	Rev 3B21 Calibration procedure and calculation added chapter 6. Default zero, span and concentrations. Additional gases. Add preliminary support for EC300.
November 9 2019	R	Rev 3B21 Calibration documentation update, Zero, Span, Compensation, additional gas references.

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Introduction

About this Manual

This document is a technical reference for the gaslab.com EC200 Electrochemical Sensor Controller. It provides the information necessary to use the sensor controller as well as information about configuring the controller for various applications.

GasLab

A convenient software application that provide for an interactive configuration, operation, for development or laboratory application is available free of charge from the gaslab.com site. It does require a USB to UART bridge cable or a USB to RS485 Bridge cable

<https://www.co2meter.com/collections/sensors/products/sdk-sensor-replacement-cables>

GasLab Software download

<https://www.gaslab.com/pages/downloads>



Chapter 1 : Overview

General

The EC200 Sensor Controller is a high performance low power controller supporting a wide variety of 20mm electro-chemical plug-in gas sensor cells. The controller supplies the necessary interface to the gas sensor cell and converts the sensor output current to a voltage that is measured by a high-resolution analog to digital converter. This digital voltage is then corrected and compensated for temperature and pressure by a microcontroller to produce an accurate gas concentration measured in ppm (parts per million). Measurements are available at the serial interface and/or can be logged to non-volatile storage for later retrieval.

In typical applications the sensor samples once per second and filters readings over 8 seconds. The sample interval is user configurable.

Measurements

The EC200 makes several measurements, typically once per second. Any or all of these are available through the streaming interface as described in Chapter 2. In the descriptions below, the letter in parenthesis is that used to report the value on the communication interface.

Unfiltered Voltage (v)

This is voltage from the analog front-end circuit. This voltage is directly proportional to the current from the electrochemical gas sensor cell. The current to voltage transfer function depends on the configuration for the sensor in use.

Filtered Voltage (V)

This is the voltage from the analog front-end passed through a low pass filter that removes short-term (seconds) disturbances.

Unfiltered Uncompensated Concentration (D)

This is the computed unfiltered gas concentration prior to compensation for temperature and pressure.

Unfiltered Concentration (z)

This is the computed unfiltered gas concentration compensated for temperature. The temperature compensation is performed using 5C degree values determined during factory calibration. Linear interpolation is used between calibration values.

Filtered Concentration (Z)

This is the filtered gas concentration compensated for temperature and temperature. This is the primary measurement made by the device.

Temperature (T)

This is the temperature reading from temperature/humidity sensor device.

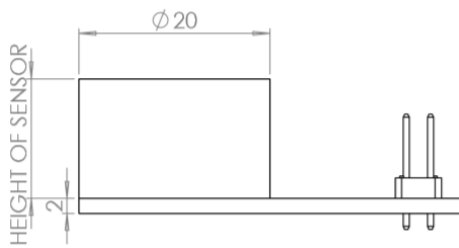
Humidity (H)

This is the Relative Humidity reading from the temperature/humidity sensor device.

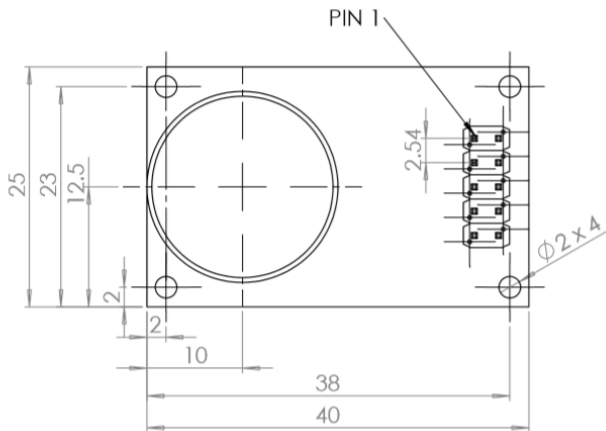
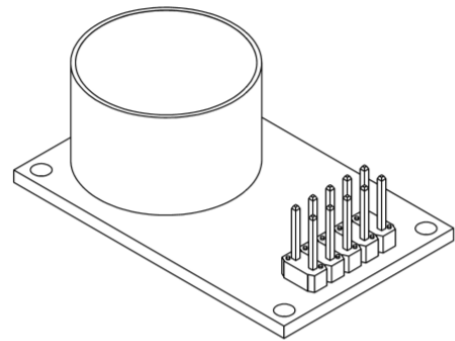
Barometric Pressure (B)

For models equipped with a barometric sensor, this is the barometric pressure. This value is corrected by the microprocessor for linearity and temperature using values determined during manufacturing of the sensor. Barometric Pressure is valid only in the range from 500 – 1150 millibar.

Dimensional Drawing



NOTE: SENSOR HEIGHT TO VARY FROM 12.5-17.5



ALL DIMENSIONS ARE
IN MILLIMETERS

Chapter 2 : Communications Interface

General

The EC200 communicates with a host system through a UART interface using either CMOS/TTL Rx and Tx or Differential RS485. The EC200 is a 3V system. The Rx input, however, is fault-tolerant to 5V and will generally interoperate with 3V to 5V systems. The EC200 also has a half-duplex RS485 interface that allows operation over long cables. The RS485 is enabled when Pin 2 is low at power up.

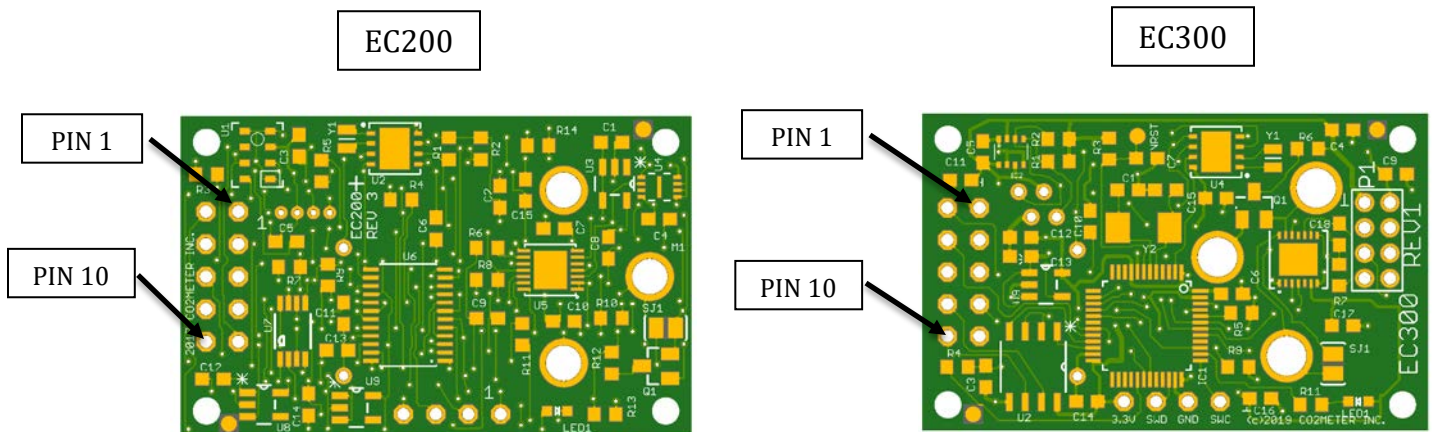
When RS485 is enabled (**Pin 2 low at power up**), the Communication Interface can be operated in either single sensor or multiple sensor mode. Multiple sensor mode permits up to 31 sensors to be multi-dropped on the same differential pair.

Physical Connections

The EC200 uses a 10 pin (2x5) header with 0.1-inch centers. When viewed from the sensor side with the connector to the left side of the board, Pin 1 is the lower right pin of the header.

Connector Assignments

Pin	Function	Pin	Function
1	Power and Signal Return	2	Select: PWM /RS485
3	+3 to +5.5V Power	4	AUX Analog -
5	Rx (Input to Sensor)	6	AUX Analog +
7	Tx (Output from Sensor)	8	RS485 A (Data -)
9	Analog Output (0 - 3V)	10	RS485 B (Data +)



Programming connector: EC200: 1-ground 2-TDIO 3-TCLK 4-VCC 2.8 TI430
 EC300 1-CLK 2-GND 3-DATA 4-VCC 3.3 STM32

Oxygen select: short = O2 open = 3 terminal sensor

EC/MX300 P1 (8 pin)
EC/MX300 AUX RHTB tube cap (4 pin)

RS485 Input

If ground is applied to Pin 2 (Select: PWM/ RS485) at power up, the RS485 interface is selected. The RS485 Interface will be used for both transmit and receive. (TTL level TX output will also occur on pin 7). Note that RS485 is two wire, half duplex. The EC200 is normally listening and enables transmit only when transmitting a reply to the host system.

Note: Streaming operation is not possible using RS485 interface.

Note: RS485 selection is only sampled at power-up, selector must be tied low before power-up for the selection to be valid.

PWM Output

If the Select/PWM output is open (or high) at power up, the TTL serial interface is selected and PWM is supplied from pin 2 If Enabled in Configuration Option word register 4, Bit 14 (16384) is set must be set to enable PWM operation.

Analog Output

Pin 9 can be configured as an analog output with a full scale range from 0.00 to 3.00V. The output is derived from a 1ms PWM filtered by a restoration filter consisting of a 10k resistor and 1uF capacitor. The output impedance is approximately 10K. Note that the impedance of the input will reduce the maximum output voltage to approximately $3.0V * Z / (Z + 10k)$. For example, with an input impedance of 50K the full-scale output will be $3.0 * 50k / 60k = 2.5$ Volts.

Analog Input (Differential)

Pins 4 and 6 provide an auxiliary differential analog input. The full-scale voltage range between inputs is -1.0V to +1V. The voltage on either pin with respect to ground must be in the range from -1.0V to +3V. NO PROTECTION IS PROVIDED FOR INPUT OVERVOLTAGE.

The typical singled ended input impedance (either pin to ground) is 200kOhm. The differential input impedance (between pins) is 300kOhm minimum 400kOhm typical.

The auxiliary analog input value is available via command "J".

Link Level Parameters

The line-level communications parameters are asynchronous 9600 baud, 8 bits, no parity, and a single stop bit, CMOS logic level 3.3-volt interface, communications is full duplex. For the RS485 interface, communications are half duplex.

TTL Protocol

The host and the controller exchange lines of data. Each line of data to and from the controller is terminated by carriage linefeed (CR LF), i.e. ASCII 0x0d, 0x0a.

The controller always responds to each line. If the line contains a valid command, the controller acts on the command and returns a response. If the line is not recognized as a valid command the controller returns an error response.

Modes

The controller operates in one of two modes, polled or streaming. In polled mode the controller is silent except in response to a command. In streaming mode, the controller reports measurements at intervals of one second (or more) as determined by configuration.

With the CMOS interface, commands may be sent at any time and the controller will continue to stream measurements until the entire command is received. With the RS485 interface, the half-duplex nature of the interface requires that the host is host transmit only in the interval between streamed measurements or responses from the controller.

At power- up the controller enters polled or streaming mode depending on configuration. The mode can be temporarily changed with the K command.

Except during calibration, the controller enters a low power state between measurements. The controller will awaken with the falling edge of any data transmission from the host.

Commands

Each of the commands supported by the controller is described in the following. Each command consists of a single letter optionally followed by a space and one or two numeric fields separated by a single space. All other letter values not listed are reserved and should not be sent.

The controller always outputs numeric values as 5 decimal digits with leading zeroes if necessary. The controller accepts numeric values with 1 to 5 digits in the range from 0 to 65535.

The controller always responds to a command. The response to a valid and properly formatted command will begin with the command letter except in the case of the "Q" command (which returns the exact line that will be send during streaming). If the command is not valid and properly formatted, the response will be an error code.

Error codes:

- 1 – Unrecognized Command
- 2 – Improper Format
- 3 – Improper Value
- 4 – Invalid Date String
- 5 – Write Error
- 6 – Read Error
- 7 – Bad Parameter
- 8 – Value already set
- 9 – Command failed

- 10 – Command not implemented
- 11 – Not configured

Error responses begin with the letter “E” following by a space and the 5-digit error number. For example, if a command with an invalid command letter is sent the response will be:

```
E 00003<cr><lf>
```

B Command – Get Barometric Pressure

This command gets the barometric pressure. The value is in tenths of millibars in the range from 500 – 1150, i.e. the values returned will be in the range 5000 to 11500.

Example Request:

```
B<cr><lf>
```

Example Response:

```
B 10156<cr><lf>
```

This response indicates a barometric pressure of 1015.6 millibars.

b Command – Get Raw Barometric Pressure

This command gets the barometric pressure ADC value in tenths of millibars referenced but not temperature compensated MPL sensor..

Example Request:

```
b<cr><lf>
```

Example Response:

```
b 26688<cr><lf>
```

C Command – Set Current Date and Time

This command is used to set the Date and Time for the real-time clock calendar. This is used for logging. The date format is ISO 8601 format, i.e. YYYY-MM-DDTHH:MM:SS where the hour is based on a 24-hour clock. The format must be exact. When using a terminal, it is usually best to do a “c” command first to see the correct format.

Example Request:

```
C 2014-08-06T13:10:22<cr><lf>
```

Example Response:

```
c 2014-08-06T13:10:22<cr><lf>
```

c Command – Get Current Date and Time

This command is used to get the current date and time.

Example Request:

```
c<cr><lf>
```

Example Response:

```
c 2014-08-06T13:10:22<cr><lf>
```

G Command – Get Sensor Type

This command is used to obtain an abbreviation for the type of sensor and its full span range. The value returned is a concentration followed by 4-character string with trailing spaces. Note that the concentration must be scaled according to the scale factor returned by the "." command. Values include: "CO", "O2", "H2S", "NO ", "SO2 ", "CL2 ", "SO2 ", "ET ", "H2 ", "HCL ", "SOH ", "HCN ", "PH3 ", and "NO2 ".

Example Request:

```
G <cr><lf>
```

Example Response:

```
G 01000 CO<space><space><cr><lf>
```

If the scale factor from "." is 1, the above response indicates that the controller is configured for a 1000ppm Carbon Monoxide sensor.

H Command – Get Relative Humidity

This command is used to get the relative humidity. The value is supplied in tenths of percent relative humidity.

Example Request:

```
H<cr><lf>
```

Example Response:

```
H 00452<cr><lf>
```

J Command – Get Auxiliary Analog Input MX200 FE channel 2

This command is used to get the voltage presented at the analog input. As this the input is differential, the value is presented in offset bipolar form. 32768 corresponds to 0. Values above 32768 are positive voltages. Values less than 32768 are negative values. The signed value can be obtained by subtracting 32768 from the value. For example, a value of 65000 is +32232. A value of 2000 is -30768. The result must be divided by 32768 to get the percentage of the full-scale range which is plus or minus 1 volt.

Example Request:

```
J<cr><lf>
```

Example Response:

```
J 34000<cr><lf>
```

This value is converted to a voltage as $(34000-32768) * 1.0/32768 = 0.0376$ volts. An example with a negative value is:

Example Response:

```
J 30000<cr><lf>
```

This value is converted to voltage as $(30000-32768) * 1.0/32768 = -0.0845$ volts.

j Command – Get Raw ADC Channel 0 AFE from EC Amplifier

Example request:

```
j <CR><LF>
```

Example response:

```
j 11000<CR><LF>
```

+/- 32768 centered on Reference and gain selected. Min/Max +/- 15-500 mV

K Command – Set Communications Mode

This command is used to the communications the communication mode. A value of 1 sets the mode to streaming and a value of 2 sets to the mode to polled. The response is a “K”

followed by the new mode. Note: a mode value of 0 is also accepted and behave exactly like Mode 2.

Example Request:

```
K 2<cr><lf>
```

Example Response:

```
K 00001<cr><lf>
```


M Command – Set Output Fields

This command is used to the fields that are sent in streaming mode, or in response to the “Q” command. A single 16-bit number is used to set the fields in accordance with the following table.

Table 1 Output control register

Measurement	ID	Mask Value	Description
Reserved		32768	
Reserved		16384	
Barometric Pressure	B	8192	Barometric Pressure
Relative Humidity	H	4096	Relative Humidity
Uncompensated Gas	D	2048	Uncompensated Unfiltered Gas Concentration
Raw ADC Value	d	1024	Raw ADC Value from analog front-end
Reserved	-	512	
Auxiliary Voltage	J	256	Auxiliary Voltage differential input.
Filtered Voltage	V	128	Filtered Voltage from analog front-end
Temperature	T	64	Temperature from RH Sensor
Temperature ADC	t	32	Raw Barometric Sensor Temp Value
Pressure ADC	b	16	Raw Barometric Pressure ADC Value
Unfiltered Voltage	v	8	Unfiltered Voltage from analog front-end
Filtered Gas	Z	4	Filtered and Compensated Gas Concentration
Unfiltered Gas	z	2	Unfiltered Compensated Gas Concentration
Reserved		1	

To set the output format add together the “Mask Values” from the above table for those readings that you wish to include in the output. For example, if want to display Filtered Gas “Z” (4) and Temperature “T” (64) add the two mask values to get 68 and use this as the value for the M command.

Example Request:

```
M 68<cr><lf>
```

Example Response:

```
M 00068<cr><lf>
```

A subsequent Q command will then give us an output as follows:

Example Request:

```
Q<cr><lf>
```

Example Response:

```
Z 00004 T 01254<cr><lf>
```

The output of the Q command is the same output that will with each line when streaming is on.

If 0 or a reserved bit is selected all fields will be reported on “Q” command or streaming mode.

P Command – Set Parameter to Value

This command is used to set the value of a parameter. The command requires the address of the parameter (0 – 31) and the new value.

Example Request:

```
P 4 10<cr><lf>
```

Example Response:

```
P 4 10<cr><lf>
```

p Command – Get Parameter Value

This command is used to get the current value for selected parameter 0-31.

Example Request:

```
p 4<cr><lf>
```

Example Response:

```
p 4<cr><lf>
```

Q Command – Get Readings

This command is used to get the readings that would be send in streaming mode. The format of the reply depends on current output format as set by the “M” command.

Example Request:

```
Q<cr><lf>
```

Example Response:

```
Z 00004 T 01254 H 00455 B 10149<cr><lf>
```

The above response indicates a gas concentration of 4ppm, a temperature of 25.4 degrees C, a relative humidity of 45.5% and barometric pressure of 1014.9 millibar.

R Command – Read Log Memory

This command is used to read the EEROM memory used for logging. Memory is organized as 32768, 16-bit words. Each word has a decimal value range from 00000 to 65535.

The R command requires two parameters. The first is an Address in the range from 0 to 32767. The second parameter is a word count in the range of 1 to 8.

The memory is organized in 256-word blocks and each read is confined to a single block. If a read operation extends across a block, the read operation wraps around to the start of that block. Wraparounds are avoided by always accessing data on a 16-byte boundary, i.e. with an address that is evenly divisible by 16.

Example Request:

```
R 32 8<cr><lf>
```

Example Response:

```
R 00514 00514 00514 00514 00514 00514 00514 00514  
<cr><lf>
```

r Command – Erase Log Memory

This command is used to erase all of log memory. After issuing this command the user should wait at least 5 seconds before issuing another command that accesses log memory. Note that when the controller responds to this command it will complete the erase operation in the background and then return to low power mode.

Example Request:

```
r 12345<cr><lf>
```

Example Response:

```
r <cr><lf>
```

T Command – Get Temperature

This command is used to obtain the current temperature. The response is in tenths of a degree C using an “excess 1000” notation. This always results in a positive value. For

example, the reading 01250 corresponds to 25.0C, the reading 01000 corresponds to 0.0C and the reading 00970 corresponds to -3.0C. In other words, just subtract 1000 and the result will be the temperature in signed tenths of degrees C. EC200 SHT

Example Request:

```
T<cr><lf>
```

Example Response:

```
T 01275<cr><lf>
```

This response indicates a current temperature of 27.5 Degrees C.

t Command – Raw Temperature voltage from Barometer

This command is used to obtain the raw temperature from the barometer. It is a signed integer proportional the temperature the barometer die is sensing. EC200 MPL

Example Request:

```
t<cr><lf>
```

Example Response:

```
t 01275<cr><lf>
```

This response indicates a current temperature of 27.5 Degrees C.

U Command – Zero Calibrate

This command is used to set the zero point for the sensor. Calibration is performed using Nitrogen gas at 26C plus or minus 1C as further discussed in Chapter 4.

Example Request:

```
U<cr><lf>
```

Example Response:

```
U 11192<cr><lf>
```

The response to the command is the numeric value corresponding to the zero point. This value can be modified manually with a subsequent “u” command to change or restore the zero point.

u Command – Set Zero Calibration Point

This command is used to manual adjust or set the zero calibration or restore to a previous zero calibration point value. A “W” to save the value otherwise will be overwritten on power up or restart.

Example Request:

```
u 11192<cr><lf>
```

Example Response:

```
U 11192<cr><lf>
```

V Command – Get Filtered voltage.

This command is used to obtain the filter voltage from the electro chemical sensor. Value is in millivolts. It is the input to the ADC PGA average value from 8 consecutive measurement cycles.

Example Request:

```
V<cr><lf>
```

Example Response:

```
V 01275<cr><lf>
```

This response indicates a voltage of +1275 mV.

v Command – Get Unfiltered voltage.

This command is used to obtain the Unfiltered voltage from the electro chemical sensor. Value is in millivolts. It is the input to the ADC with out any filter or average.

Example Request:

```
v<cr><lf>
```

Example Response:

```
v 01275<cr><lf>
```

This response indicates a voltage of +1275 mV.

W Command – Write Current Parameter Values to Flash

This command is used to write the current set of 32 parameter values to flash. By design, parameters that are changed are **not** automatically written to non-volatile memory until a W command is issued or a calibration is performed. The W command calculates the check sum (parameter 0) for parameters 1-31 parameter then writes parameters 0-31 to non-volatile memory

Example Request:

```
W<cr><lf>
```

Example Response:

```
W<cr><lf>
```

w Command – Reset Parameters to Manufacturing Defaults

This command is used to restore all parameters to their default. This will wipe out any calibration that has been performed. The unlock code of “12345” is required to prevent accidentally invoking this command. All 32 parameters will be written.

The first parameter provides a numeric sensor type which determines the default values. This should be 1 for CO and 2 for O2, see Gas type table register 6.

Example Request:

```
w 1 12345<cr><lf>
```

Example Response:

```
w 1<cr><lf>
```

X Command – Calibrate to specified concentration

This command is used to calibrate the sensor using a gas of known calibration. The sensor must have been previously zeroed. The calibration gas should be at 25 to 27-degree C. The gas reading must be stable prior to issuing this command.

Example Request:

```
X 500<cr><lf>
```

Example Response:

```
X 16076<cr><lf>
```

Assuming a sensor cell with a 1ppm resolution, this example sets the calibration for 500 ppm. The returned value of 16076 is the filtered ADC value at the calibration point.

x Command – Reserved for Factory Use

This command is reserved for factory use.

Y Command – Report Device Identification

This command is used to obtain information about the device.

Example Request:

```
Y<cr><lf>
```

Example Response:

```
Y gaslab EC200 SN 00080 VER 03 BUILD 008<cr><lf>
```

Z Command – Get Filtered Gas Concentration

This command is used to obtain the filtered and compensated gas concentration. The 5-digit value returned must be multiplied by the multiplier value to arrive at ppm. For a multiplier of 1, the value will be actual ppm.

Example Request:

```
Z<cr><lf>
```

Example Response:

```
Z 00004<cr><lf>
```

This example response would be returned for a sensor with a resolution of 1ppm that is presently seeing a gas concentration of 4ppm.

z Command – Get Unfiltered Gas Concentration

This command is used to obtain the unfiltered (i.e. current) gas concentration.

Example Request:

```
z<cr><lf>
```

Example Response:

```
z 0003<cr><lf>
```

This example response would be returned for a sensor with a resolution of 1ppm that is seeing a gas concentration of 3ppm.

. Command – Get Multiplier

This command returns the multiplier that should be applied to the gas concentration reading to arrive at ppm. This will generally be 0, 1, 10, or 100 depending on the range of the sensor. Note that 0 is used for a multiplier of 0.1, i.e. 1/10th ppm.

Example Request:

```
. <cr><lf>
```

Example Response:

```
. 00001<cr><lf>
```

[Command – Reload and Restart AFE.

Reloads the constant from parameter registers used to operate 91000 and restart 91000 used when adjusting offset, bias, and gains.

Example request:

```
[ <cr><lf>
```

Example response:

```
[<cr><lf>
```

RS 485 Interface Commands

The RS 485 Interface allows multiple sensors to be controlled from a single host over distances of several hundred feet. All devices as well as the host transmit and receive data over a single wire pair. Note that for distances greater than 10 feet, both ends of the cable should be terminated in the characteristic impedance of the line (typically 100 ohm).

The Protocol used by the RS485 Interface is identical to the TTL interface except for the addition of a “Select” command (!). The select command allows the host to specify which of the multiple devices attached to the line will respond to subsequent commands.

! Command – Select Device

This command selects the device with the specified address. For device addresses other than 0, the device with the specified address will generate the response. All other devices remain silent. For device address 0, any device on the line will respond and will return its presently configured address (parameter 4). Note that when device address 0 is used ALL devices will reply with its address – only one device should be present on the line. This feature is intended solely for identification of the device address. The device address is stored as parameter 4.

The following example selects device 5.

Example Request:

```
! 5<cr><lf>
```

Example Response:

```
! 00005<cr><lf>
```

Note that the address is provided in the response in the same format as other values, i.e. 0 to 65535 with leading zeros.

All devices will deselect when the “!” character is received.

Example request:

```
! <cr><lf>
```

Example response:

```
No response
```

This assures that a device will not remain selected due to a communications error. Devices will be selected only upon receipt of their address or the 0 address.

Self-Identification, selecting address 0 (only 1 device connected) reports programmed address from parameter word 4.

Example Request;

```
! 0<cr> <lf>
```

Example response;

```
! 00005<cr><lf>
```

Command– Restart

Same as power cycle, all 32 previously stored parameters will be reloaded. This does not reload factory defaults.

Example Request:

```
# 12345<cr><lf>
```

Example Response:

```
No response
```

Chapter 3 : Configuration

General

The sensor controller configuration is controlled by 32, 16-bit parameter values that are stored in the flash of the microcontroller. These parameters control how the analog front-end device is configured, how values are converted to concentration, and the characteristics of the communication interface.

Parameter Summary

The following table provides a summary of the 32 parameters and their default settings. All parameters are 16-bit integers. All parameter may be read by “p” command and written by “P” command. “W” command write all value to EEPROM (Note that these defaults may not be appropriate for all sensor types).

Table 2 configuration registers (3)

#	Default Value	Name	Description
0	N/A	Checksum	This is a computed value used to verify integrity
1	4294	Output Mode	Bit Mask of Output Values,
2	0	Log Mode	Bit Mask of Logging Values if 0 no logging
3		Sensor AFE Config	AFE 91000; Low byte TIACN & Load, Hi byte REFCN source zero and bias. Default is sensor dependent. 02-8199 CO-49164
4	05	Options Configuration	Configuration Option Word, ADR RS485, PWM, Streaming
5	0	Log Interval	Interval between logs in seconds if 0 no logging
6	1	Gas Type	See Table of Gas Types below
7		Zero	ADC value corresponding to zero at 25C generates at calibration U command.
8		Calibration at Reference gas	ADC value corresponding to ref gas at 25C generated by the X command.
9		Calibration Concentration	Scaled concentration of reference gas ppm stored when X command is executed.
10		Full Scale PWM	Full scale value for PWM; typically, 25K PPM for O2 and 2k PPM for CO. Typically the range for the sensor.
11		Full Scale Analog	Full scale value for Analog out typically 25K for O2 and 2K for CO. Typically the range for the sensor
12	1	Multiplier	Scale Multiplier in ppm sensor dependent.
13		Feature configuration	Bit 0 - Temperature compensation 0 = enabled. Bit 1 Pressure compensation 0 =disabled. AFE PGA 3 bits (0-5 valid; 1,2,4,8,16,32 Gains +/- 500 - 15 mV) channel: ADC 0 15-13 filtered EC, ADC 1 12-10 raw EC, ADC 2 9-7 AUX.
14		Reserved	MX/TX PWM timer base not used in EC200
15	21	Reserved	Modbus address, default 21 not used in EC200

16-31		TC Values	16 Temperature Compensation Values

Checksum (0)

The checksum is a computed value used to verify the integrity of the parameter data calculated W, U, X commands. On power up or # command, checksum for stored values is tested, if in error, default values (same as “w” command) are loaded and checksum set to 21930.

Output Mode (1)

The Output Mode is a bit mask that specifies which measurements are output in streaming mode. The bit assignments are described in Chapter 3 under the “M” command. At power-up default value is loaded. M command changes current mask, to set as default the W command is required,

Log Mode (2)

The Log Mode is a bit mask that specifies which measurements are logged when logging is enabled. The log mode bit mask has same parameter definitions as Output Mode mask.

AFE Configuration (3)

This parameter sets the configuration of the Analog Front End. The values depend on the electrical characteristics of the sensor. Configuration of the AFE is outside the scope of this document.

Configuration Option Word (4)

The configuration option word sets various device options. These include the RS485 device address, the Polling Mode at power up. Values are scribed in Chapter 3 under the “K” command.

Table 3 configuration options register (4)

Config Options(s)	Default	Bit Value	Description
Streaming	Off	32768	When this bit is set the device will stream after power up. (Until changed by K command)
PWM/ Analog OUT	Off	16384	Enable PWM and Analog Pin 2 and 9. Full scale Analog, full scale PWM must be >0
Reserved	Off	8192	
Reserved	Off	4096	
Reserved	Off	2048	
Reserved	Off	1024	-
Reserved	Off	512	-
Reserved	Off	256	-
Reserved	Off	128	-

Reserved	Off	64	-
Reserved	Off	32	-
Device Address	5	0-31	RS485 Device Address used with ! protocol EC/MX

The configuration word is set by adding the bit values for each option. For example, to set the “Select Protocol Option” with a device address of 5, parameter 4 must be set to a value of 16389 (16384 + 5). Note that streaming should also be turned off when using the select protocol.

Log Interval (5)

This is the Interval between log entries in seconds. A value of zero will disable logging.

Gas Type (6)

This is the type of gas. The values are as follows:

Table 4 Gas Type register (6)

Value	Abbreviation	Gas Species	Default 0	Default Span	Default configure	Load	Reference sensor
0	CO2	Carbon Dioxide					EC sensing not available.
1	CO	Carbon Monoxide 50-90 nA/ppm	11100	15000 11300	49157	33	CO-AF Apha 5000 ppm Cal 50ppm
	CO	Carbon Monoxide 50-90 nA/ppm	11100	15000	49157	33	CO-CF Alpha 5000 ppm Cal 50 ppm
2	O2	Oxygen 80-120 uA @20.9	17950	6900	8199 /	100	O2 A2 Alpha 20.9 Cal 20.9%
2	O2	Oxygen 60-85 uA @20.9	10925	4625	8199	100	O2 A3 Alpha 20.9 Cal 20.9 %
3	H2S	Hydrogen Sulfide 550-850 nA/ppm	11000 11144	15000 11271	49157/ 0xC005	33 10-47	H2S A1 Alpha 100 ppm Cal 50PPM
4	NH3	Ammonia-1000 8 nA +/- 4nA /ppm	11184 V12071	11230 V12084	49156	10	FECS44-1000 Figaro. Cal 50 ppm
4	NH3	Ammonia-100 17-27 nA/ ppm In 50 ppm	10296 V11843	10487 V11882	49157	33	NH3-A1 Alpha 100 ppm Cal 50
5	ET	Ethylene C2H4 65 nA/ppm	12327 V12364	15294 V13224	49156	10	CH4/ M-200 Membrapor 0-200 ppm
6	CL2	Chlorine Cl -350-50 nA/ppm	12332 V11565		49157	33 33-33	CL2-A1 Alpha 20ppm Cal 25 ppm
7	NO	Nitric Oxide 450-600 nA/PPM			49157	33 10-47	NO-A1 Alpha 250ppm Cal 50 ppm
8	SO2	Sulfur Dioxide 400-600 nA/ppm	11194 V12071	12023 V12300	49157	33 10-47	SO2-AF-Alpha 50 PPM Cal 25 ppm
9	NO2	Nitrogen Dioxide -400-700 nA/ppm	11121 V12053	10893 V11988	49157	33 33-33	NO2-AI ALPHA 20 ppm Cal 10 ppm
10	EtO	Ethylene Oxide C2H4O 2000-3200 nA/ ppm	11131 V12058	12203 V12360	49156	33 10-47	ETO-A1 0-100 Alpha Cal 20 ppm
11	HCl	Hydrogen Chloride HCl 80-130 nA/ppm				33 10-47	Alpha HCL-A1 100

12	O3	Ozone -1000 +/- 350 nA /ppm				10 10-33	O3/M5 Membrapor 0-5 ppm
13	HCN	Hydrogen Cyanide 55/85 nA/PPM				33	HCN-A1 Alpha 100 PPM Cal 20 ppm
14	C2H6O	Ethanol					
15	H2O2	Peroxide H2O2 900nA/ppm Bias 300 mV			49156	10	Membrapor H2O2/ MB-100
4	NH3	Ammonia-200	11151 V12062	11361 V12122	49156	33	FECS44-200 Figaro 200ppm Call 50 ppm
4	NH3	Ammonia-100	11100 V12050	11616 V12203	49156	33	FECS44-100 Cal 50 ppm

Zero Calibration (7)

This is the ADC value at zero calibration.

Calibration at Reference (8)

This is the ADC value at the reference calibration concentration.

Calibration Concentration (9)

This is the concentration used for span calibration was performed and saved for reference.

PWM Full Scale (10)

Full scale range for 100% PWM typically 25K for O2 and 2K for CO. 20.9K PPM/25K PPM= 83.6 % Full scale PWM.

Analog Full Scale (11)

Full scale range for 100% Analog (3 volts) typically 25K for O2 and 2K for CO. 20.9K PPM/25K PPM= 83.6 % Full scale = 2.508 volts.

Multiplier (12)

This is the multiplier value to arrive at ppm from the specified values. A value of 0 indicates that readings are in tenths of ppm. 1 indicates 1 ppm, 2 indicates 10ppm, 3 indicates 100ppm etc.

Feature Configuration (13)

Value for configuration of AFE PGA's and other selectable functions.

Table 5 ADC and compensation register (13)

Config Feature Parameter 13	Default	Bit Value	Description
Gain AFE CH0 PGA	000	32768 16384 8192	Sensor voltage input from 91000 C2 to CH0 ADC value in millivolts
Gain AFE CH1	000	4096 2048 1024	Temperature voltage input from 91000 Vout CH1 ADC value in millivolts
Gain AFE CH2	000	512 256 128	Auxiliary differential input. Note that each of these inputs must be referenced to ground within the common mode range of the input values (-1V to +2.8V).
Reserved		64	
Reserved		32	
Reserved		16	
Reserved		8	
Reserved		4	-
Pressure compensation		2	When = 1 enables pressure compensation
Temperature compensation	0	1	When = 1 disables gas sensor temperature compensation

The AFE Gain bit values are:

000 Gain of 1 (Default)
001 Gain of 2
010 Gain of 4
011 Gain of 8
100 Gain of 16
101 Gain of 32
110 Invalid - Do Not Use
111 Invalid - Do Not Use

For example, to set the gain to 8 for channel 2 (9,8,7) the gain value must be 011, i.e. bits 8 and 7 must be on. This requires a decimal value of 256 + 128 or 384 be added for this word from the default of 0).

Sequence to program;

Example; get the current value for reference

```
command: p 13 <cr> <lf>
```

```
response: p 13 00000
```


Set the value to 384

```
command: P 13 384
```

```
response: P 13 384
```

Write parameters to flash

```
command: W
```

```
response: W
```

Software reset to reload new gain value

```
command: # 12345
```

Temperature Compensation Values (16-31)

These are 16 temperature compensation values that range from -30C to 45C in 5C increments. These values are correction factors in unsigned Q14 format. In this format 32768 corresponds to 1, 32769 is 1 plus 1/32768.

The default values for these numbers is set to typical correction factors for the sensor. When auto calibration is performed, these values are set to match the actual characteristics of the sensor.

A null table no temperature corrects, would be parameters 16-31 =32768
The center or reference point of the table is 25C.

Chapter 4 : Calibration

WARNING: When performing calibration from reference gas always consult the Material Safety Data Sheet for the gas specie and concentration in use and observe all relevant safety precautions.

General

Electrochemical sensors produce a current output that is linearly proportional to the gas concentration. While extremely linear, the output level varies from sensor to sensor and from batch to batch. In order to provide an accurate output, the sensor and its controller electronics must be calibrated. Generally, this requires an accurate zero point and a second calibration point with a known concentration gas calibration.

Although the sensor output is linear, the chemical reaction that produces the output is sensitive to temperature. This sensitivity varies with temperature and varies from batch to batch and sensor to sensor. To provide an accurate reading, it is necessary to compensate for this temperature sensitivity. The EC200 provides the capability to automatically save these compensation values during an automatic calibration process.

Basic Calibration

Basic Calibration requires first that an accurate zero be set (typically with Nitrogen Gas at 25C +/- 1C) and then that a known gas concentration be provided (also at 25C +/- 1C) and allowed to completely stabilize.

The zero-calibration point is set using the U command. The reference point is set using the X command. When the X command is executed the microcontroller makes the necessary calculations for full span and stores these in the parameter storage.

By default, the temperature compensation values are set to typical values for the type of sensor involved. These typical values are sufficient for most applications. If the highest accuracy is desired, the temperature compensation can be edited.

Description of calibration table

Configuration words 15-31

-25C (parameter 16) to +50C (parameter 31) in 5 deg C increments.

Centered on +5C parameter 26

$1=32768 / 32769 = 1 + 1/32768$

Each 5C incremental step is linearly interpolated.

A Null table of non-correction would be a list of 32768's

25C does not have a Temp Co, so it is 32768 it's the calibration point for Zero gas at 25C

Temp Co table can be constructed from manufactures Temp Co table for sensor.

TempCo table for Alpha CO 1000			
Parameter	TempCo	Temp	Factor
16	40960	25	.8
17	39961	30	
18	39010	25	
19	39102	20	
20	36818	15	
21	36009	10	
22	34860	-05	
23	34493	10	
24	33781	15	
25	33437	20	
26	32768	25C	0
27	32444	30	
28	32450	35	
29	32125	40	
30	31814	45	
31	31660	50	1.0349

TempCo Table Alpha O2-AF			
Parameter	TempCo	Temp	Factor
16	40960	25	.8
17	39961	30	
18	39010	25	
19	39102	20	
20	36818	15	
21	36009	10	
22	34860	05	
23	34493	10	
24	33781	15	
25	33437	20	
26	32768	25C	0
27	32444	30	
28	32450	35	
29	32125	40	
30	31814	45	
31	31660	50	1.0349

Calculation of temperature coefficient

Expanding on the fractional nature of compensation values; i.e. if at 30C a sensor reports 1100 PPM in 1000 PPM reference gas a compensation of factor can be generated: $(1100/1000) * 32768 = 29789$ which would be the 30C table position (parameter 27).

Recommendation handling, storage and calibration;

EC sensor are allowed temperature stabilize to ambient before calibration, particularly if sensors are stored refrigerated.

Sensors being store ambient or refrigerated should be shorted to prevent polarization. Sensor stored un-shortened for long periods, should be shorted or mounted and allowed to normalize ~60 min. The EC200 sensor board have an internal shorting mechanism.

Calibrate to the application target or threshold, using calibration gas always check the expiration date of the gas.

Nitrogen for zero, consider the application, gas with low target threshold like CO (9 ppm background typical) for precision work a 99.999% should be use.

Chapter 5 : Logging

General

The EC200 equipped with 64K Bytes of logging memory. This can be used to log from 1 to 12 values at intervals of 1 second to 12 hours. Logs can be retrieved via the serial interface.

Log Blocks

The 64K bytes of logging memory are divided into 128 blocks (512 bytes each).

Each block is 256 words in length. Each block begins with a date/time stamp that is 4 words in length. This is followed by the log interval in seconds and the log mask. The log mask has a bit for each value that is logged. The number of bits that are set determines the length of each log record.

The remaining 250 words in the block contain log records, each a fixed length in words equal to the number of measurements that are logged. The entire block contains, at most, whatever number of records will completely fit in the block. For example, if only the gas concentration (Z) is logged, then the block can hold up to 250 records. If 12 measurements are logged, a block will hold 20 records (240 words) and the last 10 words of the block will remain unused. Unused log entries will always contain 65535 (0xffff hex).

Short Blocks

Each time the unit is powered up, or the log parameters are changed, or the date/time is changed, the current block is immediately closed and new log block will be started reflected the new values. The end of a short block is always indicated by a value of 65535 (0xffff).

Log Capacity

The total capacity of the log ranges from 31750 entries if only a single measurement is logged to 2540 entries if all 12 measurements are logged. Logging Gas Concentration, Temperature, Relative Humidity, and Barometric pressure (4 readings) the log will hold 7874 records. With an interval of 6 minutes, the log will hold more than a month of readings.

Date/Time Format

The first 4 words of each block contain the date/time of the first record written to the block. This data is in the native format of clock/calendar device used on the controller. The data consist of 8 bytes in little-endian order, i.e. the least significant byte of the word is first.

- Byte 0 is seconds in BCD (binary code decimal).
- Byte 1 is minutes in BCD.
- Byte 2 is hours in BCD on a 24-hour clock.
- Byte 3 is the day in BCD
- Byte 4 is not used and should be ignored.
- Byte 5 is the month in BCD

- Byte 6 is the last two digits of the year in BCD

Note that in BCD two decimal digits are encoded per byte, each with a 4-bit binary value that ranges from 0 to 9.

Block header decoding start time example;

Example request: Get first 6 words from start of block, i.e. 0, 256, 512;

```
R 0 6 <cr> <lf>
```

Example receive: 6 integer decimal values;

```
RECV:r 20773 01554 01024 65304 00005 15424
```

Convert time and date words Decimal- Hex integer- Packed BCD
5125 0612 0400 FF18

51 Minutes
25 Seconds
12 Hour (24 hour)
06 Day
00 unused
04 Month
FF unused
18 Year

00005 logging intervals in seconds.

15424 Mask for field to log.

Example of logging operation, partial block and start restart;

Set logging interval to 4 seconds start logging

```
SEND: P 5 4
```

```
RECV: P 00005 00004
```

Set logging interval to 0; stop logging

```
SEND: P 5 0
```

```
RECV: P 00005 00000
```

Read 100 word starting at 0;

```
SEND: R 0 100
```

Note; time and date and interval of 4 seconds and logging mask 4294

```
RECV:r 01540 05397 00513 65304 00004 04294 00001 0002  
RECV:r 01232 12088 00541 00003 00002 01232 12089 0540  
RECV:r 00003 00002 01232 12090 00544 00001 00002 1234  
RECV:r 12087 00555 00003 00001 01235 12087 00552 0002  
RECV:r 00002 01235 12089 00548 00002 00002 01235 2089  
RECV:r 00545 65535 65535 65535 65535 65535 65535 65535  
RECV:r 65535 65535 65535 65535 65535 65535 65535 5535  
RECV:r 65535 65535 65535 65535 65535 65535 65535 5535  
RECV:r 65535 65535 65535 65535 65535 65535 65535 5535  
RECV:r 65535 65535 65535 65535 65535 65535 65535 5535  
RECV:r 65535 65535 65535 65535 65535 65535 65535 5535  
RECV:r 65535 65535 65535 65535 65535 65535 65535 5535  
RECV:R 65535 65535 65535 65535
```

Restart logging at 7 second interval.

```
SEND: P 5 7
```

```
RECV: P 00005 00007
```

Stop logging

```
SEND: P 5 0
```

```
RECV: P 00005 00000
```

Read 100 words starting at 0- 100

```
SEND: R 0 100
```

```
RECV:r 01540 05397 00513 65304 00004 04294 00001 00002  
RECV:r 01232 12088 00541 00003 00002 01232 12089 0540
```


Chapter 6: Sensor Support

The EC200 can support a wide range of 2 terminal and 3 terminal electrochemical sensor cells. The controller uses a Texas Instruments LMP91000 Analog Front End (AFE) to interface to the cell. The AFE transforms the current output of the cell to a voltage that is read by the Analog to Digital Converter (ADC). This section describes how the EC200 can be configured for different types of electrochemical cells. Additional information can be found in the LMP91000 datasheet from Texas Instruments.

AFE Configuration

The EC200 maintains the AFE Configuration in a single 16-bit parameter p3. The actual configuration is stored in two 8-bit registers referred to as TIACN - TIA Control Register and REFCN - Reference Control Register. At power up, the most significant 8 bits of p 3 are written to REFCN and the least significant 8 bits of p 3 are written to TIACN. The 16-bit value must be written to register p3 as a decimal value. The following sections how to determine the appropriate values for a particular model of sensor cell.

ADC

The ADC converts the AFE output voltage from the AFE to digital form. The ADC has a full-scale input range from 900mV to 2700mV. The input is converted to digital values that range from 0 to 65535. The 'v' command can be used to read the current unfiltered voltage from the controller in tenths of millivolts. This output has a range from 9000 to 27000 corresponding to 900 to 2700 mV. The Raw ADC value is available in streaming mode as the 'd' value.

The raw ADC values can be converted to tenths of a millivolt with the equation:

$$V = 9000 + R*18000/65535$$

where R is the raw ADC value. A value in millivolts can be converted to a raw reading with the equation:

$$R = (V - 900) * 65535/1800.$$

The following shows the useful available reference values.

Reference mV	Source	% of Ref	Raw ADC
900	External (1800 mV)	50%	0
1206	External (1800 mV)	67%	11141
1400	Internal (2800 mV)	50%	18204
1876	Internal (2800 mV)	67%	35535

3 Terminals Cells

For three terminal cells the CE, RE, and WE terminals are connected to the corresponding pins on the AFE. The AFE is always configured in “potentiostat” mode. The voltage output of the AFE is determined by the programming of the “TIA Gain” and “Zero Reference” levels.

The Zero Reference sets the output of the AFE for zero output current from the sensor. The Gain sets the ratio of voltage output to sensor current. The gain, V/I , is typically millivolts per milliamp. The output voltage is equal to $\text{Gain} * \text{Input Current}$. For example, with a gain of 2750 ohm and sensor current of 100uA the output current will be $2750\text{mV} * 0.1\text{mA}$ or 275mV. With a gain of 7000 ohm, the same 275mV input current produces an output of 700mV.

Zero Reference

3 Terminal Cell outputs will produce a positive swing of AFE output voltage. For maximum resolution, the zero reference should be set as low as possible above 900mV. Two references, internal and external are available. The external reference is at 1.8V. The internal reference is at 2.8V. The TIA can be configured to be 20%, 50%, or 67% of the reference. The accuracy of the reference is plus or minus 0.04%.

Setting 67% of the 1.8V reference will set the zero to 1206 mV. This will allow the output to swing up 2700 mV or 1494 mV above the reference. This corresponds to a sensor current of 543 uA at the lowest gain setting.

2 Terminal Cell outputs will produce a negative swing of AFE output voltage. For maximum resolution, the zero should be set as high as possible below 2700mV. A setting of 67% of the 2.8V reference will set the zero to 1876 mV. This will allow the output to swing down to 900mV or 976mV below the reference. This corresponds to a sensor current output of 355uA at the lowest gain settings.

Gain Setting

The TIA gain can be set 2.75k, 3.5k, 7k, 14k, 35k, 120k, or 350k. The gain setting will normally be set to bring the full- scale voltage as high or low as possible for 3 terminal or 2 terminal configurations respectively. For example, a typical O₂ sensor will have an output of 80 uA to 120 uA at 20.9%. If we wish to support a full scale of 22% for an oxygen depletion application, the sensor output may be up to 127uA at 22%. A gain of 7k will produce a full-scale output of 889 mV below the 1876mV reference or 987 mV. The full range will be 987 to 1876mV for outputs from 22% to 0%.

Bias Setting

Some sensors require a bias between the WE and RE terminals. This bias may be positive or negative and can be set to 0 to 24% of the reference source (the same reference used for the zero).

Configuration Bits

The following table shows the bit assignments for the configuration value that must be written and saved as parameter 3. Note that this value must be written in decimal form.

Bit	Name	Function
15	REF_SOURCE	Reference voltage source 0 Internal 1 External
[14:13]	INT_Z	Internal zero selection (% of source ref) 00 20% 01 50% 10 67% 11 Internal zero bypassed (not used)
12	BIAS_SIGN	Selection of the Bias polarity 0 Negative (WE - RE < 0V) 1 Positive (WE-RE > 0V)
[11:8]	BIAS	0000 0% 0001 1% 0010 2% 0011 4% 0100 6% 0101 8% 0110 10% 0111 12% 1000 14% 1001 16% 1010 18% 1011 20% 1100 22% 1101 24%
[7:5]	RESERVED	RESERVED
[4:2]	TIA_GAIN	TIA Feedback Selection 000 External 001 2.75k Ohm 010 3.5k Ohm 011 7k Ohm 100 14k Ohm 101 35k Ohm 110 120k Ohm 111 350k Ohm

[1:0]	RLOAD	Load Resistance 00 10 ohm 01 33 ohm 10 50 ohm 11 100 ohm
-------	-------	--

Calibration Values

The EC200 holds calibration information as parameters 7, 8, and 9. Parameter 7 is the raw ADC value representing the sensor output at zero ppm. Parameter 8 is the raw ADC value representing the sensor output at a specified ppm. Parameter 9 is the specified ppm.

The initial default calibration values are normally written to the configuration during initial setup. These values are the theoretical zero values, span, and sensor output at span. These can be determined a priori based on the sensor datasheet values and the configuration.

During actual calibration the precise values are written for the particular installed sensor. For the span calibration both the raw ADC value (parameter 8) and the concentration (parameter 9) are written.

Design Procedure

The following general steps can be used to determine the optimal settings for a particular sensor cell.

1. First determine the output current range for the sensor. This will typically range from 0 to a few hundred microamps. Determine also whether the sensor output is positive or negative.
2. Based on the voltage swing, determine sensor current for zero (no input gas) and full scale (maximum input gas concentration).
3. Select a zero reference. For negative going sensors the reference should be as high as possible below 2.7V. For positive going sensors the reference should be as low as possible below 900mV.
4. Select a gain that will allow the output to swing over as large a range as possible while still remaining within 900mV to 2700mV. Start with the lowest gain 2750.
5. Determine the values required for the LMP 91000 registers and convert. this is p3.
6. Determine an appropriate full scale range of the sensor and calibration span..
7. Determine the default zero calibration point. this is p7
8. Determine the default span calibration point. This is p8.

Note that steps 6, 7 and 8 are optional.

Support

The quickest way to obtain technical support is via email. Please send all support inquiries to info@gaslab.com

Please include a clear, concise definition of the problem and any relevant troubleshooting information or steps taken so far, so we can duplicate the problem and quickly respond to your inquiry.

Warranty

This device comes with a 90 day (warranty period) limited manufacturer's warranty, starting from the date the meter was shipped to the buyer.

During this period of time, gaslab.com warrants our products to be free from defects in materials and workmanship when used for their intended purpose and agrees to fix or replace (at our discretion) any part or product that fails under normal use. To take advantage of this warranty, the product must be returned to gaslab.com at your expense. If, after examination, we determine the product is defective, we will repair or replace it at no additional cost to you.

This warranty does not cover any products that have been subjected to misuse, neglect, accident, modifications or repairs by you or by a third party. No employee or reseller of gaslab.com's products may alter this warranty verbally or in writing.

Liability

All liabilities under this agreement shall be limited to the actual cost of the product paid to gaslab.com. In no event shall gaslab.com be liable for any incidental or consequential damages, lost profits, loss of time, lost sales or loss or damage to data, injury to person or personal property or any other indirect damages as the result of use of our products.

Returns

If the product fails under normal use during the warranty period, an RMA (Return Material Authorization) number must be obtained from gaslab.com. After the item is received gaslab.com will repair or replace the item at our discretion.

To obtain a RMA number, call us at or email us at (386) 256-4910 - info@gaslab.com

When requesting a RMA please provide reason for return and original order number. If we determine that the product failed because of improper use (water damage, dropping, tampering, electrical damage etc.), or if it is beyond the warranty date, we will inform you of the cost to fix or replace the product.


For more information visit our website: www.gaslab.com/pages/faq

Contact Us

We are here to help!

For information or technical support, please contact us.

 info@gaslab.com

 (386) 872 - 7668

 www.gaslab.com

Address:

GasLab, Inc.

131 Business Center Ste.

A3 Drive Ormond Beach,

FL 32174 USA