

**HART Applications
SEC-5000 Gas Detector**

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1 Introduction

The SEC5000 is a fully functional Gas Detector, capable of detecting a wide range of gases using infrared absorption. The primary means of digital communication with the Gas Detector is the one-wire proprietary method developed by Sensor Electronics. However, the SEC5000 can also use HART (Highway Addressable Remote Transducer) digital Communication.

This document contains complete information on interfacing the SEC5000 to HART equipment, such as a PC and HART Modem. Questions about the SEC5000 HART version may be directed to Sensor Electronics Corporation at 952-938-9486. Additional useful HART information and products may be found at

ProComSoll, Ltd, 13001 Athens Avenue #220, Lakewood, OH 44107.

Romilly's HART and Fieldbus Web Site, www.romilly.co.uk.

Nesebar, Inc. web site, www.nesebarinc.com.

Note 1: Please refer to the SEC5000 Manual [SEC 5000 IREvolution Gas Detector Instruction and Operating Manual, Part Number 1460005, Revision C] for more complete information on non-HART aspects of Gas Detector Operation.

Note 2: The SEC5000 is available in both HART and standard versions. The HART version must be explicitly indicated when ordering.

Note 3: HART is a trademark of the HART Communication Foundation [FieldComm Group, 9430 Research Blvd, Suite 1-120, Austin, TX 78759]. The use of the term HART in this and other Sensor Electronics Documents does not imply or guarantee adherence to the standards and practices of the HART Communication Foundation.

2 HART Equipment and Connections

Figure 2.1 shows how to connect HART hardware using either a PC and HART Modem or a HART Hand-Held Communicator. (Note: Sensor Electronics Corp. supplies only the SEC5000 Gas Detector. Other items must be purchased separately.)

The Current Sense Resistor typically ranges from 230Ω to 600Ω. In addition to the connections shown, the Current Sense Resistor is often connected to a separate meter or data acquisition system.

The White-Wire may be used to Calibrate the SEC5000 by connecting it to either Ground (Black) or +24V (Red), as further explained in the SEC5000 Manual. Or the White-Wire may be left open and HART

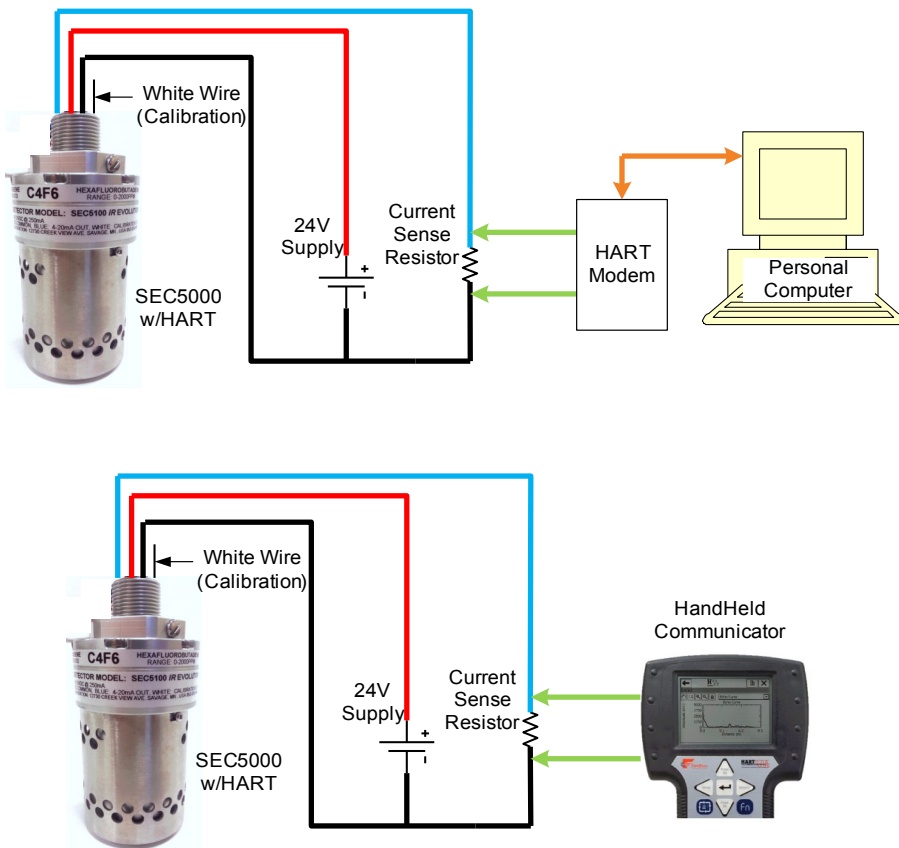


Figure 2.1 – HART Connections

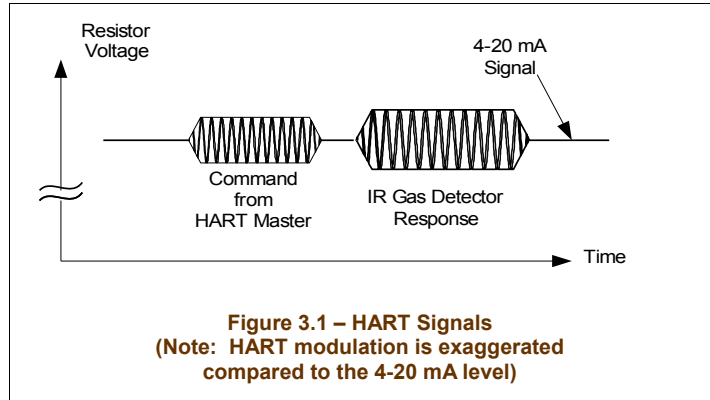
Commands issued to perform the Calibrations.

The White-Wire shown in **Figure 2.1** may also be connected to a Sensor Electronics Corp. PCLink (not shown) to provide an alternate means of digital communication, as explained in the SEC5000 Manual.

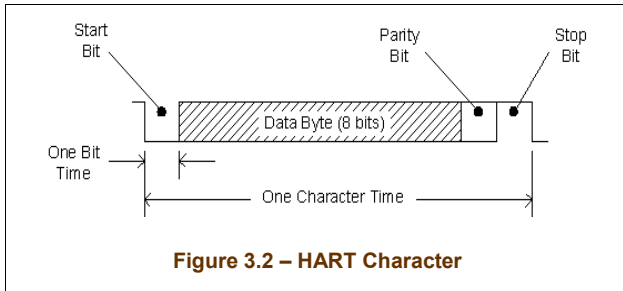
3 HART Description

HART communication consists of a series of Command-Response transactions. A HART Master sends a command. This is followed by a response from a HART Slave. In **Figure 2.1** the SEC5000 is the HART Slave (also called a Field Instrument). The Master is either the Modem / PC or the Handheld communicator. (There are some communications that are not Command-Response. But these are outside the scope of this brief explanation.)

Developed in the 1980s, HART was the first digital communication protocol for process instruments that (ideally) did not disturb the 4-20 mA analog process signal. Consequently, the HART signal consists of relatively small bursts of AC voltage superimposed on the DC voltage produced by the 4-20 mA. This is illustrated in **Figure 3.1**. The command from the HART Master is usually created by AC-coupling a low-impedance (voltage) source across the Current Sense Resistor, while the Gas Detector Response is a modulation of the 4-20 mA current. Both the Command and Response signals are typically a few hundred mV pp.



3.1 HART Character



The modulation is frequency-shift-keying (FSK) with 1200 Hz representing a logic 1 and 2200 Hz representing a logic 0. The bit rate is 1200 bits/second. Asynchronous communication with start and stop bits is used to delineate one byte or character. This makes it possible to use UARTs and other commonly available hardware to implement HART. A single character is as illustrated in **Figure 3.2**. The asynchronous communication setup is as follows:

Start Bit, 8 data bits, Odd Parity, and One Stop Bit.

Odd Parity = 0 if there are an odd number of “1” bits in the 8 data bits or Odd Parity = 1 if there are an even number of “1” bits in the 8 data bits. The Odd Parity is also called longitudinal parity. Some UARTs have the Parity calculation built in, so that the Odd Parity value can simply be read as part of a register.

3.2 HART Frame (Message)

A signal burst (message) typically contains 10 to 30 bytes, depending on the command or response. The content of the burst is listed in **Table 3.1**.

The preamble is allowed to vary in length, depending on the Field Instrument's requirements. Most Field Instruments devices of recent design need only 5 preamble bytes. The preamble value is 255 (0xFF). Notice that this creates a character that is a logic 1 at all times (Parity = Stop Bit = 1) except for the start bit. This series of start bits is used to synchronize to the incoming carrier. Notice also that, at carrier startup, the receiver will see some of the preamble as lost or corrupt. The receiver need only see two consecutive valid preamble bytes, followed by a valid start delimiter, to declare that this is a valid incoming message. Anything else must be discarded.

Part of Message	Length in Bytes	Purpose
Preamble	5-20	Synchronization & Carrier Detect
Start Delimiter	1	Synchronization & Shows Which Master
Address	1 or 5	Choose Field Instrument and Indicate Which Master
Command	1	Tell Field Instrument What to Do
Number Data Bytes	1	Indicate Number of bytes between here and Checksum
Status	0 (if Master) 2 (if Field Instrument)	Field Instrument Indicates its Health and Whether it did as Master Ordered
Data	0 to 253	Command or Response Argument (Process Variable, for example)
Checksum	1	Error Control

Table 3.1 – HART Message

In simple setups using a modem and personal computer, the start delimiter has the value 2 for a command and 6 for a response. A list of the commands implemented by the SEC5000 is given in §4.

A Field Instrument response must echo the Address and Command sent by the Master.

3.3 HART Field Instrument Address

Each Field Instrument ideally has a unique 38-bit Address, so that a Master can select one among multiple Field Instruments that may be connected to the same Current Sense Resistor. The Address consists of a 6-bit vendor ID, an 8-bit vendor device classification, and a 24 bit serial number. The vendor ID and device classification are assigned by the HART Communication Foundation, with the goal that no two Field Instruments will ever have the same address. The 38-bit address is usually stored in non-volatile memory. Once assigned to a Field Instrument, the 38-bit Address does not change.

In addition to the 38-bit Address, also known as a Long Address, each Field Instrument has a 4-bit Address or Short Address. The Short Address is also called a Polling Address. The possible values for the Short Address are 0 through 15. The Short Address can be set to any of these values by a Master.

The Short Address is used to discover the 38-bit address, as follows: In larger installations, the Field Instrument is usually commissioned. That is, it is tested, programmed, cataloged, etc.; prior to installation. During commissioning it can be connected into a HART network in which it is the *only* Field Instrument. The HART Master of this network searches all 16 Short Addresses until it receives a response. This response contains the 38-bit address, which can then be placed into a database.

The search uses HART Command 0. This is the only HART Command that allows either the Short or Long Address. If there is a response to HART Command 0 (Trial Address = Short Address), the response includes the 38-bit Address as part of the Data (Item 7 in **Table 3.1**).

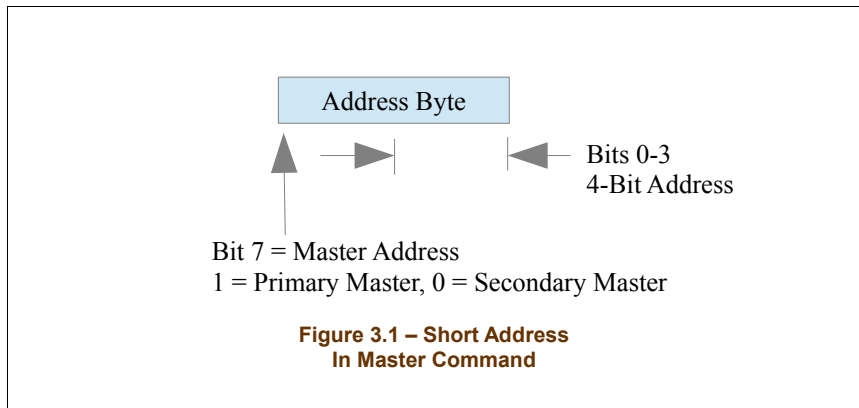
3.4 HART Master Address

The HART network can have both a PC / Modem and a Handheld communicator connected at the same time. These are

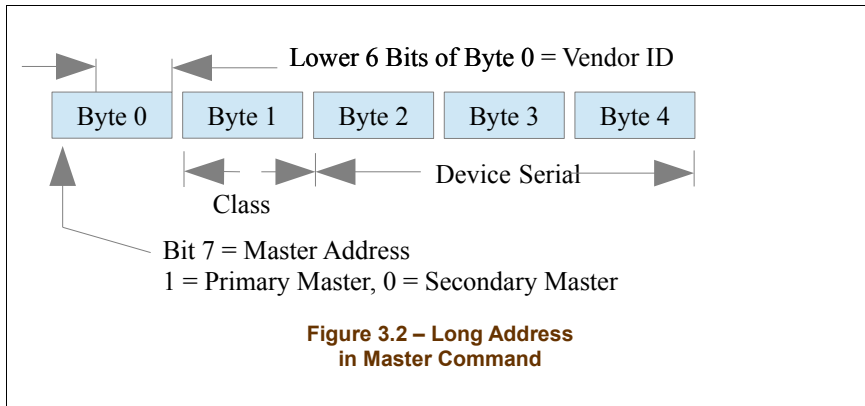
called Primary and Secondary Masters, respectively. To distinguish between the two, a one-bit Address is used. A Primary Master has an Address of 1 and a Secondary Master has an Address of 0.

3.5 Command Address

A given command or response must contain only complete bytes. When the Master issues a command, the Address transmitted (3rd item in **Table 3.1**) is either 1 byte in length or 5 bytes (40 bits) in length. The 1-byte Address includes the 4 bits of Field Instrument Short Address and the one-bit Address of the Master, as shown in **Figure 3.1**. Both the Master Address and the 4-Bit Address must be echoed in the Field Instrument Response.



The 5-byte Address includes the 38 bits of the Field Instrument Long Address and the one-bit Address of the Master, as shown in **Figure 3.2**.



Note: Bit 6 in either the Short Address or in Byte 0 of the Long Address is also significant, but its use is outside the scope of this document. Refer to the full HART Specification for more details. For purposes of this description, Bit 6 is assumed to always have a value of 0.

3.6 Error Control

The checksum byte is the exclusive-OR of all of the previously transmitted bytes, starting with the start delimiter.

The checksum is also known as vertical parity. The combination of vertical parity (Checksum) and longitudinal parity (the Odd Parity added to each byte) has been shown to be comparable to a CRC in terms of its ability to detect errors. If there is an error in a command, the addressed Field Instrument still responds in some instances and does not in others. Generally, however, it does not act on any command that contains an error.

If there is an error in a response, the Master repeats the command.

3.7 Write Protection

HART Field Instruments have varying amounts of non-volatile memory such as EEPROM. In addition to operating parameters, some HART parameters are also stored in this memory. In the SEC5000 these can be write-protected. When write protection is turned ON, these parameters can't be changed using HART commands.

In the SEC5000 a password is needed to turn write-protection ON or OFF. There are two levels of passwords: a user password and an SEC password. The user password allows the user to create and use a password of his/her choice. The SEC password is a password that can be used to restore a user password and to change some factory parameters that the user cannot access. The SEC password is coded into the program and cannot be changed.

4 SEC5000 HART Commands

There are 3 types of HART command: Universal, Common Practice, and Device Specific. The SEC5000 does all of the Universal commands, and a few of the Common Practice commands. These are listed below in **Table 4.1**. Probably the most important Device Specific command is called white-wire-over-HART. “White-Wire” is a proprietary digital communication protocol that is common to many Sensor Electronic Corp. devices, including the SEC5000. It is a way of sending any white-wire command over the HART communication channel. The white-wire command becomes the “data” part of the HART command (Item 7 of **Table 3.1**). This greatly reduces the overall number of HART commands that must be implemented. Examples of commands that can be performed in this way are self-test, SPAN, and ZERO. There are actually two HART commands associated with white-wire-over-HART. One of them (146) sends the command. The other (147) gets the response. **Table 4.2** lists the SEC5000 commands that can be issued in this manner.

Command Number	Type of Command	Purpose
0	Universal	Read Long Addr, Rev Levels, etc.
1	Universal	Read Primary Variable, Units.
2	Universal	Read Current Level in mA, Primary Variable in % of Range
3	Universal	Read Gas Concentration, Temp, Pressure.
6	Universal	Write Short Address
7	Universal	Read Short Address
8	Universal	Read Dynamic Variable Classifications
9	Universal	Read One Device Variable w. Status
11	Universal	Read same info as in Cmd 0 Using Tag as Address
12	Universal	Read Message (User Scratch Area)
13	Universal	Read by Tag, Descriptor, Date
14	Universal	Read Prim Variable Sensor Info.
15	Universal	Read Output Info.
16	Universal	Read Final Assy Number.
17	Universal	Write Message (User Scratch Area).
18	Universal	Write Tag, Descriptor, Date.
19	Universal	Write Final Assy. Number.
20	Universal	Read Long Tag.
21	Universal	Read Unique Identifier Associated with Long Tag.
22	Universal	Write Long Tag.
38	Common	Reset 'Config Changed' Flag
48	Common	Read Additional Status
146	SEC	Send WW Command.
147	SEC	Get WW Response.
148	SEC	Read Cal Value.
149	SEC	Read Cal Date.
150	SEC	Read Gas Value.
154	SEC	Read Gas Name.
155	SEC	Read Unit Type.
156	SEC	Read Build Date of Sensor.

157	SEC	Read Firmware Revisions.
158	SEC	Read I2C State.
159	SEC	Read Flash-Error Codes.
160	SEC	Write New Password.
161	SEC	Set or Clear Write Protect.

Table 4.1 – SEC5000 HART Commands

Zero	Read Range	Store Target Temp	Read Warmup Time
Span	Abort Pwrup Fault	Read Target Temp	Write Warmup Time
Hot Zero	Clear Config Byte	Load Table Two	Abort Warmup
Assign Serial Number	Ld Actual Bal Value	Zero CH1 Command	Initiate Self Test
Bal Pot RAM	Ld Actual Span Value	Span CH1 Command	Abort Self Test
AGC Pot Value	Start 4-20 mA Cal.	Raw Analytical CH1	User Mem Set Ptr
Span Pot RAM	Get Firmware Version	CH1 Analytical Value	User Mem Wr
Hot Bal Factor Value	Store Cal Date	CH1 Ref Value	User Mem Rd
Analytical Drift Comp	Get Cal Date	Zero Comp Cmd	Device Type Read
Unit Status Byte	Spanning Adjust Level	Span Comp Cmd	Device Type Write
Unit Error Byte	Raw Analytical	Comp Off Cmd	Press Parameter Rd
Unit Config Byte	Choose FCR Table	Comp On Cmd	Press Set Zero
Read Unit Serial	Load Table One	Comp Status Cmd	Press Set FS
Unit Temperature	Read Table Checksum	Ld Actual Comp Value	Press Rd Zero
Z Analytical Value	Cool Zero Unit	Output Select Read	Press Rd FS
Z Reference Value	Cool Balance Factor Value	Output Select Write	Span Tweak Wr
Ch0 Analyt Value	Read Cal Value	4 mA Value Read	Span Tweak Rd
Ch0 Ref Value	Beers Table Index	4 mA Value Write	Read Pressure
Four Volt DC Value	Read Gas Name	Rd Comp Factor	Dir Test 0
4-20 mA Value	Write Gas Name	Comp Parameters	Dir Test 1
Gas Level Value	Read Gas Units	4 mA Span Value Rd	Dir Test 2
Norm Gas Level Value	Write Gas Units	4 mA Span Value Wr	Wr Comp Factor
FCOR Value	Load Range	24VDC Rd	Dir Test 3

**Table 4.2 – WW-Over-HART Commands
(See SEC5000 Manual for Information
on These Commands)**

5 Command-Response Example

In this example, the primary variable is read, which is the Gas Concentration. Five preambles are assumed. The vendor ID is 0x2320. The device ID is 0x080706. Then the command bytes are (with labels)

0xFF, 0xFF, 0xFF, 0xFF, 0xFF,	preambles
0x82,	start delimiter
0xA3, 0x20, 8, 7, 6,	address
1,	command
0,	argument byte count
9	checksum

The received response is

0x7F, 0xFF, 0xFF,	minimum of two good preambles
0x86,	start delimiter
0xA3, 0x20, 8, 7, 6,	address echo
1,	command echo
7,	byte count
0x8B,	HART units code for PPM
0x44, 0x7A, 0, 0,	variable in IEEE float * = 1000.0
0,0,	status 1 = good, status 2 = good
0xBF	checksum

* ANSI/IEEE Standard 754-1985, Standard for Binary Floating Point Arithmetic.