

MOLECULAR PROPERTY SPECTROMETER™ (MPS™) 6.0 ULTRA LOW POWER (ULP) FLAMMABLE GAS SENSOR USER MANUAL



Notices

SM-UM-0015-04

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Table 1: Document Revision Table

Version	Issue Date (DD/MM/YYYY)	Change
SM-UM-0015-01	16/01/2025	First edition.
SM-UM-0015-02	24/07/2025	Added support for preamble bytes and added priorities in the Status Fields section, updated product name.
SM-UM-0015-03	29/08/2025	Updated cross references
SM-UM-0015-04	27/04/2026	Added advisory against interrupting the startup sequence

1 How the MPS 6.0 ULP Works

The MPS 6.0 Ultra Low Power (ULP) Flammable Gas Sensor is a smart sensor with built-in environmental compensation that detects and accurately quantifies over a dozen gases as well as gas mixtures. It is intrinsically safe, robust, extremely poison-resistant, and calibrated for all gases by performing only a single calibration with methane. Sensor readings are output on a standard digital bus.

The MPS transducer is a micro-machined membrane with an embedded Joule heater and resistance thermometer. The transducer is mounted on a PCB and packaged inside a filtered enclosure that is permeable to ambient air. The presence of a flammable gas causes changes in the thermodynamic properties of the air/gas mixture. These properties are measured by the transducer and processed by patented algorithms to report an accurate concentration and to classify the flammable gas.

Other sensing technologies (e.g. catalytic bead, NDIR) require a “k-factor” multiplier to convert raw sensor signals to gas concentrations in %LEL. These “k-factors” are based on known relative sensitivities of these sensors to different gases. A single “k-factor”, corresponding to a particular gas, must be selected manually during system setup; if the sensor is then exposed to a gas other than the one selected, significant errors in reported concentration occur.

In contrast, the MPS 6.0 ULP applies a real-time conversion factor automatically, using the latest measured thermal properties of the ambient air/gas and the environmental conditions (Figure 1). The %LEL values reported for the bulk, which may contain a mixture of gases, achieve the same high levels of accuracy achieved with single gases. Additional smart algorithms enable determination of the class of gas present, according to the categories in Figure 2.

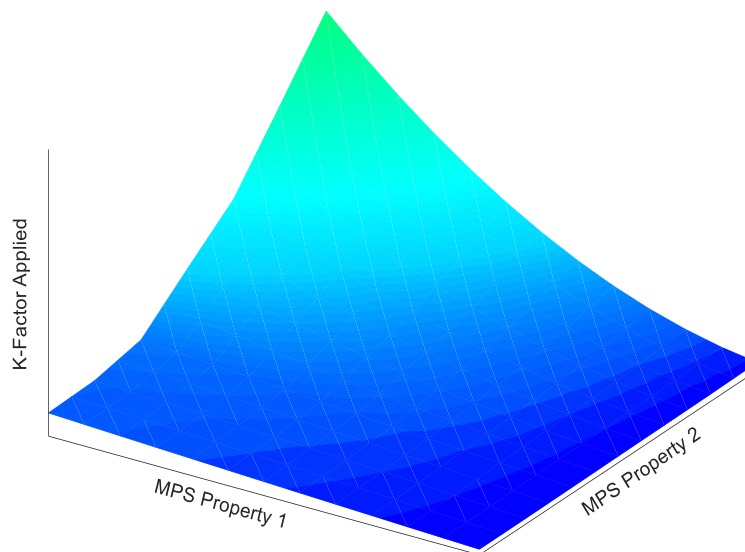


Figure 1: The MPS uses multiple measured properties of the air/gas mixture to automatically apply a real-time conversion factor—enabling high accuracy for over a dozen different gases at all times.

CLASS 1: Hydrogen

Molecular Weight: 2.0 [g/mol]

Density: 0.09 [kg/m³]

Number of Carbons: 0



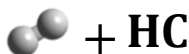
CLASS 2: Hydrogen Mixture

Avg. Mol. Weight: 1-14 [g/mol]

Avg. Density: 0.1-0.6 [kg/m³]

Number of Carbons: varies

*This classification is unique as it guarantees the presence of hydrogen and another flammable gas



CLASS 3: Methane/Natural Gas

Avg. Mol. Weight: 16 to 19 [g/mol]

Avg. Density: 0.6-0.9 [kg/m³]

Typical Number of Carbons: 0-2

*Gases having molecular properties similar to that of methane may be classified as methane (e.g. ammonia, acetylene)



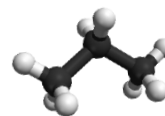
CLASS 4: Light Gas (or Light Gas Mixture)

Avg. Mol. Weight: 25 to 75 [g/mol]

Avg. Density: 1.2-2.5 [kg/m³]

Typical Number of Carbons: 1-4

Example Gases: Ethane, Propane, Isopropanol



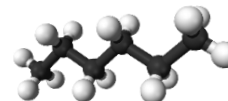
CLASS 5: Medium Gas (or Medium Gas Mixture)

Avg. Mol. Weight: 50 to 120 [g/mol]

Avg. Density: 1.5-4.0 [kg/m³]

Typical Number of Carbons: 2-8

Example Gas: Pentane



CLASS 6: Heavy Gas (or Heavy Gas Mixture)

Avg. Mol. Weight: 80+ [g/mol]

Avg. Density: 3.5+ [kg/m³]

Typical Number of Carbons: 6+

Example Gases: Octane, Toluene, Xylene

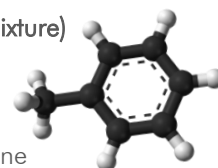


Figure 2: The MPS 6.0 ULP outputs the class of gas present. This capability to discriminate amongst gases is what enables the sensor to provide accurate %LEL readings for over a dozen different flammable gases.

2 Communicating with the MPS 6.0 ULP

This section describes the software interface requirements for the MPS 6.0 ULP and is useful to system integrators when designing the sensor assembly into a final product. It communicates over the serial interface using the UART (Universal Asynchronous Receiver/Transmitter) protocol via synchronous (sensor receives a request and sends a response) method or asynchronous method (used only during measurements where the sensor receives the measurement command and sends periodic responses).

2.1 Serial (UART) Communication

Communication with the system over the serial interface (UART) will allow an external user or system to execute the commands provided in the Command Table in Section 2.1.5. Users may also refer to the Command Descriptions in Section 2.1.6 for usage descriptions.

Serial connection parameters:

Table 2: UART Settings

Parameter	Size
Baud Rate	38400
Data Size	8 bits
Parity	None
Stop Bit	1 bit

2.1.1 Data Representation

All integer values (16 bits or 32 bits) are represented in Little Endian format (LSB first). This means when an integer is transmitted on the serial interface, the least significant byte (LSB) is transmitted first and the most significant byte (MSB) is transmitted last.

Floating point numbers are represented in IEEE 754 format.

2.1.2 Protocol Specification

Communication protocol for the MPS 6.0 ULP is appropriately described using the Synchronous Method as an example. Communication to and from the MPS 6.0 ULP is made up of “packets.” The communication paradigm is that of “request” and “reply.” An external host sends a “request” packet to the sensor. The sensor returns a “reply” packet to the external host. A packet consists of a fixed size “header” and a variable length “payload.” It is possible for a packet to have no payload (length of zero) where a packet contains only a header. The payload, if any, typically consists of “parameters” for a request or “result” for a reply. Even when a reply does not contain any result, a reply is still sent with the header as an acknowledgement of the request.

2.1.2.1 Command Request

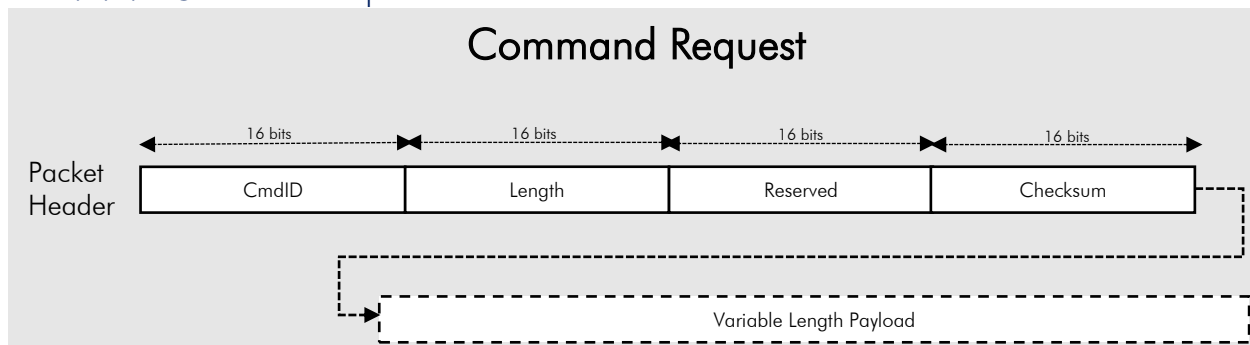


Figure 3: Request Packet Structure

The Request Packet (Figure 3) consists of the following fields:

Table 3: Request Packet

Field	Size	Description
CmdID	2 Bytes	Command ID of this request (see Command Table in Section 2.1.5). Although CmdID uses only 1 byte, it is extended to 2 bytes in the Request Header for alignment purposes.
Length	2 Bytes	Length of the Payload (0 if no payload)
Reserved	2 Bytes	Reserved for future use (zero filled)
Checksum	2 Bytes	Checksum of the entire packet
Variable Length Payload	variable	Command parameters for this request

2.1.2.2 Command Reply

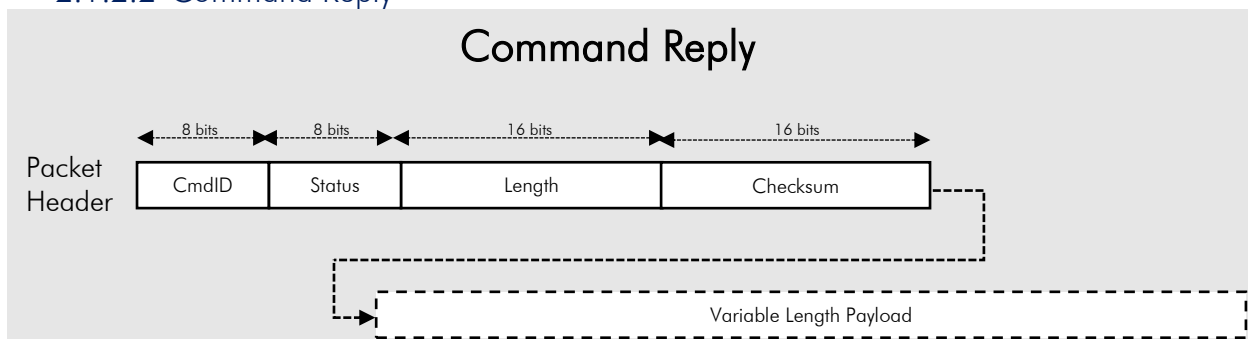


Figure 4: Reply Packet Structure

The Reply Packet (Figure 4) consists of the following fields:

Table 4: Reply Packet

Field	Size	Description
CmdID	1 Byte	Command ID (should match the original request)
Status	1 Byte	Return status of the request
Length	2 Bytes	Length of the Payload (0 if no payload)
Checksum	2 Bytes	Checksum of the entire packet
Variable Length Payload	variable	Command parameters for this request

2.1.2.3 Status Fields

The Status field consists of the following possible return values. If multiple simultaneous statuses apply, the highest priority (lowest number) will be reported (Ω represents the lowest priority status):

Table 5: Status field description (table continued on next page)

Fault	Fault Message	Explanation	Priority	%LEL Output	User action
0x00	OK	MPS is operating normally and has no errors	Ω	Normal	None.
0x01	CRC_FAILED	Transmitted data failed checksum	1	N/A	Verify checksum calculation is correct. See Section 2.1.3.
0x02	BAD_PARAM	Invalid parameter	1	N/A	Verify the payload of the UART command.
0x05	UNKNOWN_COMMAND	Unknown Command ID specified	1	N/A	Verify Command ID is correct. See Section 2.1.5.
0x07	INCOMPLETE_COMMAND	Incomplete or truncated command	1	N/A	Verify the entire packet header and payload (if any) are fully sent.
0x21	HW_ERR_VDD	Internal supply voltage out of range	4	-100 %LEL	Supply 3.0-5.0 \pm 5% VDC and power cycle. If the error persists, contact support.
0x22	HW_ERR_VREF	Internal reference voltage out of range	3	-100 %LEL	Contact support.
0x23	HW_ENV_XCD_RANGE	Environmental (Temp., Press., Humid.) out of range	9	Normal	Return the sensor to the specified operating range. See Section 5.
0x24	HW_ENV_SNSR_MALFUNCTION	Environmental sensor malfunction	6	-100 %LEL	The sensor was exposed to an extreme environmental condition that can permanently damage it, rendering it unsuitable for accurate readings. As a fail-safe, this error permanently latches the sensor and disables further operation; see Section 8.
0x25	HW_ERR_MCU	Microcontroller error	2	-100 %LEL	Contact support.
0x26	SENSOR_INITIALIZATION	Sensor in initialization mode (4 cycles)	10	0 %LEL	Do not apply gas during this period. Wait 4 cycles (~16 sec) for sensor to complete initialization.
0x27	SENSOR_STARTUP	Sensor in start-up mode. No zeroing performed.	11	-100 %LEL	Do not intentionally apply gas to the sensor during this period or status 0x33 can occur.

Fault	Fault Message	Explanation	Priority	%LEL Output	User action
0x30	SENSOR_NEGATIVE	Sensor output < -15%LEL; accuracy affected if flammable gas initially detected while in this condition	12	-15 %LEL	Wait for sensor to return to zero. If message persists > 10 minutes, contact support.
0x31	CONDENSATION_DETECTED	Condensation condition exists at sensor (out of specification)	14	Normal	Raise temperature and/or lower humidity. See Section 5.
0x32	HW_SENSOR_MALFUNCTION	MPS transducer malfunction	5	-100 %LEL	Contact support.
0x33	GAS_DETECTED_DURING_STARTUP	Sensor has detected flammable gas during start-up period	7	Normal	Sensor integrator recommended to report high gas alarm (>50%LEL) until gas is no longer detected. Re-start sensor in clean air.
0x34	SLOW_GAS_ACCUMULATION_DETECTED	Sensor has detected a slow accumulation of gas	8	Normal	Sensor integrator recommended to report high gas alarm (>50%LEL) until gas is no longer detected. Re-start sensor in clean air.
0x35	BREATH_OR_HUMIDITY_SURGE	Sensor has detected condition indicative of human breath or humidity surge	13	Normal	Sensor integrator recommended to not breathe on sensor. Exposure to breath or humidity surges may result in false positive readings.

2.1.3 Checksum Calculation

The algorithm for checksum calculation is that of 16-bit CRC CCITT with start byte 0xFFFF. Checksum is computed over the entire packet (header and payload). The checksum field in the header is initialized with zeros before computing checksum. If there is no payload, checksum is computed against the header only. The following sample C code can be used to calculate the checksum for a buffer of a given size:

```

#include <stdlib.h>
#include <stdint.h>

static uint16_t crc_table[256] = { 0x0000, 0x1021, 0x2042, 0x3063, 0x4084,
0x50a5, 0x60c6, 0x70e7,
0x8108, 0x9129, 0xa14a, 0xb16b, 0xc18c, 0xd1ad, 0xe1ce, 0xf1ef,
0x1231, 0x0210, 0x3273, 0x2252, 0x52b5, 0x4294, 0x72f7, 0x62d6,
0x9339, 0x8318, 0xb37b, 0xa35a, 0xd3bd, 0xc39c, 0xf3ff, 0xe3de,
0x2462, 0x3443, 0x0420, 0x1401, 0x64e6, 0x74c7, 0x44a4, 0x5485,
0xa56a, 0xb54b, 0x8528, 0x9509, 0xe5ee, 0xf5cf, 0xc5ac, 0xd58d,
0x3653, 0x2672, 0x1611, 0x0630, 0x76d7, 0x66f6, 0x5695, 0x46b4,
0xb75b, 0xa77a, 0x9719, 0x8738, 0xf7df, 0xe7fe, 0xd79d, 0xc7bc,
0x48c4, 0x58e5, 0x6886, 0x78a7, 0x0840, 0x1861, 0x2802, 0x3823,
0xc9cc, 0xd9ed, 0xe98e, 0xf9af, 0x8948, 0x9969, 0xa90a, 0xb92b,
0x5af5, 0x4ad4, 0x7ab7, 0x6a96, 0x1a71, 0x0a50, 0x3a33, 0x2a12,
0xdbfd, 0xcdbc, 0xfbbf, 0xeb9e, 0x9b79, 0x8b58, 0xbb3b, 0xab1a,
0x6ca6, 0x7c87, 0x4ce4, 0x5cc5, 0x2c22, 0x3c03, 0x0c60, 0x1c41,
0xedae, 0xfd8f, 0xcdec, 0xddcd, 0xad2a, 0xbd0b, 0x8d68, 0x9d49,
0x7e97, 0x6eb6, 0x5ed5, 0x4ef4, 0x3e13, 0x2e32, 0x1e51, 0x0e70,
0xff9f, 0xefbe, 0xdfdd, 0xcffc, 0xbf1b, 0xaf3a, 0x9f59, 0x8f78,
0x9188, 0x81a9, 0xb1ca, 0xa1eb, 0xd10c, 0xc12d, 0xf14e, 0xe16f,
0x1080, 0x00a1, 0x30c2, 0x20e3, 0x5004, 0x4025, 0x7046, 0x6067,
0x83b9, 0x9398, 0xa3fb, 0xb3da, 0xc33d, 0xd31c, 0xe37f, 0xf35e,
0x02b1, 0x1290, 0x22f3, 0x32d2, 0x4235, 0x5214, 0x6277, 0x7256,
0xb5ea, 0xa5cb, 0x95a8, 0x8589, 0xf56e, 0xe54f, 0xd52c, 0xc50d,
0x34e2, 0x24c3, 0x14a0, 0x0481, 0x7466, 0x6447, 0x5424, 0x4405,
0xa7db, 0xb7fa, 0x8799, 0x97b8, 0xe75f, 0xf77e, 0xc71d, 0xd73c,
0x26d3, 0x36f2, 0x0691, 0x16b0, 0x6657, 0x7676, 0x4615, 0x5634,
0xd94c, 0xc96d, 0xf90e, 0xe92f, 0x99c8, 0x89e9, 0xb98a, 0xa9ab,
0x5844, 0x4865, 0x7806, 0x6827, 0x18c0, 0x08e1, 0x3882, 0x28a3,
0xcb7d, 0xdb5c, 0xeb3f, 0xfb1e, 0x8bf9, 0x9bd8, 0xabbb, 0xbb9a,
0x4a75, 0x5a54, 0x6a37, 0x7a16, 0x0af1, 0x1ad0, 0x2ab3, 0x3a92,
0xfd2e, 0xed0f, 0xdd6c, 0xcd4d, 0xbdaa, 0xad8b, 0x9de8, 0x8dc9,
0x7c26, 0x6c07, 0x5c64, 0x4c45, 0x3ca2, 0x2c83, 0x1ce0, 0x0cc1,
0xef1f, 0xff3e, 0xcf5d, 0xdf7c, 0xaf9b, 0xbfba, 0x8fd9, 0x9ff8,
0x6e17, 0x7e36, 0x4e55, 0x5e74, 0x2e93, 0x3eb2, 0x0ed1, 0x1ef0,
};

uint16_t crc_generate(uint8_t *buffer, size_t length, uint16_t startValue)
{
    uint16_t crc;
    uint8_t *p;
    int ii;

    crc = startValue;

    for(p = buffer, ii = 0; ii < length; ii++) {
        crc = (crc << 8) ^ crc_table[(crc >> 8) ^ *p];
        p++;
    }

    return crc;
}

```

For more information on how to use the above function, please look at the sample test program “Sample Code” located here: nevedanano.com.

2.1.4 Start-Up and Measurement Sequence

Figure 5 describes the recommended steps after powering on the sensor plus the measurement sequence for getting answer data in the synchronous communication mode. The major steps consist of the following:

- After powering on the sensor, wait for the sensor to boot up completely (~3 seconds).
- Verify communication channel by asking the sensor for version information.
 - Protocol version can be used to determine available commands, answers or new data.
- Start measurement in “continuous” mode.
- Wait for the first measurement to complete
 - This takes ~4 seconds.
- Get Answer.
- Repeat process to get answer at the rate shown in Figure 5.

The sensor may have a UART response latency of ~200 ms. This can happen when the UART request coincides with the measurement cycle. One strategy to prevent this latency is to send the Start Measurement command, wait for one second, send the Get Answer command and then continue sending the Get Answer command every 4 seconds thereafter.

Note: The sensor’s cycle time is set to 4 seconds. If multiple requests to read the Answer register (0x01) were made within the sensor’s 4-second window, one might get the same answer. This depends on whether a new measurement is calculated between multiple Answer requests. The MPS Cycle Count (“COUNT”) in the Answer Response is incremented after each measurement is calculated. Therefore, when processing an “answer,” one should compare the COUNT value in the answer against the COUNT value from the previous answer. If the COUNT value did not increment, this is a repeated answer. If the COUNT value incremented, this is a new answer from the latest measurement cycle. When continuous measurement is stopped and restarted, the COUNT value resets with the first measurement.

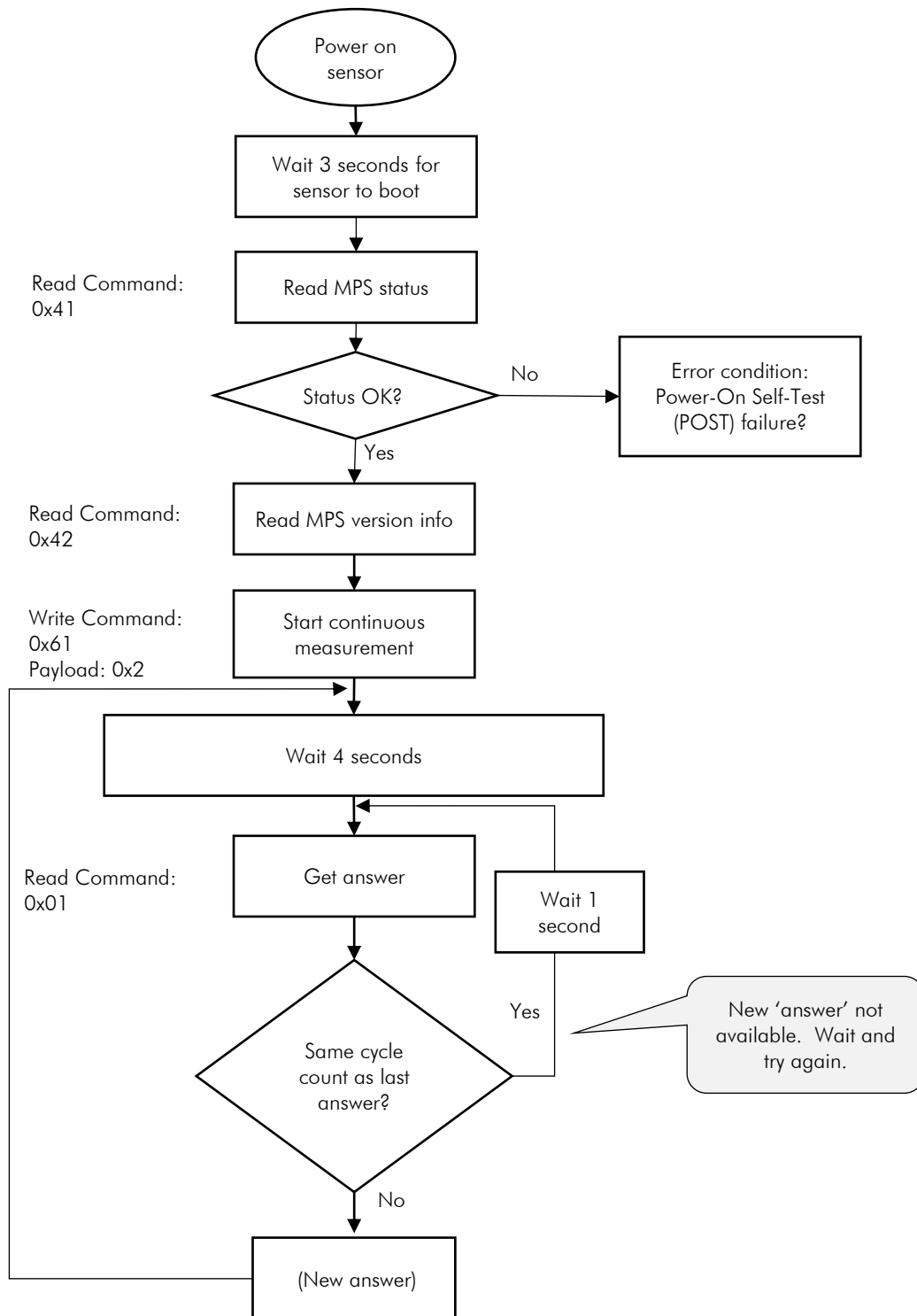


Figure 5: Startup and Measurement Sequence for Synchronous Communication

Another option for UART communication is asynchronous communication. In this case, shown in Figure 6, the start measurement command is sent with a specific payload described in Section 2.1.6.13. This supports an alternative communication paradigm (colloquially called “chatty mode”) where the sensor completes measurements every 4 seconds and transmits the measurement data via UART to the host controller. This paradigm has two major advantages:

- The host controller always receives the most current measurement data as soon as it is available
- The host controller can be in a power-saving mode between sensor measurement cycles.

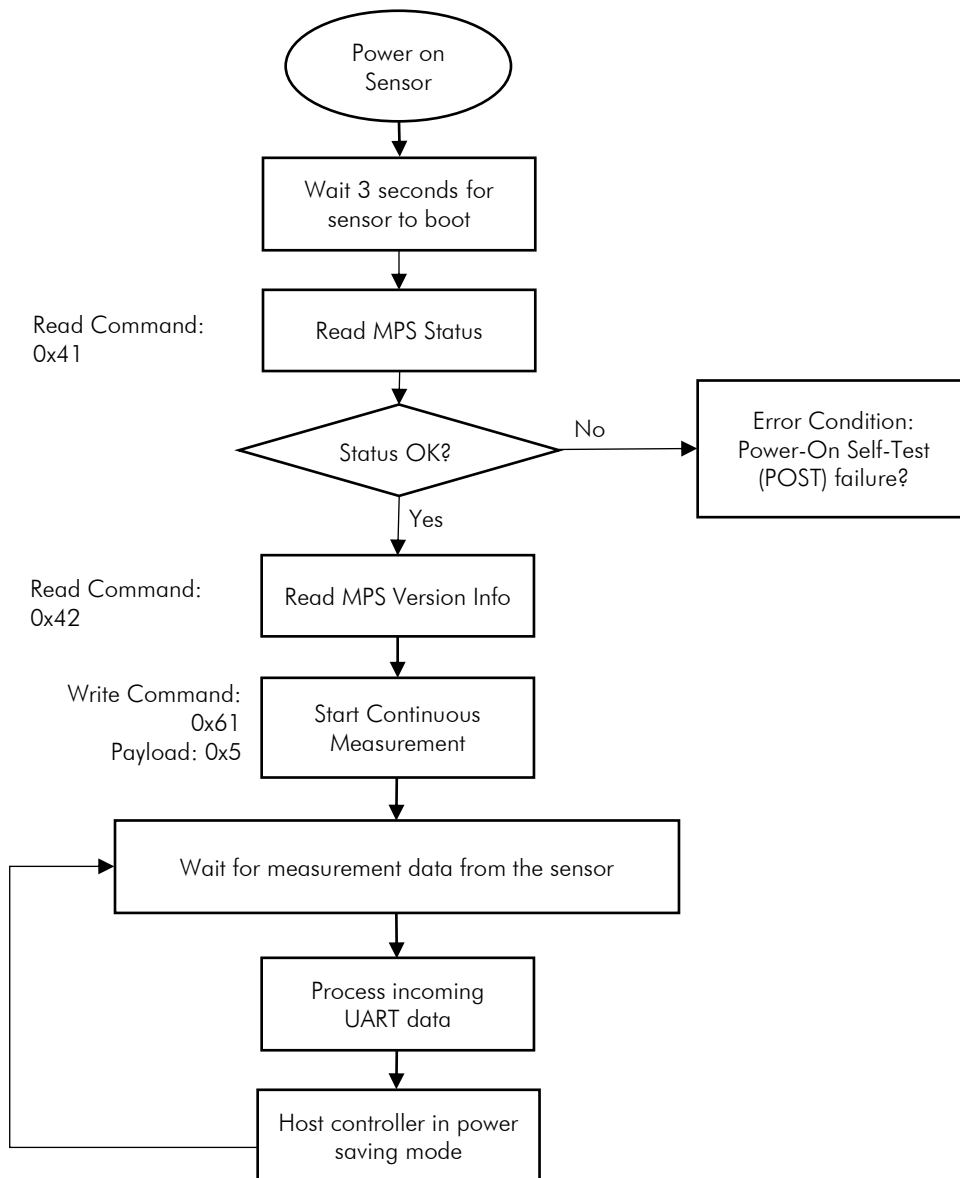


Figure 6: Startup and Measurement Sequence for Asynchronous Communication

Upon issuing the “start measurement” command, the MPS begins its start-up sequence, detailed in Figure 7. For the first 31 seconds, the status is set to SENSOR_STARTUP, the concentration is set to –100 %LEL, and the sensor will not respond to gas. After this, the sensor will check for the presence of gas on cycles 1 through 8, each cycle lasting 4 seconds. **During the first 31 seconds after starting measurements, the sensor is performing a self-cleaning step. During this step, it is possible to damage the MPS transducer if power is removed from the sensor or if the sensor is interrupted by a “stop measurement” (0x61 with a payload of 0x03) command or the reset command (0x62). To avoid this, best practice is to wait 60 seconds after continuous measurements start before interrupting the sensor.**

- If gas is not detected at any point in the first 8 cycles, the sensor remains in the SENSOR_STARTUP status and the concentration reported is 0 %LEL. It will then proceed to the initialization phase, lasting 4 cycles (16 seconds), during which the status is set to SENSOR_INITIALIZATION and concentration is 0 %LEL. Once initialization is complete, the status is set to 0x00. ***Note: The sensor provides TrueLEL accuracy, gas ID capability, and the full –15-110 %LEL detection range only for gases arriving after initialization.***
- If gas is detected during any of the first 8 cycles, a %LEL concentration is reported, the status is set to GAS_DETECTED_DURING_STARTUP, and the gas ID defaults to 253 (“Unknown Gas”). The “k-factor” for methane will be used to calculate concentration in %LEL. The sensor will continue to give the GAS_DETECTED_DURING_STARTUP status and to take new readings for all 8 cycles, and for all cycles thereafter while gas is still being detected. The sensor *will not* proceed to the initialization phase nor enter TrueLEL mode until gas is no longer detected. It is recommended that the integrator reports high gas alarm (>50 %LEL) while the GAS_DETECTED_DURING_STARTUP status persists. ***Note: the MPS does not provide TrueLEL concentration accuracy, gas identification accuracy, nor detect the concentration ranges specified on the datasheet for gases already present before, or arriving during, start-up and initialization.*** Once gas is no longer detected, the sensor will proceed to the initialization phase.

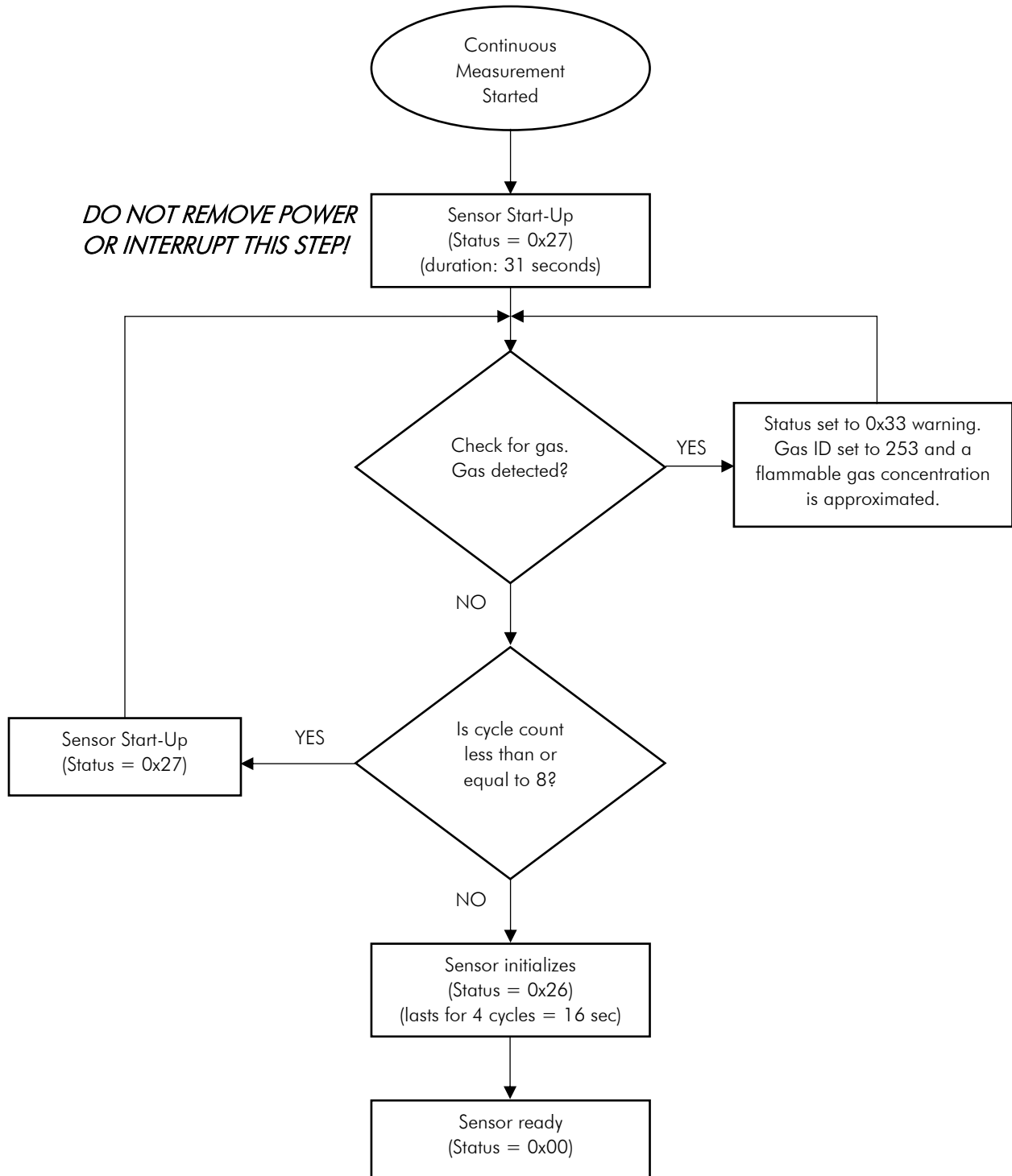
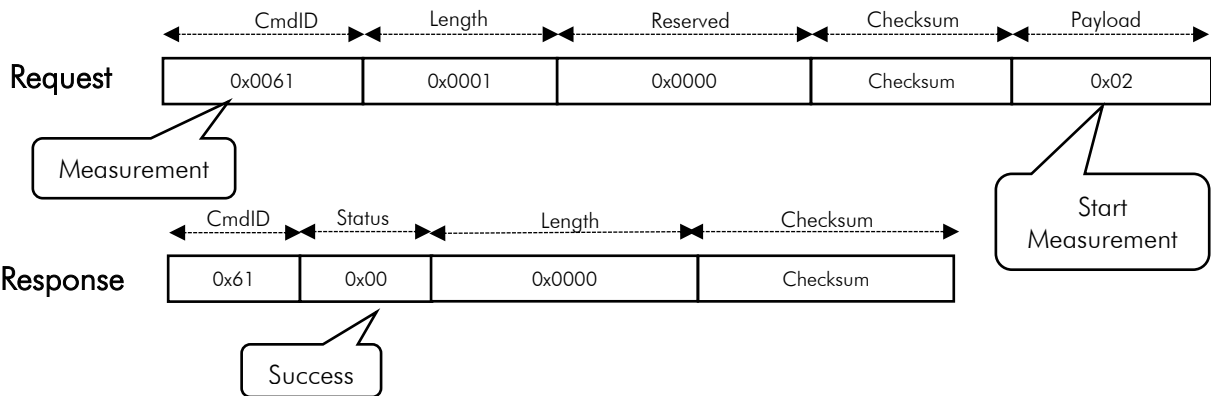


Figure 7: Sensor Start-up Sequence.

Figure 8 describes sample Request and Response packets for the Perform Measurement and Get Answer Vector sequences.

Perform Measurement



Get Answer Vector

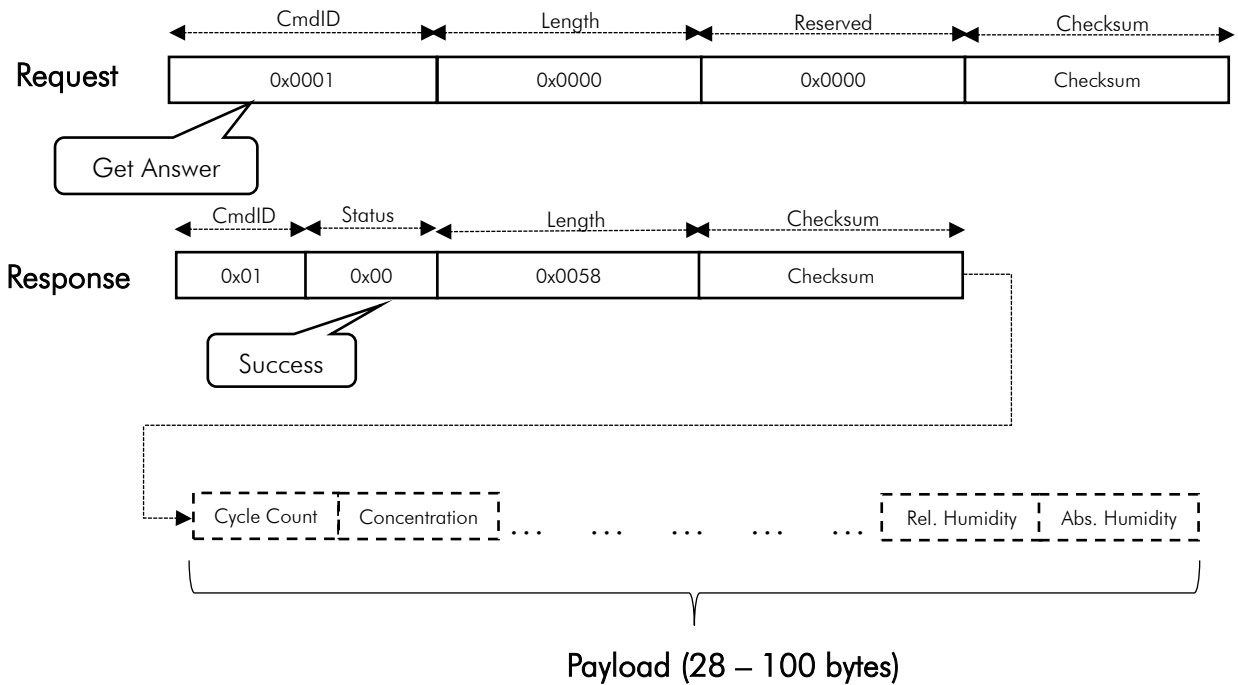


Figure 8: Sample Request and Response Packets for Performing Measurement and Get Answer Vector.

2.1.5 Command Table

Table 6: UART commands with calculated checksum

Hex Code	Command ID	Payload Length (bytes)		Request Packet (Little-Endian Format)				
		Request	Response	CmdID	Length	Reserved	Calculated Checksum*	Payload
0x01	ANSWER	0	28	0x01 0x00	0x00 0x00	0x00 0x00	0xed 0x76	Null
0x03	CONC	0	4	0x03 0x00	0x00 0x00	0x00 0x00	0x4b 0xf9	Null
0x04	ID	0	4	0x04 0x00	0x00 0x00	0x00 0x00	0x53 0x3e	Null
0x21	TEMP	0	4	0x21 0x00	0x00 0x00	0x00 0x00	0x85 0xd	Null
0x22	PRES	0	4	0x22 0x00	0x00 0x00	0x00 0x00	0xf0 0xc5	Null
0x23	REL_HUM	0	4	0x23 0x00	0x00 0x00	0x00 0x00	0x23 0x82	Null
0x24	ABS_HUM	0	4	0x24 0x00	0x00 0x00	0x00 0x00	0x3b 0x45	Null
0x2A	SET_PREAMBLE_BYTES	1	0	0x2a 0x00	0x01 0x00	0x00 0x00	(Table 9)	
0x2B	GET_PREAMBLE_BYTES	0	4	0x2b 0x00	0x00 0x00	0x00 0x00	0xf9 0x9c	Null
0x41	STATUS	0	1	0x41 0x00	0x00 0x00	0x00 0x00	0x3d 0x80	Null
0x42	VERSION	0	8	0x42 0x00	0x00 0x00	0x00 0x00	0x48 0x48	Null
0x43	SENSOR_INFO	0	100	0x43 0x00	0x00 0x00	0x00 0x00	0x9b 0x0f	Null
0x61	MEAS	1	0	0x61 0x00	0x01 0x00	0x00 0x00	0x57 0x93	0x02
0x61	MEAS	1	0	0x61 0x00	0x01 0x00	0x00 0x00	0x35 0xb7	0x22
0x61	MEAS	1	0	0x61 0x00	0x01 0x00	0x00 0x00	0xb0 0xe3	0x05
0x61	MEAS	1	0	0x61 0x00	0x01 0x00	0x00 0x00	0xd2 0xc7	0x25
0x61	MEAS	1	0	0x61 0x00	0x01 0x00	0x00 0x00	0x76 0x83	0x03
0x62	RESET	0	0	0x62 0x00	0x00 0x00	0x00 0x00	0x20 0x33	Null

*Checksum is calculated from the example shown in this table. Refer to Section 2.1.3 for checksum calculation.

2.1.6 Command Descriptions

2.1.6.1 Command 0x01 – ANSWER – Read Complete Answer

Description: Returns a complete answer in one read operation.

Parameters: N/A

Response:

CYCLE_COUNT	32-bit signed value. Cycle Number of this measurement (incremented after each measurement)
CONC	32-bit floating point value. Flammable gas concentration [%LEL (ISO) or %LEL (IEC)]
ID	32-bit unsigned value. Flammable gas ID. See “Command 0x04 – ID” for descriptions of gas ID values.
TEMP	32-bit floating point value. Ambient temperature [°C]
PRESSURE	32-bit floating point value. Ambient pressure [kPa]
REL_HUM	32-bit floating point value. Ambient relative humidity [%RH]

ABS_HUM 32-bit floating point value. Ambient absolute humidity
 $\left[\frac{g}{m^3}\right]$

2.1.6.2 Command 0x03 – CONC – Read Flammable Gas Concentration

Description: Returns flammable gas concentration [%LEL (ISO) or %LEL (IEC)] as measured by the MPS.

Parameters: N/A

Response: CONC 32-bit floating point value. Flammable gas concentration [%LEL (ISO) or %LEL (IEC)]

Table 7: Gas concentration

Concentration	Description & Sensor Outputs
< -15 %LEL	Reported concentration is -15 %LEL. Gas ID set to 254 (Under Range). SENSOR_NEGATIVE status.
≥ -15 %LEL and < -5 %LEL	Reports measured concentration. Gas ID set to 254 (Under Range).
≥ -5 %LEL and ≤ 0 %LEL	Reports 0 %LEL concentration. Gas ID set to 0.
> 0 %LEL and < 110 %LEL	Reports measured concentration.
≥ 110 %LEL	Reported concentration is 110 %LEL. Gas ID set to 255 (Over Range).

2.1.6.3 Command 0x04 – ID – Read Flammable Gas ID

Description: Returns flammable gas ID as determined by the MPS.

Parameters: N/A

Response: ID 32-bit unsigned value. Flammable gas ID.

Table 8: Gas ID details

ID	Description
0	No Gas
1	Hydrogen
2	Hydrogen Mixture
3	Methane
4	Light Gas
5	Medium Gas
6	Heavy Gas
253	Unknown Gas
254	Under Range – Concentration less than -5 %LEL
255	Over Range – Concentration greater than or equal to 110 %LEL

Note: All gas IDs, including Under Range and Over Range conditions, will continue to be output on every cycle until the determined ID value changes.

2.1.6.4 Command 0x21 – TEMP – Read Temperature

Description: Returns the ambient temperature (°C) as reported by the integrated environmental sensor.

Parameters: N/A

Response: TEMP 32-bit floating point value. Ambient temperature (°C).

2.1.6.5 Command 0x22 – PRES – Read Pressure

Description: Returns the ambient pressure (kPa) as reported by the integrated environmental sensor.

Parameters: N/A

Response: PRESSURE 32-bit floating point value. Ambient pressure (kPa).

2.1.6.6 Command 0x23 – REL_HUM – Read Relative Humidity

Description: Returns the ambient relative humidity (%RH) as reported by the integrated environmental sensor.

Parameters: N/A

Response: REL_HUM 32-bit floating point value. Ambient relative humidity (%RH).

2.1.6.7 Command 0x24 – ABS_HUM – Read Absolute Humidity

Description: Returns the ambient absolute humidity ($\frac{g}{m^3}$) as calculated by the MPS.

Parameters: N/A

Response: ABS_HUM 32-bit floating point value. Ambient absolute humidity ($\frac{g}{m^3}$).

2.1.6.8 Command 0x2A – Set Number of Preamble Bytes

Description: Sets the number of preamble bytes for use in asynchronous communication. The MPS uses “0xFF” as its preamble byte. This command should be used sparingly, and in many cases need only be used once. There is no need to resend the command on every power cycle, as the value is stored in flash memory the first time it is specified.

Parameters: The parameter to the Set Number of Preamble Bytes command is 1 byte in length and may be set to any value from 0 through 32.

Response: N/A

Table 9: Calculated Checksum for All Preamble Byte Configurations

Number of Preamble Bytes	Payload	Calculated Checksum	Number of Preamble Bytes	Payload	Calculated Checksum
0	0x00	0x77 0xe8	17	0x11	0x67 0xea
1	0x01	0x56 0xf8	18	0x12	0x04 0xda
2	0x02	0x35 0xc8	19	0x13	0x25 0xca
3	0x03	0x14 0xd8	20	0x14	0xc2 0xba
4	0x04	0xf3 0xa8	21	0x15	0xe3 0xaa
5	0x05	0xd2 0xb8	22	0x16	0x80 0x9a
6	0x06	0xb1 0x88	23	0x17	0xa1 0x8a
7	0x07	0x90 0x98	24	0x18	0x4e 0x7b
8	0x08	0x7f 0x69	25	0x19	0x6f 0x6b
9	0x09	0x5e 0x79	26	0x1a	0x0c 0x5b
10	0x0a	0x3d 0x49	27	0x1b	0x2d 0x4b
11	0x0b	0x1c 0x59	28	0x1c	0xca 0x3b
12	0x0c	0xfb 0x29	29	0x1d	0xeb 0x2b
13	0x0d	0xda 0x39	30	0x1e	0x88 0x1b
14	0x0e	0xb9 0x09	31	0x1f	0xa9 0x0b
15	0x0f	0x98 0x19	32	0x20	0x15 0xcc
16	0x10	0x46 0xfa			

2.1.6.9 Command 0x2B – Get Number of Preamble Bytes

Description: Returns the number of preamble bytes currently set for the sensor.

Parameters: N/A

Response: PREAMBLE_BYTES 32-bit unsigned value.

2.1.6.10 Command 0x41 – STATUS – Read MPS Status

Description: Returns the status of the MPS; refer to Section 2.1.2.3 for status descriptions.

Parameters: N/A

Response: STATUS 8-bit unsigned value. Status of MPS.

2.1.6.11 Command 0x42 – VERSION – Read MPS Version Info

Description: Returns the software, hardware and protocol versions of the MPS.

Parameters: N/A

Response: SW_VERSION 8-bit unsigned values. Version is W.X.Y.Z
 HW_VERSION 8-bit unsigned values. Version is W.X
 PROTOCOL_VERSION 8-bit unsigned values. Version is W.X

Table 10: MPS version info

MPS Version Info																															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
SW Version W [7:0]								SW Version X [7:0]								SW Version Y [7:0]								SW Version Z [7:0]							
33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
HW Version W [7:0]								HW Version X [7:0]								Protocol Version W [7:0]								Protocol Version X [7:0]							

2.1.6.12 Command 0x43 – SENSOR_INFO – Read MPS Sensor Info

Description:	Returns information about the sensor.		
Parameters:	N/A		
Response:	SERIAL_NUM	Sensor serial number.	32 bytes, zero-padded ASCII string.
	SENSOR_TYPE	Sensor type.	32-bit unsigned integer. (Note: “MPS 6.0 ULP” SENSOR_TYPE = 0x03)
	SENSOR_SKU	SKU of the sensor.	32 bytes, zero-padded ASCII string.
	CAL_DATE	Date of last calibration.	16 bytes, zero-padded ASCII string. Format is MM/DD/YYYY.
	MFG_DATE	Date of manufacture.	16 bytes, zero-padded ASCII string. Format is MM/DD/YYYY.

2.1.6.13 Command 0x61 – MEAS – Perform Measurement

Description:	Sets the sensing mode (idle, single, or continuous) and “concentration unit” in the measurement.		
Parameters:	The parameter to the Measurement command is 1 byte in length but consists of two, 4-bit values: Concentration Unit (bits 7:4) and Mode (bits 3:0).		

Table 11: Measurement command

Measurement Value (Byte)	
Conc. Unit [7:4]	Mode [3:0]

The “concentration unit” (bits 7:4 of the measurement byte) can be either %LEL (ISO) or %LEL (IEC). By specifying the desired unit, the response for commands 0x01 (read answer) and 0x03 (read concentration) will be either %LEL (ISO) or %LEL (IEC). Invalid “concentration unit” parameters are defaulted to 0x0.

Table 12: Concentration unit

Unit	Name	Description
0x0	PERCENT_LEL (ISO)	Concentration reported as %LEL predominately aligned with ISO 10156:1996
0x2	PERCENT_LEL (IEC)	Concentration reported as %LEL predominately aligned with IEC 60079-20-1

The measurement mode (bits 3:0 of the measurement byte) consists of the following possible values:

Table 13: Measurement mode

Mode	Name	Description
0x2	MPS_CONT	MPS operates in an autonomous, continuous mode
0x3	MPS_STOP	Stop measurement – no measurements are being taken
0x5	MPS_CONT	Like the 0x2, the MPS operates in an autonomous, continuous mode with the exception that the sensor transmits the answer data on the UART bus after each measurement.

Response: N/A

2.1.6.14 Command 0x62 – RESET – Reset MPS

Description: Perform a soft reset of the MPS, clearing all data and states.

Parameters: N/A

Response: N/A

2.1.7 Configuration Parameters

All configuration parameters related to the sensor are set by NevadaNano during manufacturing. The sensor does not support any user adjustable parameters except for the setting of preamble bytes (see Section 2.1.6.8).

2.1.8 Battery Backup

The sensor does not have a battery backup. On power loss, the sensor stops measurements and all “Answer” data are lost. Critical configuration parameters however remain stored and unchanged.

2.1.9 Confidence Signal

A confidence signal is an indicator that the sensor is working as expected. In the MPS 6.0 ULP, there are two confidence signals:

- The cycle count incrementing by one every ~4 seconds (digital communication).
- The sensor status code returned in the “Answer” data (digital communication).

3 Electromechanical Integration

The MPS 6.0 ULP is available in the Series 4 (“S4”) form factor.

The S4 has the same cylindrical shape and dimensions as many industry-standard (catalytic and infrared-type), “4 series” combustible gas sensors and is Intrinsically Safe (IS) certified. The specific dimensions are listed below.

To improve water ingress protection, a user may elect to affix a microporous membrane (e.g., Porex PTFE PM21ML) to the sensor intake. The addition of such a membrane may slow the speed of response, dependent upon the gas. Lighter gases (e.g., methane) are relatively unaffected; however, for heavier gases like toluene and xylene, one can expect slower response times and some suppression of reported concentration.

The sensor housing of the S4 is not sufficiently smooth at a microscopic level to expect gaskets to form a perfectly gas- or liquid-tight seal.

3.1 Series 4 (“S4”)

The Series 4 pinout and critical dimensions are indicated in Figure 9. The sensor interface pins are compatible with the following receptacles (one receptacle per pin) or socket assemblies (one socket per sensor):

Table 14: Sensor Interfacing

Manufacturer	Part number	Description
Mill-Max	9401-0-15-15-23-27-10-0	Closed bottom, individual pin receptacle
Mill-Max	0384-0-67-80-23-27-10-0	Open bottom, individual pin receptacle
Andon	R420-SP05-04T-436P55-R27-L14	5-pin, through-hole socket assembly
Andon	R420-SP05-04T-440P55-R27-L14	5-pin, surface-mount socket assembly

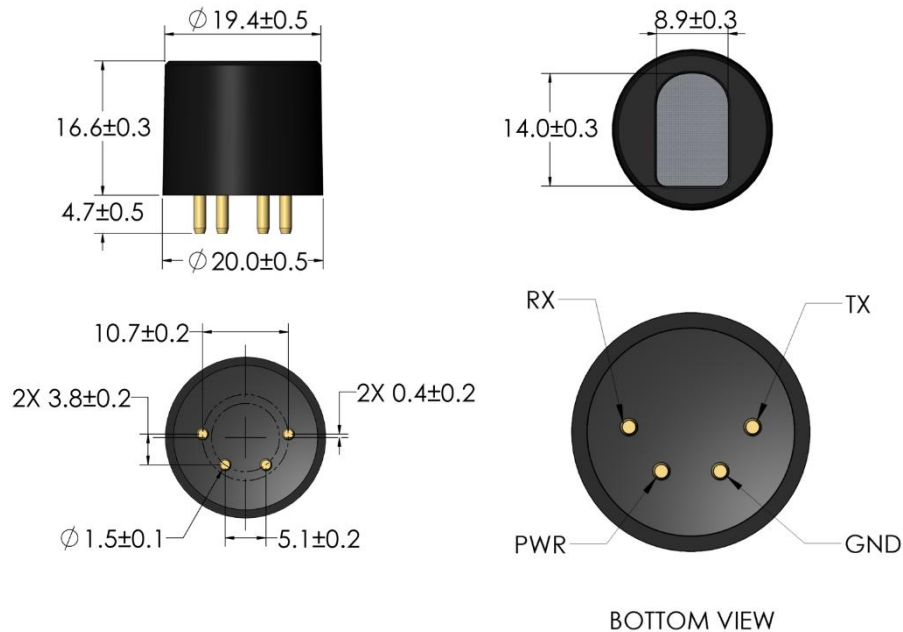


Figure 9: MPS 6.0 ULP mechanical dimensions (in mm) and pinout.

Do not solder to the S4 pins. This will void the warranty.

The “S4” is a standard “4 series” size – 20 mm ϕ , and 16.6 mm high. The sensor housing is constructed from Ultem PEI plastic. The sensor holds an ATEX-default IP2X rating, and has passed additional testing in accordance with MIL-STD-810G Method 510.5 for dust resistance. The sensor is susceptible to liquid ingress and will not function properly if water or other liquids inundate the sensor chamber.

3.2 Powering the MPS

To power the MPS 6.0 ULP, the following criteria need to be met:

- Voltage range must be $3.0\text{-}5.0\text{ V} \pm 5\%$
- Ripple and noise should not exceed 50 mV
- The supply should be capable of providing up to 35 mA without appreciable voltage drop
 - Note: a typical sensor draws a peak current of 22 mA, but worst-case analysis of electronic component tolerances allows for the statistically improbable possibility of current consumption up to 35 mA. System designers should therefore use 35 mA as a maximum possible current draw, while using an average current of 0.45 mA and peak current of 22 mA for calculation of typical performance, e.g. battery life. The current draw is non-monotonic and will vary based on the internal activity cycle of the sensor.

4 Testing the MPS 6.0 ULP

The MPS determines the presence and quantity of flammable gas by differentiating its molecular properties from the ambient gas in which the sensor is started. The MPS is optimized to operate in “real world” conditions. When testing the MPS in a laboratory environment, it is important to not introduce unrealistic, artificial conditions that can confuse the computed result. In particular, it is important that care is taken to ensure that the ambient gas composition remains consistent throughout testing.

An example of an improper test procedure (shown in Figure 10c and d) would be alternating between ambient air (which contains argon, carbon dioxide and other trace gases) and flammable gas + synthetic “zero air” balance (which contains none of the trace constituent gases in ambient air). To properly simulate the real-world application (Figure 10a) in artificial laboratory testing, the same type of “air” must be used for the background and the carrier of the flammable gas for the duration of the test. An example of a proper protocol is shown in Figure 10b. Using a variation of the “incorrect” procedure will invalidate the accuracy of MPS measurements.

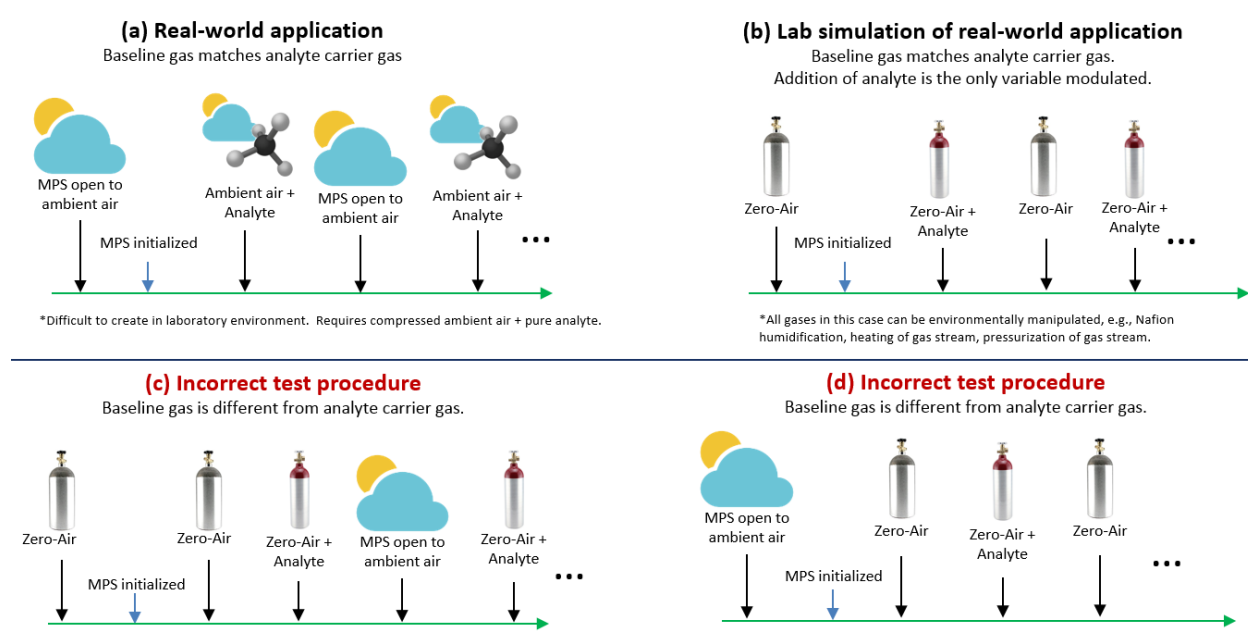


Figure 10: a) The real-world flammable gas leak scenario. (b) The method for simulating the real-world scenario in a laboratory. Incorrect test procedures are shown in (c) and (d); in these cases, the carrier-only condition does not use the same “air” as the carrier + flammable gas condition, causing inaccurate results.

A “best practice” for performance testing in a laboratory is to use a humidified zero-air background, followed by a switch to a humidified analyte stream with the same zero-air composition as balance gas, then a switch back to humidified zero-air to clear the test chamber. This mimics real-world MPS performance, where flammable gas is introduced into relatively invariant ambient air (Figure 10a).

For best results, make sure the sensor initializes in the same background later used to deliver flammable gases. For example, if testing with flammable gas in a balance of zero air, make sure that the sensor is operating in zero air during start-up and initialization (refer to Figure 7).

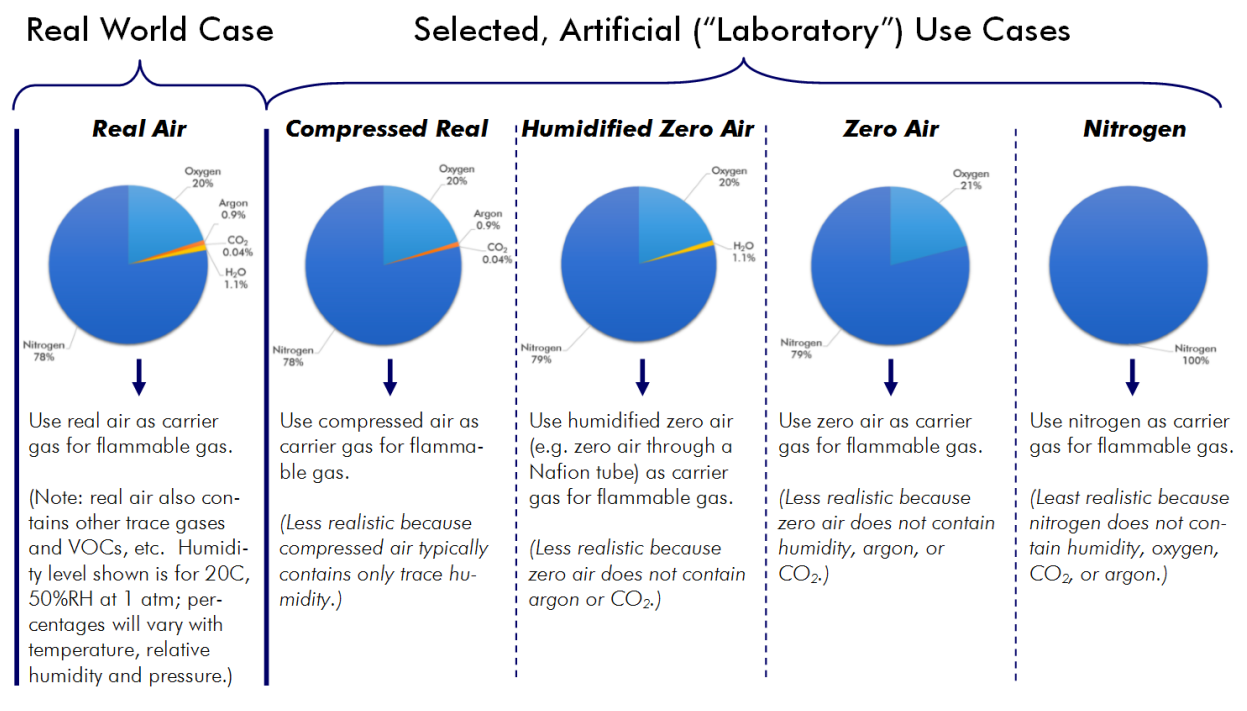


Figure 11: Various "air" options for use as the carrier, or background, gas during flammable gas testing. The best practice is to use one of the options toward the left side of the figure. In addition, do not switch between two different types of "air" during an experiment, as this can produce unwanted (and unrealistic) testing artifacts.

4.1 Typical Test Setups

Various test setups can be used to perform tests with the MPS 6.0 ULP. One common test setup uses two regulated gas cylinders: zero air (20.9 %volume oxygen in nitrogen), and 50 %LEL methane in a balance of zero air.

4.1.1 Setup #1: Gas Testing in Various Environmental Conditions

Regulated gas cylinders are connected to a gas mixing system (e.g. Environics 4040) to control gas flow rates and concentrations. The gas travels through a heat exchanger and humidity-permeable tubing (e.g. Nafion™ TT-110¹), allowing the gas to reach the chamber temperature and relative humidity. Gas then flows serially through each of the MPS sensors and out a vent exhaust-tube. The environmental chamber is programmed with the required temperature/humidity profiles for each test.

¹ permapure.com

Gas profiles are created in the gas mixing system software to deliver the analyte at the correct time. Flow rate is constant at 300 mL/min for both analyte and zero air throughout the tests.

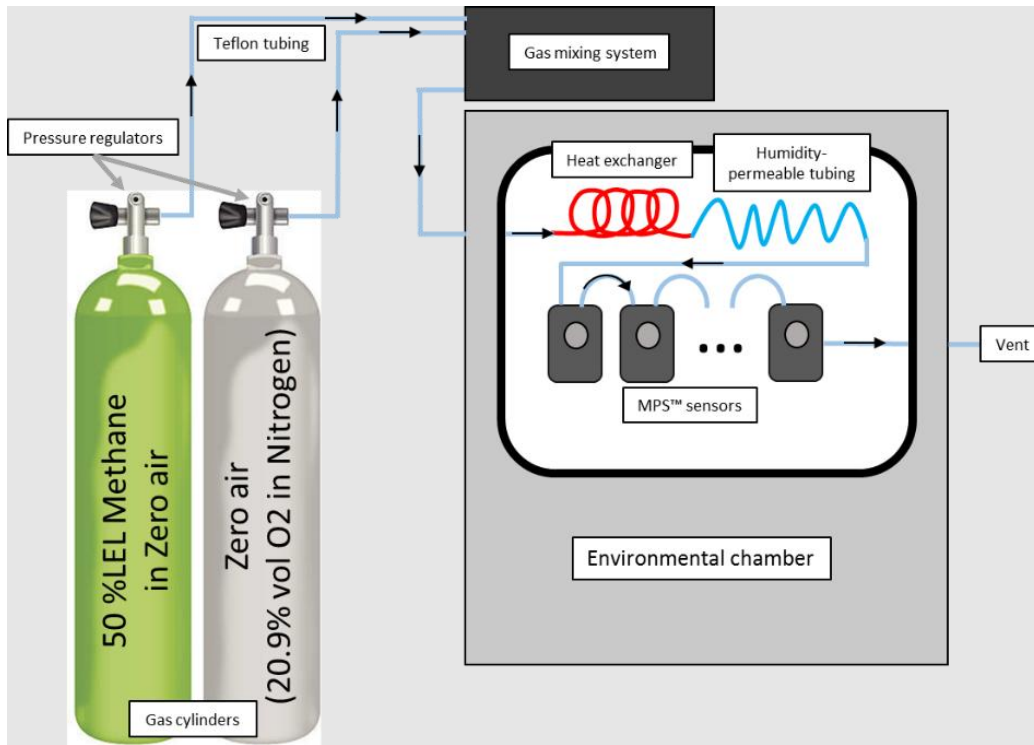


Figure 12: Setup #1: Gas Testing in Various Environmental Conditions

4.1.2 Setup #2: General Benchtop Testing

Regulated gas cylinders are connected together via a 3-way valve, a rotameter, and humidity-permeable tubing to the sensors. The sensors are encased in a plastic box with a removable lid that seals against the face of the sensor. The lid contains an inlet and an outlet that allows for multiple sensors to be connected in series. The 3-way valve allows gas switching, the rotameter enables flow control, and the Nafion™ tubing humidifies the gas stream. The flow is regulated at 300 mL/min throughout the test to maintain near-constant gas concentration throughout all sensors.

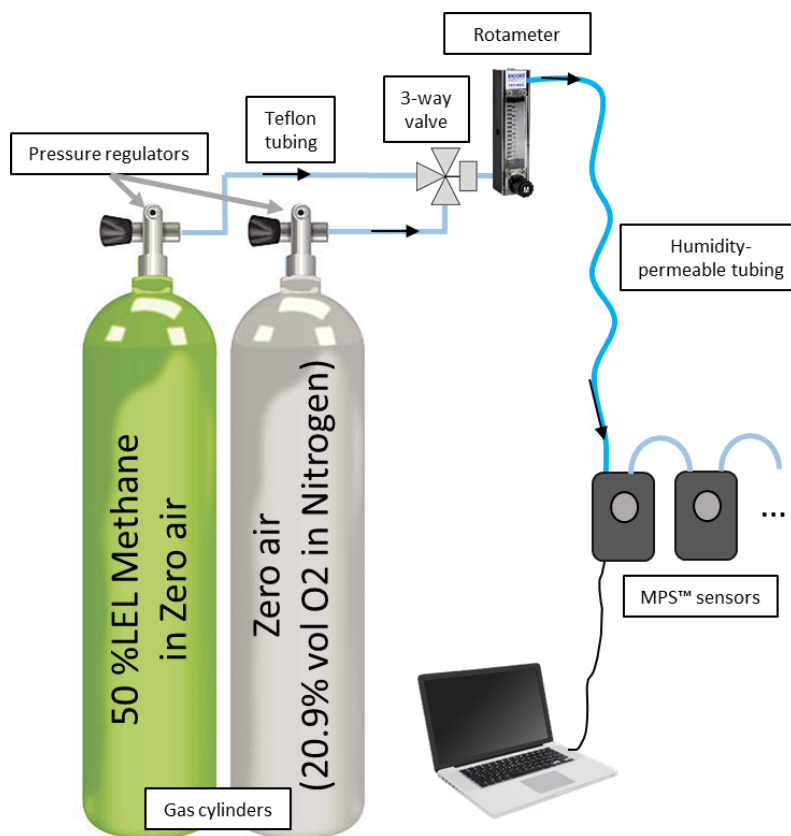


Figure 13: Setup #2: General benchtop testing.

4.2 Bump Test Gas Concentrations

The following compressed gas cylinder mixtures can be applied to the MPS while it is already operating in normal, ambient air. Ambient air consists of 78.08% Nitrogen, 20.95% Oxygen, 0.93% Argon, and 0.04% Carbon Dioxide, by volume. This constitutes the air that we typically breathe, only without humidity. The addition of the flammable gas reduces the relative concentrations of the other constituents, with examples shown here for 50 %LEL concentrations of methane (ISO and IEC) and for pentane (ISO); however, this method can also be applied to other flammable gases. Contact NevadaNano for guidance.

Table 15: Compressed gas cylinder mixtures

	Nitrogen	Oxygen	Argon	CO ₂	Flammable Gas
Synthetic (dry) air at 50 %LEL (ISO) methane	76.13%	20.43%	0.91%	0.04%	2.50%
Synthetic (dry) air at 50 %LEL (IEC) methane	76.36%	20.49%	0.91%	0.04%	2.20%
Synthetic (dry) air at 50 %LEL (ISO) pentane	77.49%	20.79%	0.92%	0.04%	0.75%

The following compressed gas cylinder mixtures can be used for single- or multi-gas monitors. These are also applied to the MPS while it is already operating in normal, ambient air.

Table 16: Single or multi-gas monitor mixture

	Nitrogen	Oxygen	Argon	CO ₂	Flammable Gas	H ₂ S	CO
"Quad Mix" with 50 %LEL (ISO) methane	Balance	18.00%	0%	0%	2.50%	25 PPM	100 PPM
"Quad Mix" with 50 %LEL (IEC) methane	Balance	18.00%	0%	0%	2.20%	25 PPM	100 PPM

The following compressed gas cylinder mixtures can be delivered only if the sensor has been initialized in zero air prior to delivery of the gas. Zero air consists of only 79.1% Nitrogen and 20.9% Oxygen by volume.

Table 17: Compressed gas mixture after zero air

	Zero Air	Flammable Gas
50 %LEL (ISO) methane	Balance	2.50%
50 %LEL (IEC) methane	Balance	2.20%

5 Environmental Faults and Conditions Affecting Accuracy

The MPS 6.0 ULP is specified to operate in the following conditions: -40 to 75 °C, 0 to 100 %RH, and 80 to 120 kPa. The MPS will fail safe and permanently latch to a non-functional state if exposed to extreme excursions outside of its environmental specifications (e.g. liquid water inside sensor, or temperatures > 85 °C). The sensor has built-in self-test capabilities to detect and report excursions outside these regimes:

- Status 0x23, HW_ENV_XCD_RANGE: Environmental (Temp., Press., Humid.) out of range
- Fault 0x24, HW_ENV_SNSR_MALFUNCTION: Environmental (Temp., Press., Humid.) extremely out of range. Sensor permanently latches.
- Status 0x31, CONDENSATION_DETECTED: Condensation condition exists at sensor

So long as the sensor is not subjected to environmental conditions extremely outside of its specification, it will continue to make measurements. The impact on sensor performance and output in these conditions is summarized in the following table:

Table 18: Sensor performance in certain conditions

Condition	Fault reported	Impact on sensor performance and output
Sensor environment out of range	0x23 - HW_ENV_XCD_RANGE	The sensor will still detect and report flammable gas, though output accuracy can be diminished while the condition persists.
Condensation condition at sensor	0x31 - CONDENSATION_DETECTED	The sensor will still detect and report flammable gas, though output accuracy can be diminished while the condition persists and for one minute afterward.
Breath or humidity surge detected	0x35 - BREATH_OR_HUMIDITY_SURGE	The sensor will still detect and report flammable gas, though output accuracy can be diminished while the condition persists and for 45 seconds afterward.
Rapid humidity changes	None	If the sensor is already reporting flammable gas, no adjustments are made to sensor output. If gas is not being detected, the sensor output may be automatically adjusted to 0 %LEL for a maximum of 5 cycles (20 seconds) in a row during a rapid humidity increase. This adjustment has been programmed such that the largest possible concentration change to go unreported is 15 %LEL (methane). The sensor will still detect and report flammable gas, though accuracy can be diminished for up to 60 seconds.
Rapid temperature change	None	The sensor will still detect and report flammable gas, though output accuracy can be diminished while the condition persists. For an MPS sensor exposed on all sides to ambient air, it is possible for this condition to occur when moving from conditioned, indoor air to cold or hot outdoor conditions, or vice versa. For MPS sensors integrated in portable or fixed detector units, the added thermal mass and insulation provided by the unit serves to slow the thermal transients acting on the MPS, making this condition less likely.

Sensor accuracy can also be diminished in certain cases of extremely slow gas accumulation occurring over time scales of many hours or days. These cases are still detected by the MPS, and reported via the fault message “SLOW_GAS_ACCUMULATION_DETECTED.” However, because TrueLEL accuracy is not available in this fault case, it is recommended that the detector output a high gas alarm (>50%LEL).

6 Hazardous Locations and System Integration

Integrating the MPS into intrinsically safe systems requires additional design consideration. Refer to the MPS Hazardous Locations User Guide (nevadanano.com) for information regarding certifications, protection concepts, entity parameters, etc.

7 Sensor Data for Temperature, Humidity, and Pressure

The MPS 6.0 ULP is equipped with an integrated sensor that measures temperature, humidity, and pressure. These data are available to end users (Section 2.1.6) and are generally representative of ambient environmental conditions; note, however, the MPS environmental sensor measures the conditions *within* the sensing chamber, which may not perfectly match ambient environmental conditions due to the slight self-heating of the sensor chamber by the MPS’ internal electronics. Typically, environmental readings provided by the MPS are slightly warmer than ambient and have

lower *relative* humidity than ambient, while the *absolute* humidity (which can be calculated, if desired, using the MPS' temperature and relative humidity outputs) tends to track well with the ambient absolute humidity. MPS environmental readings are dependent on the temperature and heating profile of the system into which the sensor is integrated and the MPS' proximity to components that generate additional heat.

8 Warranty information

MPS Flammable Gas Sensors carry a 2-year warranty against defects in materials and workmanship, as specified in the Standard Limited Warranty in Section 8.1. The warranty is voided if the sensors are used under conditions other than those specified in the sensor datasheet or this user manual. Please pay particular attention to these things:

- Do not use or otherwise expose the sensor to the following environmental conditions:
 - Temperatures above 90°C or less than -60°C
 - Ambient pressures above 130 kPa or less than 30 kPa
- Do not allow water or other liquids to accumulate inside the sensor
- Do not solder to the S4 sensor pins
- Observe the correct supply polarity and voltage ranges

8.1 MPS 6.0 ULP Standard Limited Warranty

Nevada Nanotech Systems, Inc. warrants its MPS 6.0 ULP, (referred to hereafter as the Product) manufactured and sold by Nevada Nanotech Systems, Inc. to be free from defects in materials and workmanship for a period of two years from the date of original purchase. This warranty is expressly limited to the original owner who purchases the equipment directly from Nevada Nanotech Systems, Inc. or from an authorized Nevada Nanotech Systems Distributor and is non-transferrable.

To maintain this limited warranty, the product must be operated, used, and maintained in accordance with the conditions specified in the MPS™ 6.0 ULP Datasheet, the MPS™ 6.0 ULP User Manual, and the MPS™ Hazardous Locations User Guide. Abuse, mechanical damage, alterations, or other operations not done in accordance with these documents voids the Nevada Nanotech Systems Standard Limited Warranty.

With respect to firmware, the obligation of Nevada Nanotech Systems under this limited warranty is limited to a firmware upgrade, performed by Nevada Nanotech Systems, when such upgrade is deemed necessary, solely by Nevada Nanotech Systems, to address a critical safety or functional issue. This warranty is limited to the above and expressly excludes firmware upgrades that include enhanced or modified functionality of features.

Nevada Nanotech Systems does not warrant that the electronic or software operation of the Product will be uninterrupted or error-free, or that all such errors may be corrected. In addition to all other limitations, this limited warranty is limited by and does not apply to the following: (1) products or parts that have been altered or modified (e.g., to alter functionality or capability) by anyone other than

Nevada Nanotech Systems; (2) damage caused by use with another product; (3) damage caused by accident, abuse, misuse, liquid contact, fire, or other external cause; (4) damage caused by operating the Product outside Nevada Nanotech System product guidelines; (5) Products whose electronic module housings have been opened or otherwise tampered with; and (6) defects caused by normal wear and tear or otherwise due to the normal aging of the Product, unless damage has occurred due to a defect in materials or workmanship.

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The foregoing limitations will apply even if any warranty or remedy provided under this Agreement fails of its essential purpose. Some jurisdictions do not allow exclusion or limitation of incidental or consequential damages or how long an implied warranty lasts, so the above limitations may not apply to you. This limited warranty gives the Purchaser specific legal rights, and the Purchaser may also have other additional rights, which vary from State to State or by countries.

In the event of any dispute regarding the Product, prior to bringing any civil suit, the Purchaser and Nevada Nanotech Systems agree to resolve any Claims by ARBITRATION that must be brought through a mutually acceptable arbitrator in Reno, Nevada. Such arbitration will be conducted under the Commercial Arbitration Rules (Amended and Effective October 1, 2013) of the American Arbitration Association (available at <http://www.adr.org/commercial>). For the purposes of this section, references to "Purchaser" include the original OEM manufacturer, its officers, directors, employees, customers, beneficiaries, and assigns, and references to "Claim" shall include any dispute, claim or controversy arising from or relating to: (1) the Product, whether based in contract; tort; fraud; misrepresentation; state or federal statute, regulation, ordinance; or any other legal or equitable theory, and (2) this limited warranty. There shall be no right or authority for any Claims to be arbitrated on a class action basis. This Dispute Resolution agreement is part of a transaction involving

interstate commerce and is governed by the Federal Arbitration Act, which governs its enforcement and interpretation.

No other person or company is authorized to change this limited warranty, and the Purchasers are solely responsible for any other additional warranties regarding any other products that the Products are incorporated into.

To obtain warranty service for the Product, the Purchaser must contact Nevada Nanotech Systems by calling +1 775 972 89431, or emailing returns@nevadanano.com. Nevada Nanotech Systems will provide a Return Merchandise Authorization (RMA) form for the Purchaser to complete. The Purchaser is responsible for any necessary shipping charges for returned or replaced products and all returns must be clearly marked with the RMA number issued. Nevada Nanotech Systems will decide, at its discretion, to repair or replace any of its Products found to be defective. Any replacement under this limited warranty will only be made with the same or similar product of the same or similar value and will not include cash, credits, or other types of products. All repaired or replacement products will be covered for two years from the date of the original purchase. If Nevada Nanotech Systems determines that the problem with the Product is not covered under this limited warranty, Nevada Nanotech Systems will notify the Purchaser and inform the Purchaser of service or replacement alternatives that are available on a fee basis.

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