F-901B SENSOR MODULE

User Manual

Revision 1.7

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1554 NE 3rd Ave, Camas, WA 98607, USA
Phone: (360) 833-8835
www.felixinstruments.com

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IMPORTANT SAFEGUARDS

To reduce the risk of fire, electrical shock, injury to persons or permanent damage to this device, these safety precautions should always be followed:

- Use the included 12VDC power supply or specified power connector to operate this device. Inappropriate voltage supply or power connector could cause irreparable damage to this device. See Cables Assembly.
- Make sure power plug and Modbus cable are plugged in and secured before powering up the device. Power connector will not make connection to GND if not fully plugged into the socket.
- If sampling via tubing, make sure that the tubes are securely attached to the device before operating. Use the included hydrophobic filter to prevent liquid water from entering device. See Cables and Tubes Installation.
- Do not operate the device with an obstructed flow path. Obstruction during air sampling will damage the internal micropump.
- Do not expose this device to any liquids.
- Sensors must not be exposed to temperature, humidity and pressure that are outside the operating range. See sensor Specifications.
- Lifetime of up to 2 years for C2H4/O2 sensor and 5 years for CO2 sensor can be expected for discontinuous sampling. Continuous exposure to relative humidity >90% or <15% and Volatile Organic Compounds (VOCs) over a long period of time must be avoided. See Operating mode.

F-901B Specifications

Measurements	C2H4, CO2, O2, RH, Temperature, Barometric Pressure
Air Sampling Rate	120 mL/min in Continuous Mode
Measuring Rate	(typically) 5-minute intervals
Communication	Modbus via RTU/RS485 & TCP/IP
Sampling Port	Inlet/outlet with Luer lock fittings
Operating environment	0°C - 50°C, 15-90% relative humidity non-condensing
Power Input	12VDC regulated
Avg. Power Consumption	2.5W
Dimensions	172mm x 103mm x 55mm
Weight	0.98kg
Enclosure	Powder-coated aluminum

Ethylene (C2H4) sensor

Type	Electrochemical
Nominal Range	0-1000 ppm
Accuracy	±5% ± 5ppm
Lower Detection Limit	2 ppm
Response Time (T90)	< 3 minutes
Temperature Range	0 °C to 50 °C
Pressure Range	1013mbar ± 10 %
Relative Humidity Range	15 % to 90 % R.H. non-condensing
Long Term Output Drift	< 5 % per month in continuous exposure
Lifetime	2 years

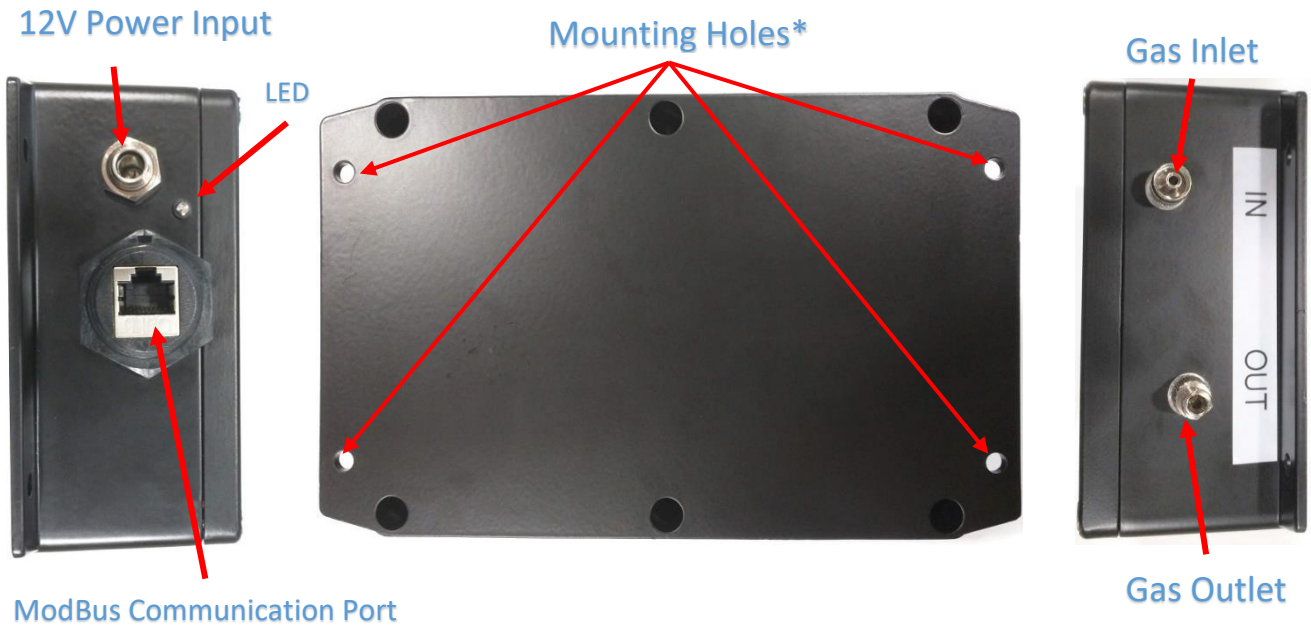
Carbon Dioxide (CO2) sensor

Type	NDIR (non-dispersive infrared)
Nominal Range	0-100%
Accuracy	±3% ± 300ppm
Lower Detection Limit	100ppm
Response Time (T90)	< 20s
Warm Up Time	< 1 minute
Pressure Range	950mbar to 10000mbar
Temperature Range	0 °C to 50 °C
Relative Humidity Range	0 to 90 % R.H. non-condensing
Lifetime	5 years

Oxygen (O2) Sensor

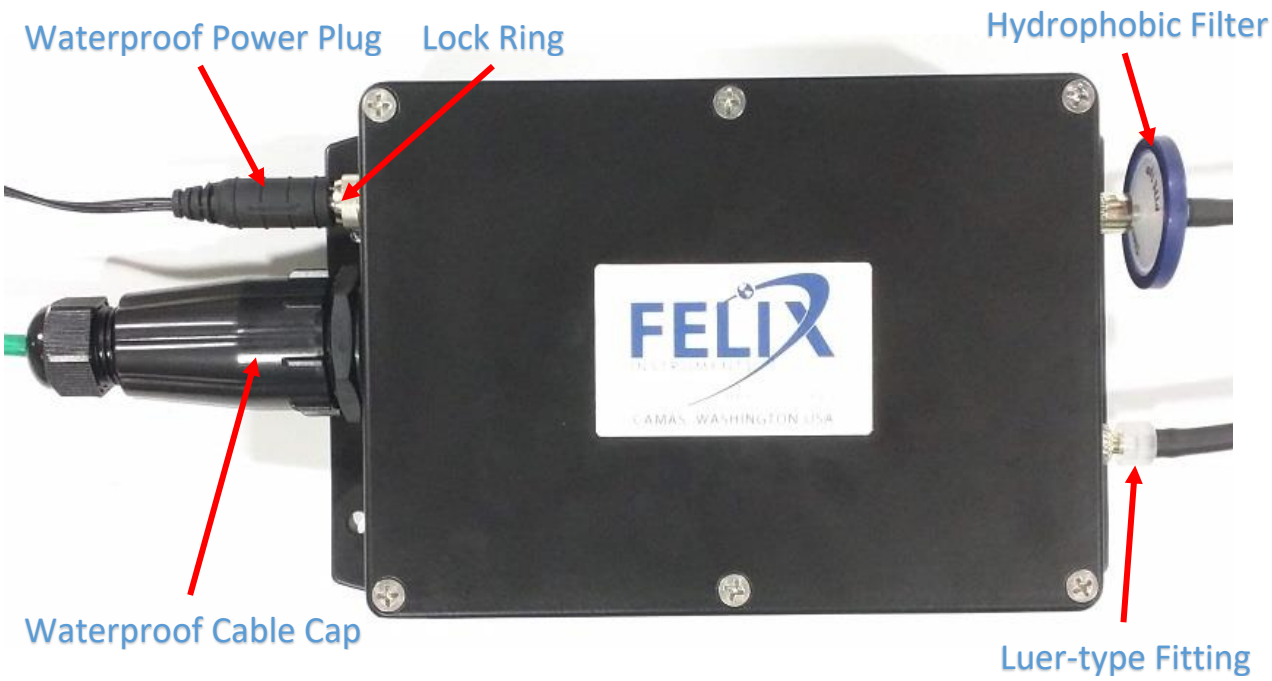
Type	Electrochemical
Nominal Range	0-100%
Accuracy	±2% ± 100ppm
Lower Detection Limit	0.1%
Response Time (T90)	< 5s
Temperature Range	0 °C to 50 °C
Pressure Range	500mbar to 2000mbar
Relative Humidity Range	0 % to 99 % R.H. non-condensing
Lifetime	2 Years

Instrument Overview



*accepts M5 or #10 screw

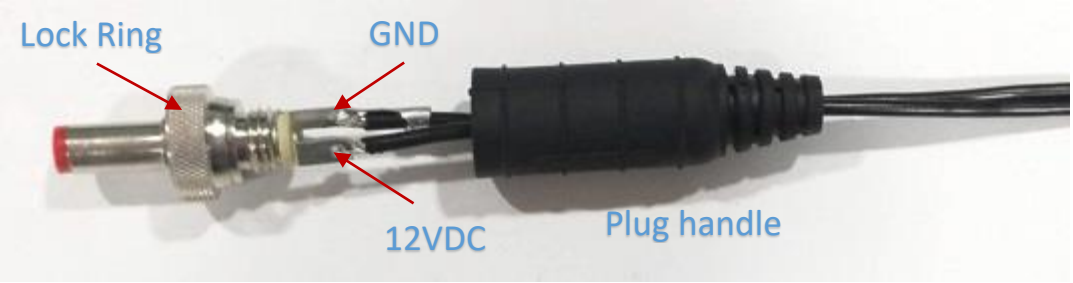
Cables and Tubes Installation

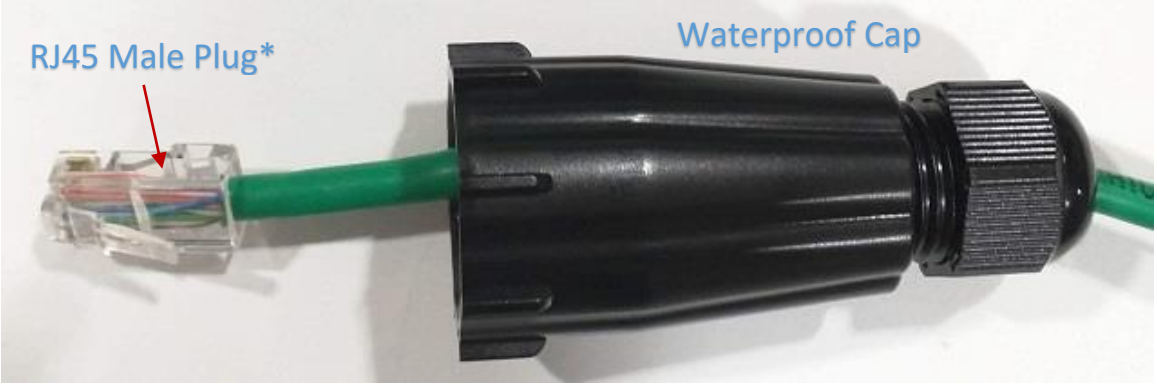


IMPORTANT:

- USE ONLY SPECIFIED POWER PLUG AND CABLE CAP
- MAKE SURE POWER CABLE AND MODBUS CABLE ARE **SECURED** BEFORE POWERING UP DEVICE
- MAKE SURE THERE IS NO FLOW OBSTRUCTION AT INLET/OUTLET BEFORE POWERING UP DEVICE
- USE HYDROPHOBIC FILTER DURING SAMPLING TO PROTECT THE SENSOR FROM CONDENSATION

Cables Assembly





*See Pin Description for correct wiring

Connector Mating Parts (not supplied):

Part number	Description	Manufacture
767KS12	DC Power Plug Sealed IP68	Switchcraft
630125673867	Patch Cable Cap IP67 water and dust protection	InstallerParts

Principle of Operation

Flow cycle

There are two flow cycles during the F-901B operation:

- Sampling Cycle: air from inlet port is pulled into sensors chamber by a micropump, then expelled out to the outlet port.

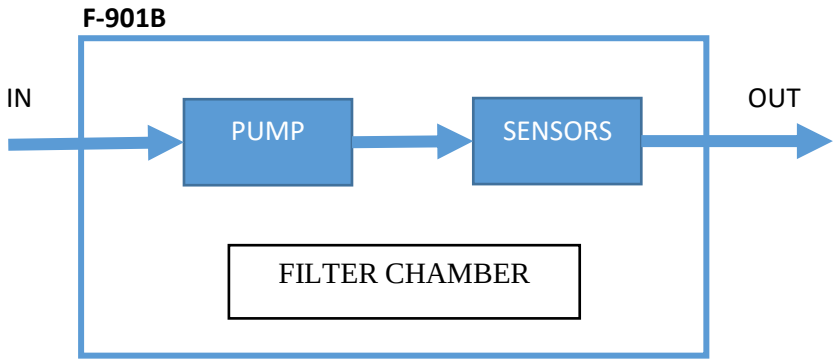


Figure 1 sampling cycle

- Cleaning Cycle: Air is circulated inside the F-901B through the sensor and filter chamber. Sensors are now isolated from the outside air.

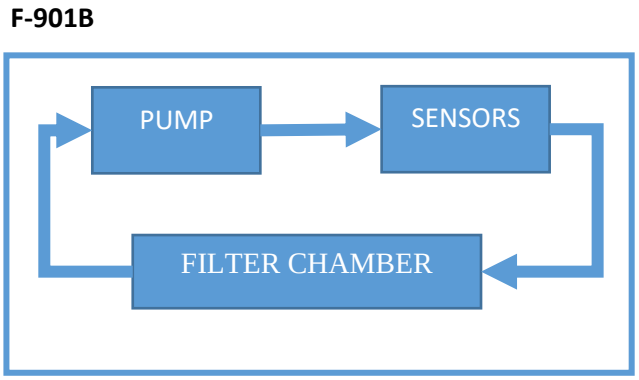


Figure 2 cleaning cycle

Operating modes

- **Trigger measurement mode:** during this mode, device alternates between sampling (Figure 1) and cleaning cycles (Figure 2). Sampling cycle lasts for 35 seconds then immediately followed by cleaning cycle for 30 seconds. The whole routine will then repeat after some idle time. Final sensor readings are updated at the end of sampling cycle and remain the same until the next update (see TRIGGER_INTEVAL). Use this measurement mode to increase sensors lifetime and prevent baseline drift, especially when operating in high VOC/humidity environments. The rule of thumb is the less exposure, the longer sensor lifetime. This is the default operating mode (5-minutes interval).
- **Continuous measurement mode**: during this mode, air is sampling continuously as shown in Figure 1. Sensor readings are updated every second. **IMPORTANT**: Do NOT use this mode for long exposure applications.

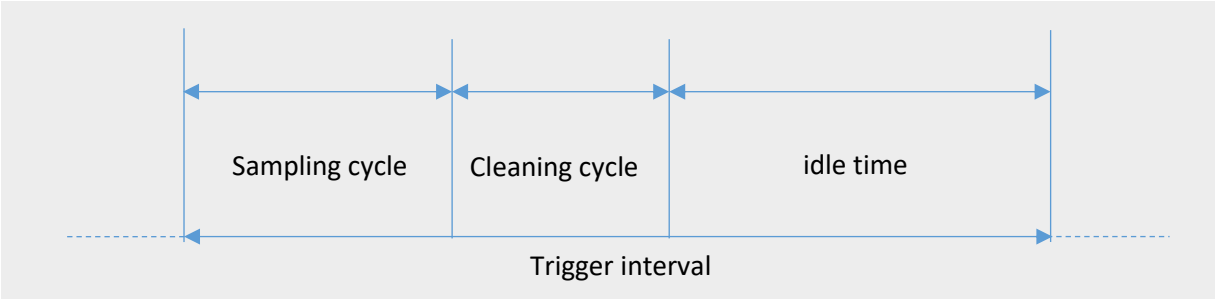


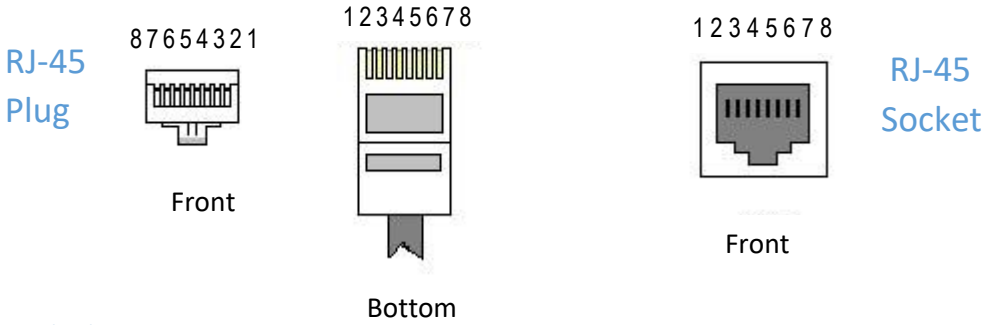
Figure 3 Trigger measurement timing

MODBUS

The F901B supports the standard Modbus protocol in both RTU and TCP/IP mode:

- TCP/IP: the factory default mode. Upon powering up, the F901B initializes the Modbus TCP/IP protocol via the default static IP address 192.168.1.50 port 502 (This address is configurable via Modbus commands).
- RTU: The F901B sensor can be configurated to operating in RTU (RS485) mode by setting the MODBUS_MODE register and swapping the internal cables inside the sensor. See below for RTU specifications. Please contact Felix Instruments for details on how to configure sensor hardware in RTU mode.

RTU RS485 Configuration



Pin Description

Pin	Name	Type	Description
1	3.3V	Reference potential	3.3V Reference Voltage
2	GND	Reference potential	Local device ground
3	UART_TX	Digital Output	Firmware update interface
4	B (D-)	Bus In/Out	Driver output and receiver input
5	A (D+)	Bus In/Out	Driver output and receiver input
6	UART_RX	Digital Input	Firmware update interface
7	BOOT	Digital Input	Firmware update interface
8	RESET	Digital Input	Microcontroller reset input (Active-Low) Firmware update interface

IMPORTANT: use pin 4,5 (B/A) and GND for Modbus RS485 communication. Pin 3,6,7,8 are reserved for firmware updating and are **3.3V** tolerant.

Absolute Maximum Rating

Voltage range at A or B ..... -8V to 12V
Voltage range at pin 3,6,7,8 ..... -0.3V to 4V
Electrostatic discharge at A and B ..... ±8kV

RS485 Modbus Parameters

Parameter	Value
Default address	50
Baud Rate	19200
Data bits	8
Parity	Even
Stop bits	1

F-901B MODBUS Specifications

- Operates as a slave, half-duplex mode
- Modbus functions supported:
  - 0x01 - Read Coils
  - 0x03 - Read Holding Registers
  - 0x04 - Read Input Registers
  - 0x05 - Write Single Coil
  - 0x06 - Write Single Register
  - 0x0F - Write Multiple Coils
  - 0x10 - Write Multiple Registers
- Exception messages supported
- Default address:
  - RTU: 50
  - TCP/IP: 192.168.1.50

Input Registers

Mode: Read-only, size: 16 bits

Name	Address	Description
C2H4	0	C2H4 measurement x 10, ppm
CO2	1	CO2 measurement x 100, %
O2	2	O2 measurement x 10, %
TEMPERATURE	3	Temperature measurement x 10, C (Note: 16bit signed number)
RELATIVE HUMIDITY	4	Relative Humidity measurement x 10, %
BAROMETER	5	Barometric pressure measurement x 10, mbar
VAPOR PRESSURE	6	Vapor pressure of water measurement x 10, mbar
ERROR STATUS	9	0 = OK. 1 = C2H4 offset error, Sensor over-exposed or KMnO4 filter needs to be replaced.
C2H4_RAW	10	C2H4 raw measurement, count
O2_RAW	11	O2 raw measurement, count

DEV_TYPE	100	Default device type ID: 9011
FIRMWARE	101	Firmware version

Note:

- Above addresses are offsets. The function address for input register is [30001 + offset]
- Temperature and Humidity are measured at the sensor's inlet and may not represent room condition or remoted/localized spots. External temperature probe provided in F901B v2 sensor.

Holding Registers

Mode: Read/Write, size: 16 bits (unsigned)

Name	Address	Default	Description
PUMP_POWER	0	50	Internal pump power 0-100%
C2H4_SPAN	1		C2H4 span calibration parameter. Calibration formula: C2H4_SPAN = C2H4_CUR*C2H4_SPAN_CUR/C2H4_CAL Note: C2H4_CAL: expected calibration concentration C2H4_SPAN_CUR: Current span value C2H4_CUR: Current C2H4 measurement
C2H4_ZERO	2		C2H4 zero calibration parameter
O2_SPAN	3		O2 span calibration parameter. Calibration formula: O2_SPAN = O2_CUR*O2_SPAN_CUR/O2_CAL Note: O2_CAL: expected calibration concentration O2_SPAN_CUR: Current span value O2_CUR: Current O2 measurement
O2_ZERO	4		O2 zero calibration parameter
CO2_SPAN	5		CO2 span calibration parameter. Calibration formula: CO2_SPAN = CO2_CAL*CO2_SPAN_CUR/CO2_CUR Note: CO2_CAL: expected calibration concentration CO2_SPAN_CUR: Current span value CO2_CUR: Current CO2 measurement
CO2_ZERO	6		CO2 zero calibration parameter
TRIGGER_INTERVAL	20	300	Interval between Trigger measurements in seconds. Writing a value greater than 0 to this register enables Trigger mode (see Operating modes). Writing a 0 to this register disables the Trigger mode (switches to Continuous mode after finishing any on-going Trigger measurement). Note that a single Trigger mode measurement takes at least 65 seconds. To ensure sensor stability and longevity, use the default or longer intervals, and avoid intervals of less than 180 seconds.
SLAVE_ADDR	30	50	Device Modbus RTU slave address. Update this register to change the slave address. Valid slave addresses: 0-99
MODBUS_MODE	31	0	0: TCP/IP (LED blinks 2 times at boot) 1: RTU (LED blinks 3 times at boot) 2: Auto Config Mode. During boot up, if the internal TCP/IP cable is plugged in and the device is connected to active ethernet hub/router or the F901C Controller, the device will select TCP/IP mode. Otherwise, RTU mode is selected.
IP_ADDR0	32	192	Device local IP address
IP_ADDR1	33	168	Device local IP address

IP_ADDR2	34	1	Device local IP address
IP_ADDR3	35	50	Device local IP address

Note:

- Above register addresses are offsets. The function address for holding register is [40001 + offset]
- Values written to the above holding registers remain after Power-off/Reset

IMPORTANT:

- Changing the pump power to different value than the factory default may affect measurement accuracy. In such case, a complete sensor re-calibration is recommended.
- Backup calibration parameters before overwriting their values (performing a calibration) or update device firmware (all parameters will be erased). All F-901B comes with factory calibration using standard certified gases.

Coils

Mode: Read/Write, size: 1 bit

Name	Address	Default	Description
SPAN_209_O2	1	False	Request to calibrate O2 sensor span using fresh air (20.9%)
ZERO_CO2	2	False	Request to zero CO2 sensor using fresh air (400ppm) or known CO2 concentration
ZERO_CO2_N2	6	False	Request to zero CO2 sensor with 100% N2 (0%CO2)
CONF	7	False	Confirmation of zero action
RESET	9	False	True: (software) reset False: no action

Note:

- Above addresses are offsets. The function address for coil is [00001 + offset]
- See Calibration section on how to use the coil registers to perform calibrations.

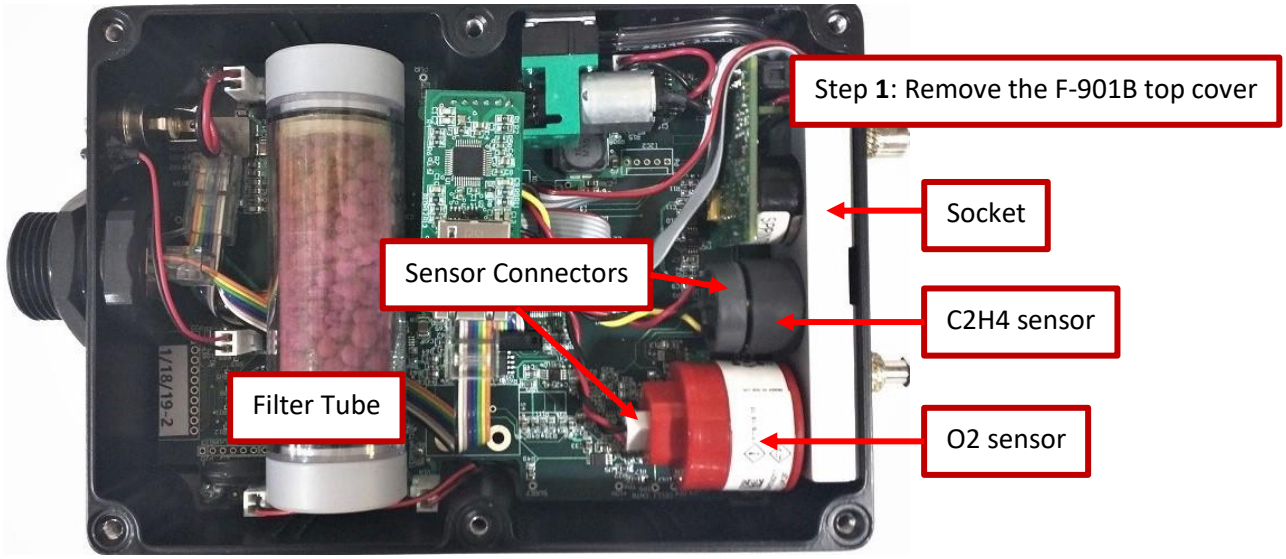
IMPORTANT: backup calibration parameters before performing a calibration. A calibration will overwrite the factory calibration parameter in the Holding register.

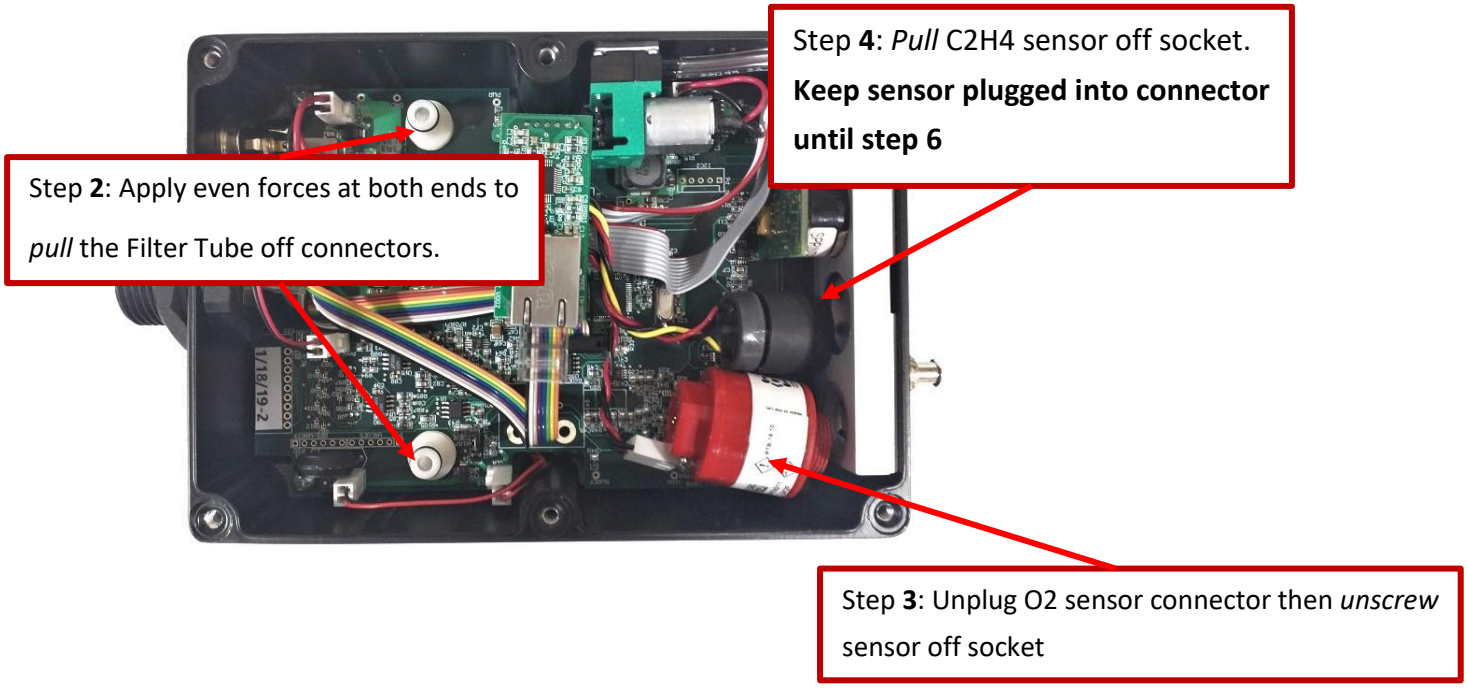
Maintenance of the F-901B

Replacing the Ethylene (C2H4), Oxygen (O_2) Sensor and Potassium Permanganate Filter (KMnO4)

IMPORTANT:

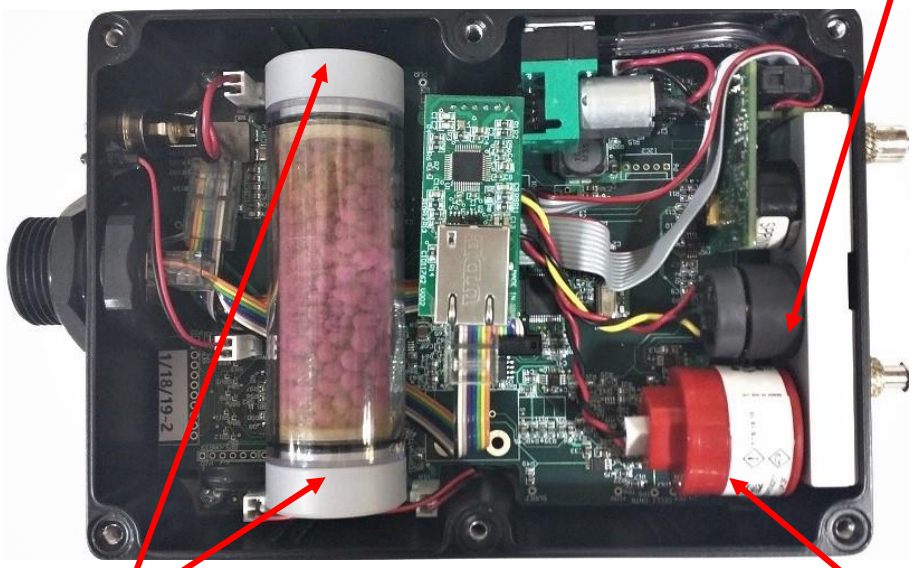
- **Power off device before you proceed**
- Make sure you have sufficient ESD (electrostatic discharge) protection
- Follow the below steps carefully to ensure proper sensor installations





Step **5**: remove short-cutting spring from new C2H4 sensor. (the spring keeps sensor from sensitivity/baseline drift during storage. Save it later for your old sensor)

Step **6**: remove old C2H4 sensor from connector, Plug in the new C2H4 sensor then push into socket



Step **8**: Apply force to both ends, gently push new Filter tube into connectors

Step **7**: screw new O2 sensor into socket then plug in connector

Note: Replace the KMnO4 filter when beads color turns to dark brown. Filter lifetime of >1.5 years can be expected when setting TRIGGER_INTERVAL > 10 minutes.

Calibration

All units are shipped factory-calibrated. Over time all sensors require recalibration to ensure accuracy. There are several options for calibration:

- You can ship your F-901B or individual sensor back to us for calibration
- You can order pre-calibrated sensors from us to replace your current sensors
- You can calibrate the sensors yourself

The performance of a sensor or the whole instrument should be checked regularly with calibration gas. Replace sensor when its sensitivity (span) is below 50 % of its initial value. The calibration interval depends on a number of factors including application, environmental conditions, regulations and accuracy requirements.

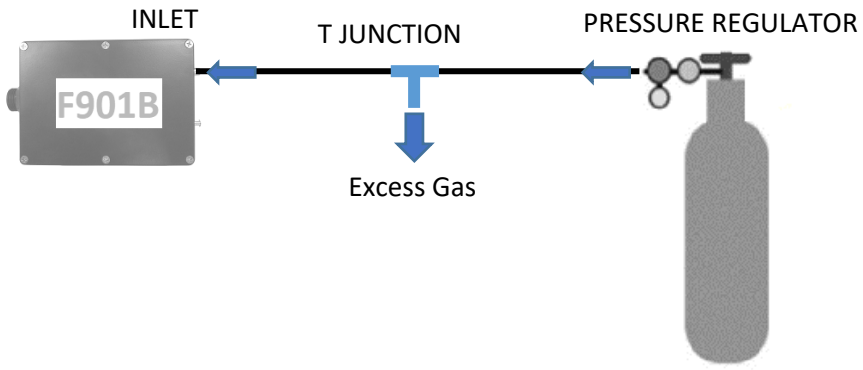
User calibration

Sensor calibration typically involves a zero (baseline) and a span (sensitivity) calibration. Zero calibration commonly uses "zero gas" such as 100% N2 while span calibration uses target gas for calibration. Below are recommended calibration gases for the F-901B:

Sensor	Zero	Span
C2H4	100% N2, or Fresh ambient air + KMnO4 filter	200ppm or 500ppm C2H4
CO2	100% N2, or Fresh ambient air + Soda-lime filter Fresh ambient air (400ppm)	20% or 90% CO2
O2	100% N2	Fresh ambient air (20.9%) or 50% O2

Note:

- If possible, calibrate the device with the gas sensor at conditions similar to the intended usage. Use a gas mixture representing the gas matrix in the application then perform the span calibration with the target gas. In some rare cases, the cross-sensitivity to a different gas can be used.
- If you use pressurized gas bottle and pressure-controlled regulator, follow the setup below to properly applying gas to the device. If you use an On-demand regulator, sensor can be connected directly to regulator without the T junction.



Calibration Procedures

C2H4 Sensor Calibration

Calibrating span on the C2H4 sensor should be performed in Trigger measurement mode. During this mode sensor only sampling for 35 seconds per sampling interval, therefore make sure calibration gas is applied properly during the sampling duration. Ignore initial measurements if necessary (flush measurements).

A zero calibration is not necessary, however you can use Holding Register address 2 (C2H4_ZERO) to fine-tune the measurement baseline.

To perform a span calibration for C2H4 sensor:

1. Make sure sensor is in Trigger measurement mode, with at least a 3-minute (180 seconds) Trigger Interval
2. Apply *Calibration gas* at device inlet
3. Monitor sensor measurement at Input Registers address 0 and wait until readings stabilized (typically 2 to 3 measurement updates)
4. Read sensor's SPAN value at Holding Registers address 1
5. Calculate Span value using the provided formula and round this value to the nearest integer

   For example: Calibrating sensor with 100ppm C2H4 standard gas; current sensor measurement is 800 (80.0ppm) and current span value is 50. New span value = 800*50/1000 = 40

6. Write new span value back to the sensor's Holding Register (address 1)
7. Read next sensor measurement at Input Register address 0 to verify if sensor is calibrated correctly.

CO2 Sensor Calibration

CO2 Zero Calibration

CO2 sensor requires a thorough flush and stable signal in order to perform a zero calibration, therefore zero calibration of CO2 sensor should only be performed in the Continuous Measurement mode.

There are several ways to perform zero calibration. You can use certified standards with known concentration of CO2 for instance 0% CO2 or 1000ppm. If such standards are not available, you can use fresh air (~400ppm) provided that it is not contaminated from CO2 producing sources (e.g human, fruits in storage/ripening ...)

- Perform a zero calibration using 100% N2 (0% CO2)
  1. Put device in Continuous measurement mode (write 0 to TRIGGER_INTERVAL Register address 20)
  2. Apply 100%N2 at device inlet
  3. Monitor sensor measurement at Input Register address 1 and wait until reading stabilized (~2 minutes)
  4. Set *ZERO_CO2_N2* Coil (address 6) to request zero action (write 1 or TRUE value to the register)
  5. Set CONF Coil (address 7) to confirm. After confirmation, the device will perform zero action and automatically reset coils. A new zero value will also be updated on Holding Registers address 6
  6. Read sensor measurement at Input Register address 1 to verify if sensor is calibrated correctly. This value should be 0 (0ppm)
  7. Put device back to default Trigger measurement mode (write 300 to TRIGGER_INTERVAL register address 20)

- Perform a zero calibration using fresh ambient air (400ppm CO2)
  1. Put device in Continuous measurement mode (write 0 to TRIGGER_INTERVAL Register)

2. Apply fresh air (400ppm) at device inlet
3. Monitor sensor measurement at Input Register address 1 and wait until reading stabilized (~2 minutes)
4. Set *ZERO_CO2* Coil (address 2) to request zero action (write 1 or TRUE value to register)
5. Set CONF Coil (address 7) to confirm. After confirmation, the device will perform zero action assuming the provided gas is 400ppm. Coils will automatically be reset. A new zero value will also be updated on Holding Registers address 6
6. Read sensor measurement at Input Register address 1 to verify if sensor is zero-ed correctly. This value should be 4 (400ppm or 0.04%).
7. Put device back to default Trigger measurement mode (write 300 to TRIGGER_INTERVAL Register)

- Perform a zero calibration using a known concentration of CO2 (other than 400ppm)
    1. Put device in Continuous measurement mode (write 0 to TRIGGER_INTERVAL register address 20)
    2. Apply known concentration at device inlet (for instance 1000ppm)
    3. Monitor sensor measurement at Input Register address 1 and wait until reading stabilized (~2 minutes)
    4. Set *ZERO_CO2* Coil (address 2) to request zero action (write 1 or TRUE value to register)
    5. Set Holding Register address 16 to the known concentration, for instance 10 (1000ppm or 0.1%)
    6. Set CONF Coil Register (address 7) to confirm. After confirmation, the device will perform zero action using the known concentration at Holding Register address 16. Coils will automatically be reset. A new zero value will also be updated on Holding Registers 6.
    7. Read sensor measurement at Input Register address 1 to verify if sensor is calibrated correctly. This value should be the same as the one written to Holding Register 16.
    8. Put device back to default Trigger measurement mode (write 300 to TRIGGER_INTERVAL Register)

CO2 Span Calibration

Calibrating span on the CO2 sensor can be performed in either Trigger or Continuous measurement mode.

To perform a span calibration for CO2 sensor:

1. Apply *Calibration gas* at device inlet
2. Monitor sensor measurement at Input Register address 1 and wait until readings stabilized (typically 2 to 3 measurement updates in Trigger mode or >=2 minutes in Continuous mode)
3. Read sensor's SPAN value at Holding Registers (address 5)
4. Calculate Span value using the provided formula and round this value to the nearest integer

   For example: Calibrating sensor with 15% CO2 standard gas, current sensor measurement is 1400 (14%) and current span value is 8000. New span value = 1500*8000/1400 = 8571

5. Write new span value back to the sensor's Holding Register (address 5)
6. Read sensor measurement at Input Register address 1 to verify if sensor is calibrated correctly.

O2 Sensor Calibration

Calibrating span on the O2 sensor can be performed in either Trigger or Continuous measurement mode. You can use certified standards with known concentration of O2 or fresh ambient air (20.9% O2).

A zero calibration is not necessary, however you can use Holding Register address 4 (O2_ZERO) to fine-tune the measurement baseline.

- Perform a zero calibration using fresh ambient air (20.9% O2)

1. Apply fresh air at device inlet
2. Monitor sensor measurement at Input Register address 2 and wait until reading stabilized (typically 2 to 3 measurement updates in Trigger mode or >=2 minutes in Continuous mode)
3. Set *SPAN_209_O2* Coil (address 1) to request calibration action (write 1 or TRUE value to register)
4. Set CONF Coil (address 7) to confirm. After confirmation, the device will perform calibration action assuming the provided gas is 20.9%. Coils will automatically be reset. A new span value will also be updated on Holding Registers address 3
5. Read sensor measurement at Input Register address 2 to verify if sensor is calibrated correctly. This value should be 209 (20.9%).

- To perform a span calibration for O2 sensor using a known concentration (certified standard gas):
    1. Apply *Calibration gas* at device inlet
    2. Monitor sensor measurement at Input Register address 2 and wait until readings stabilized (typically 2 to 3 measurement updates in Trigger mode or >=2 minutes in Continuous mode)
    3. Read sensor's SPAN value at Holding Registers (address 3)
    4. Calculate Span value using the provided formula and round this value to the nearest integer

       For example: Calibrating sensor with 10% O2 standard gas, current sensor measurement is 110 (11%) and current span value is 170. New span value = 110*170/100 = 187

    5. Write new span value back to the sensor's Holding Register (address 3)
    6. Read sensor measurement at Input Register address 2 to verify if sensor is calibrated correctly.

Warranty Information

Seller's Warranty and Liability:

Felix Instruments- Applied Food Science warrants new equipment of its own manufacturing against defective workmanship and materials for a period of one year from date of sale. The results of ordinary wear and tear, neglect, misuse, accident and excessive deterioration due to corrosion from any cause are not to be considered a defect.
Felix Instruments' liability for repairing or replacing defective parts during the warranty period is contingent on examination by a Felix Instruments authorized representative. Felix Instruments liability will not extend beyond repairing or replacing parts from the factory where they were originally manufactured. Repair or alteration by an unauthorized technician voids warranty.
Material and equipment which is not manufactured by Felix Instruments are to be covered only by the warranty of its manufacturer. Felix Instruments will not be liable to the Buyer for loss, damage, or injury to persons or to property by the use of equipment manufactured by other companies.

Buyer accepts the terms of warranty through the use of this instrument and any accessory equipment. There are no understandings, representations, or warranties of any kind, express, implied, statutory, or otherwise (including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose), not expressly set forth herein.

All instrument repairs or replacement covered under warranty require a Returned Material Authorization (RMA) number. Please contact Felix Instruments technical support department at support@felixinstruments.com to obtain an RMA number before shipping instrument to CID Bio-Science, Inc.

Buyer is responsible for shipping charges to Felix Instruments headquarters:

1554 NE 3rd Ave.
Camas, WA 98607
USA

Felix Instruments is responsible for return shipping charges on repairs and/or replacement covered by warranty.

Warranty Registration Card

1554 NE 3rd Ave, Camas, WA 98607, USA
Phone: (360) 833-8835 Fax: (360) 833-1914 e-mail: sales@felixinstruments.com Web: www.felixinstruments.com

PRODUCT REGISTRATION CARD

Please complete and return this form to Felix Instruments within 30 days to validate your Warranty on Parts & Labor.

Registration Information:

Your Name:_____ Title:_____

Company/University:_____

Address:_____

City:_____ State:_____ Zip:_____

Country:_____Email_____

Phone:_____ Fax:_____

Felix Instruments Serial Number(s):_____

Purchase Date:_____Purchase Price:_____

Your opinions will help improve our service. Please answer the following questions.

1. What was the basis of your product selection?

□ Representative Recommendation
□ Price
□ Product Features
□ Product Design
□ Technical Specifications
□ Brand Name
□ Warranty
□ Service
□ Other _____

2. What other competing brands did you consider? _____

3. Where did you first learn of this product?

□ Advertisement in _____
□ Representative
□ Friend/Colleague
□ Exhibit
□ Other _____

4. Who selected this product?

□ I did
□ Research Group
□ University Department
□ Purchasing
□ Other _____

5. Comments/Suggestions:

_____