

GENERAL PURPOSE THERMAL MASS FLOW METER MODEL 4140/4143



OPERATION AND SERVICE MANUAL

P/N 1980383, REVISION H
JULY 2020



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| | |
|---|--|
|  | WARNING |
| | TSI® Incorporated flow meters employ a heated platinum sensor. They should not be used with flammable or explosive gasses or mixtures. |

| | |
|---|--|
|  | Caution |
| | TSI® Incorporated flow meters are not medical devices under FDA 510k and in no situation should they be utilized for human respiration measurements. |

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Chapter 1

Unpacking and Parts Identification

Carefully unpack the instrument and accessories from the shipping container. Check the individual parts against the list of components in Table 1. If any parts are missing or damaged, notify TSI® Incorporated (TSI®) immediately.

Table 1. List of Components

| Qty | Item Description | Part/Model |
|-----|---|--|
| 1 | Mass Flow meter, 0.25 inch inlet/outlet (Air, Oxygen, Nitrogen) | 4140 |
| | Mass Flow meter, 0.25 inch inlet/outlet (Air, Oxygen, Nitrogen, Nitrous Oxide)* | 41403 |
| | Mass Flow meter, 0.375 inch inlet/outlet (Air, Oxygen, Nitrogen) | 4143 |
| | Mass Flow meter, 0.375 inch inlet/outlet (Air, Oxygen, Nitrogen, Nitrous Oxide)* | 41433 |
| 1 | Filter Model 4140: 60 mm ULPA filter with 0.25 inch barbed fittings Model 4143: 63 mm HEPA filter with 0.375 inch barbed fittings | 1602317 1602342 |
| 1 | AC Adapter 100 to 240 V, N. America NEMA 5-15 plug, grounded 100 to 240 V, Europlug, CEE 7/16, grounded 100 to 240 V, Great Britain, grounded, fused 100 to 240 V, Australia/NZ | 8918-NA 8918-EC 8918-GB 8918-AT |
| 1 | Operation and Service Manual for Model 4140/4143 | 1980383 |
| 1 | RS232 Serial Command Set Manual, 4000/4100 | 1980340 |

*Other than the specifications in [Appendix A](#), all references to 4140 and 4143 in this manual apply to the 41403 and 41433, respectively.

Table 2. Optional Accessories

| Item Description | Part/Model |
|---|------------|
| Computer Cable, mini-DIN to 9-pin RS-232 | 1303583 |
| Analog Cable, mini-DIN to cable with tinned wires | 1303584 |
| Carrying Case for Model 4140/4143 | 1319201 |

Parts Identification

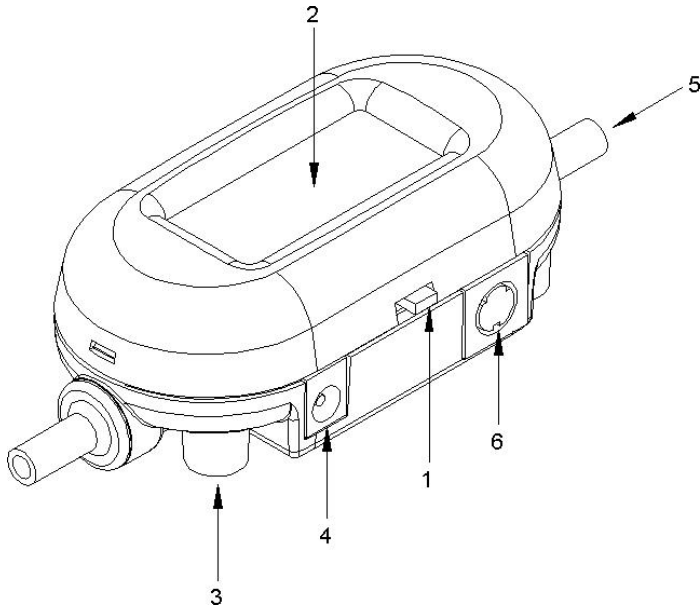


Figure 1-1 Model 4140/4143 Mass Flow Meter

- 1. On/Off Switch
- 2. Display
- 3. Mounting Inserts (2)
- 4. DC Power Input
- 5. Flow Inlet
- 6. Computer Serial Interface, Analog Output, and Optional Power Input Connection

Chapter 2

Setting-Up

Supplying Power

The flow meter can be powered in one of two ways: through the power jack using the supplied AC adapter or through the mini-DIN connector. The DC power input connector is shown below along with the power requirements.

Power Supply: 7.5 VDC \pm 1.5 V, 300 mA maximum



When supplying power through the optional TSI® interface cable, line up the arrow on the connector with the bottom side of the flow meter. Flow meter connector pin-out designations are shown below.

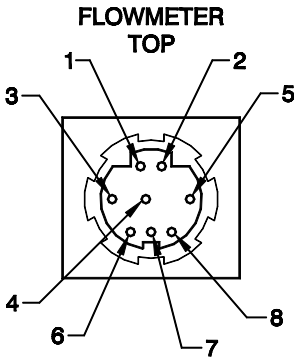


Table 3. Connector Pin-out and Color Code for TSI® Cable PN 1303584

| PIN | Function | CABLE COLOR CODE |
|-----|----------------------|------------------|
| 1 | Power Input (+) | Black |
| 2 | Power Ground (-) | Green |
| 3 | Analog Output (+) | Red |
| 4 | Analog Ground (-) | Brown |
| 5 | (no connection) | Blue |
| 6 | RS232 Receive (in) | White |
| 7 | RS232 Transmit (out) | Yellow |
| 8 | Logic Ground | Gray |

Connecting Filter and Flow Tubes

The Model 4140/4143 has a thermal sensor exposed to the gas flow that must be protected from foreign matter and particles. TSI® supplies a filter that should be connected to the inlet of the flow meter, however, any filter will work as long as it has a minimum efficiency of 99.9%.



CAUTION

Always use a filter on the inlet of the flow meter. Failure to filter the gas flow may change the calibration and/or permanently damage the sensor.

NOTE: Flow direction is identified by the large arrow printed on the bottom side of the flow meter.

After attaching the filter connect the flow tube to the inlet of the filter. Connecting a tube to the outlet of the flow meter will create back pressure. See [Appendix A](#) for flow meter accuracy specifications when operating at various pressures. In general, minimize back pressure on the flow meter to maintain higher accuracy.

RS232 Configuration and Operation

Many flow meter operating parameters can be easily configured through the RS232 serial port. Likewise, the flow rate, temperature, pressure, and volume can be read through the serial port. Refer to the **Series 4000/4100 RS232 Serial Command Set** manual for a detailed description of the commands and command syntax.

RS232 Settings: Baud Rate..... 38.4 k
 Data Bits 8
 Parity..... None
 Stop Bits 1
 Flow Control..... None

Table 4. Changeable Operating Parameters

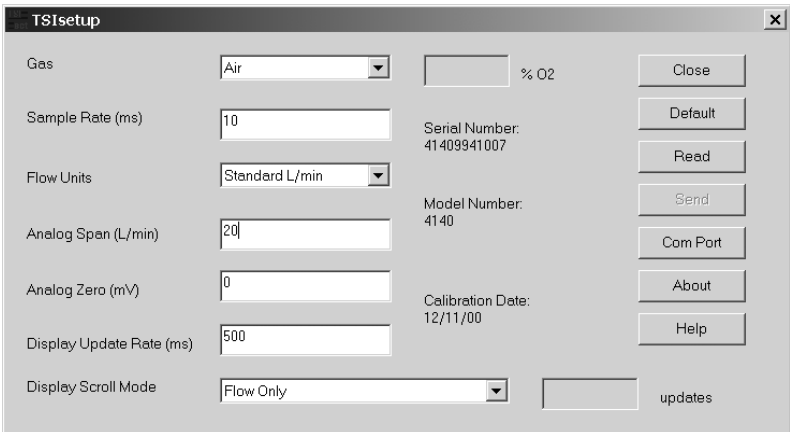
| Function | Command |
|--|---------|
| Select Gas Calibration air, O ₂ , N ₂ , or N ₂ O (if available) | SGn |
| Select Standard or Volumetric Flow Measurement | SUn |
| LCD Display Update Rate (controls averaging) | SURnnnn |
| Select Measurement Display Scroll Mode | SDMFTPn |
| Select Measurement Displayed on LCD Display | SDMm |
| Select Measurement Units on LCD Display | SDUn |
| Select Data Update Rate for Analog Output | SSRnnnn |
| Set Analog Output Full-Scale Flow Rate Value | SASnnn |
| Set Analog Output Zero Value | SAZnnn |

Configuration Software

TSI® has several software utilities to help you communicate with your flow meter to change parameters and to obtain flow data. You can download the latest versions of these at no charge from our web site:

<https://tsi.com>


1. If you only want to change one or more of the operating parameters shown in Table 4 (above), the easiest way is to use the software utility called **“TSI setup.”** This uses convenient drop-down menus to help change these parameters. After you have made your changes, be sure to click on “Send” to store the changes in the flow meter’s memory.



2. If you want to communicate directly with the flow meter using the basic RS232 commands shown in the ***Serial Command Set Manual***, you can use a terminal program. HyperTerminal[®] program is a common terminal program that is included with most versions of the Microsoft[®] operating system. Setting up HyperTerminal[®] program to communicate with your flow meter can sometimes be confusing. You can download a document from our web site that helps you configure HyperTerminal[®]. Download the document called ***“Using HyperTerminal to communicate with TSI Flow meters.”***
3. If you plan to develop a more sophisticated program for data collection and control using LabVIEW[™] program can download a demonstration program called ***“Real-time Demo Program”*** and the source code ***“Source Code for Real-time Demo Program.”*** This program is intended to be a basic demonstration program and not a practical laboratory tool. It does, however, have a convenient implementation of the VOLUME measurement function that can be useful for basic tests.

Chapter 3

Operation

| | |
|---|--|
|  | CAUTION |
| | TSI® flow meters ARE NOT medical devices under FDA 510k and in no situation should they be utilized for human respiration measurements. |

Overview

The Model 4140/4143 flow meter measures mass flow rate, temperature and absolute pressure of the gas inside the flow tube. All measurements made by the Models 4140/4143 are NIST traceable.

ON/OFF Switch

Slide the switch to the ON position. The power switch is marked in the international symbols 'I' for *on* and 'O' for *off*.

Warm-up Time

The flow meter will provide readings immediately upon power-up. Recommended warm-up time of the flow meter is 5 minutes.

Flow Rate Measurement

Flow rate data can be obtained from the Model 4140/4143 through the LCD display, RS232 serial port, or the linearized analog output. The analog output is a 0 to 10 volt DC linear signal representing 0 to 20 Std L/min. The analog output scaling is user selectable. Refer to the **Series 4000/4100 RS232 Serial Command Set** manual for instructions on how to obtain flow data through the serial port.

Gas calibrations (air, 100% O₂, 100% N₂ or 100% N₂O) can be selected through the RS232 serial port. Refer to the **Series 4000/4100 RS232 Serial Command Set** manual. The LCD display will indicate the calibration being utilized: air, O₂, N₂, or N₂O.

Flow can be displayed in units of standard liters per minute (Std L/min^{*}) or in volumetric units of liters per minute (L/min). Refer to [Appendix B](#) for a description of the two measurements. Selecting

^{*}TSI instruments defines standard conditions as 21.1°C (70° F) and 101.3 kPa (14.7 psia, 1 bar).

between the two measurements is accomplished through the serial port. Refer to the **Series 4000/4100 RS232 Serial Command Set** manual for instructions on how to select between flow units.

The Model 4140/4143 has an independent temperature sensor in the flow tube to measure the gas temperature. The temperature sensor is used for temperature compensation of flow rate and for converting flow from standard to volumetric units. Temperature can also be displayed on the LCD and is available through the RS232 serial port in the units of degrees Celsius (°C).

NOTE: At low flow rates, the temperature inside of the flow tube will increase because of the heat generated by the thermal flow sensor. This effect is normal and the temperature of the incoming gas will be measured once flow resumes.

Pressure Measurement

The Models 4140/4143 measure absolute pressure near the outlet of the flow meter in the SI units of kilo-Pascals (kPa). Pressure measurements are required when converting from standard to volumetric flow. Absolute pressure can be displayed on the LCD and is available through the RS232 serial port.

Select Measurement Displayed

By using RS232 commands the LCD display can be set up to continuously display either flow rate, temperature, or pressure. See the **SDMm** command in the **Series 4000/4100 Serial Command Set** manual.

Display “Scroll” Mode

By using RS232 commands the LCD display can be set up to continuously scroll between flow rate, temperature, and pressure. The scroll rate is adjustable and the user can specify the parameters to be displayed. See the **SDMFTPn** command in the **Series 4000/4100 Serial Command Set** manual.

Volume Measurement

These flow meters measure total volume by integrating flow over time. This is a calculated measurement performed by the flow meter and is only available using the RS232 serial port. Volume is not displayed on the LCD display. Refer to the **Series 4000/4100 RS232 Serial Command Set** manual for instructions on using the volume function.


Chapter 4

Maintenance

Flow Sensor

Periodically inspect the flow sensor by looking into the outlet of the flow meter. Remove dust, particles and fibers from the sensor with clean, dry compressed air. The flow sensor will break if touched.

Never run liquids through the flow meter and never touch the sensor with a brush. Dust or other deposits on the flow sensor will degrade the 4140/4143 flow meter's flow accuracy.

| | |
|---|--|
|  | CAUTION |
| | The flow meter must be switched off for cleaning. Only use clean, dry, compressed air when attempting to remove contamination from the sensor. |

Re-certification

To maintain a high degree of confidence in the measurements made by the Model 4140/4143, TSI® recommends that the instrument be returned to TSI® every 12 months for re-certification. The flow meter will be recalibrated and returned with a certificate of calibration to US National Institute of Standards Technology (NIST) traceable standards. This “annual checkup” assures you of consistently accurate readings; it is especially important in applications where strict calibration records must be maintained.

Cases

If the instrument case or storage case needs cleaning, wipe it off with a soft cloth dipped in isopropyl alcohol or mild detergent. **NEVER** submerge the flow meter or allow liquids to enter the flow tube.

Storage

When storing the flow meter, always cover the ends of flow tubes with the caps provided to prevent dust or other foreign matter from entering the tube.

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Chapter 5

Troubleshooting

Table 5 lists the symptoms, possible causes, and recommended solutions for common problems encountered with Series 4100 flow meters. If the symptom is not listed, or if none of the solutions solves the problem, please contact TSI® Customer Support at 1-800-680-1220 or 651-490-2860.

Table 5. Troubleshooting

| Symptom | Possible Causes | Corrective Action |
|--|--|--|
| No display. | Unit not switched on. | Switch on the unit. |
| | No power to instrument. | Plug in AC adapter or check power source on mini-DIN connector. |
| Temperature reads high at low or zero flows. | Temperature sensor is being heated from the flow sensor. | The temperature value will track the actual gas temperature once the flow rate through the flow meter exceeds 1 Std L/min. |
| Flow readings fluctuate greatly. | The flow is fluctuating. | Improve inlet conditions or increase display averaging time. |
| Display shows flows over-range with no flow passing through flow tube. | The sensor may be damaged or broken. | Return flow meter to TSI® for service . |

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Appendix A

Specifications*

| Flow Measurement | |
|--|--|
| Measurement Range | 0.01 to 20 Std L/min. |
| Accuracy | |
| Air and 100% O ₂ | 2% of reading or .005 Std L/min, whichever is greater, |
| 100% N ₂ | 3% of reading or .010 Std L/min, whichever is greater, |
| 100% N ₂ O | 3% of reading or .010 Std L/min, whichever is greater, |
| (41403 and 41433 only) | Accuracy stated at standard conditions (21.1°C and 101.3 kPa) |
| | See notes 1 through 6 below. |
| Resolution (Display)..... | 0.001 Std L/min between 0.01 and 9 Std L/min 0.01 Std L/min between 9 and 20 Std L/min |
| Response..... | Less than 4 msec, 63% of final value at full scale flow |
| Temperature Measurement | |
| Measurement Range | 0 to 50°C |
| Accuracy | ±1°C, at flows greater than 1 L/min. See note 2 below. |
| Resolution (Display)..... | 0.1°C |
| Response..... | Less than 75 msec, 63% of final value for 20°C step change in temperature at full scale flow |
| Static Pressure Measurement (Measured inside flow tube near the exit) | |
| Measurement Range | 50 to 199 kPa Absolute |
| Accuracy | ±1 kPa, See note 7 below. |
| Resolution (Display)..... | 0.1 kPa |
| Response..... | Less than 4 msec. |
| | 63% of final value for 30 kPa step change |
| Over Pressure..... | 620 kPa |
| Burst Pressure | |
| Tested to 690 kPa without rupture. DO NOT exceed 690 kPa. | |
| Pressure Drop | |
| See Chart. | |

| Volume | |
|---|---|
| Measurement Range | 0.001 to 99.99 Liters |
| Accuracy | |
| Air and 100% O ₂ | 2% of Reading at flows greater than 2.5 Std L/min |
| 100% N ₂ | 3% of Reading at flows greater than 2.5 Std L/min |
| 100% N ₂ O | 3% of Reading at flows greater than 2.5 Std L/min |
| (41403 and 41433 only) | See notes 1 through 5 below. |
| Instrument Temp. Range | |
| Operation, Ambient..... | 0 to 50°C |
| Storage, Ambient..... | -20 to 60°C |
| Gas Calibrations | |
| Air, O ₂ , N ₂ , N ₂ O (41403 and 41433 only), User selectable through serial port | |
| Physical Dimensions | |
| External Dimensions..... | See Diagram |
| Tube Adapters | Model 4140/41403: 0.25 inch O.D. straight Model 4143/41433: 0.375 inch O.D. straight |
| (Inlet & Outlet) | |
| Weight | 86 grams |
| Flow Body Material | Polycarbonate |
| Mounting Threads..... | 6-32, 0.25 in. (6 mm) |
| Computer Interface | |
| Connector | 8 pin mini-DIN |
| Type | RS232 Serial |
| Baud Rate | 38,400 |
| Data Bits..... | 8 |
| Parity | None |
| Stop Bits | 1 |
| Flow Control | None |
| Analog Output (Flow Only) | |
| Range..... | 0 to 10 V |
| Resolution | 13 bit |
| Maximum Current | 5 ma |
| Flow Accuracy | See note 6 below. |
| Power | |
| AC adapter or power supplied through mini-DIN 7.5 VDC ± 1.5 V, 300 mA maximum | |

NOTES:

- 1 Accuracy stated at standard conditions of 21.1°C and 101.3 kPa.
 - Add an additional 0.0003 Std L/min or 0.075% of reading, whichever is greater, per 1°C away from standard conditions when operating within the range of 0°C to 50°C.
 - Add an additional 0.015% of reading per 1 kPa above 101.3 kPa or
 - Add an additional 0.022% of reading per 1 kPa below 101.3 kPa when operating within the pressure range of 70 kPa to 101.3 kPa.
- 2 Accuracy stated with gas temperature and flow body temperature within $\pm 10^\circ\text{C}$ of one another.
- 3 Accuracy stated measuring dry gas (less than 10% R.H.).
- 4 Includes $\pm 0.5\%$ of reading repeatability.
- 5 Volumetric flow rate is calculated from the mass flow measurement. Add an additional 0.25% of reading to the flow accuracy to account for the uncertainty in measuring gas temperature and pressure.
- 6 For analog output, accuracy offset increases from 0.005 to .02 Std L/min.
- 7 Add uncertainty of 0.2 kPa for every 10°C away from 21.1°C.

**Specifications subject to change without notice.*

(continued on next page)

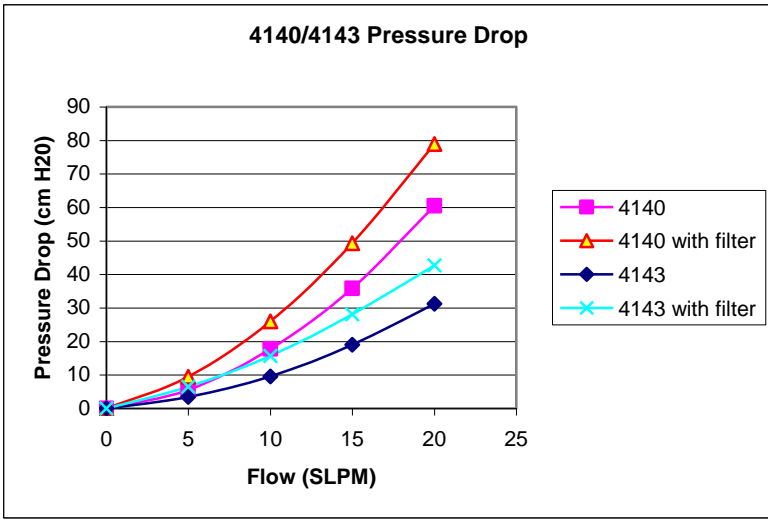


Figure A-1 Pressure Drop

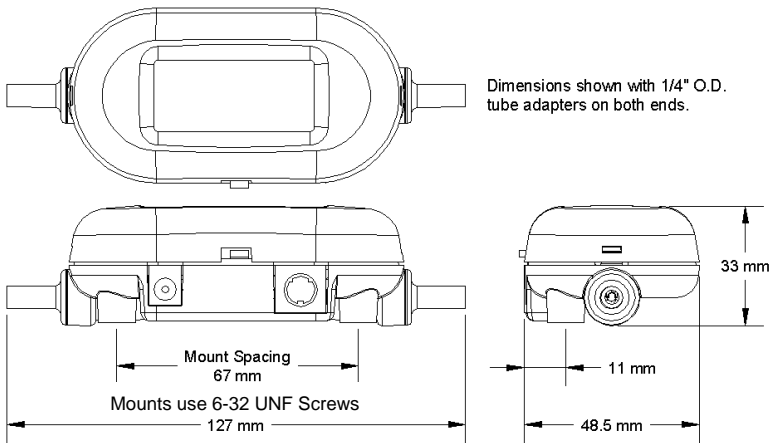


Figure A-2 Model 4140/4143 Dimensions

Appendix B

Standard Flow Rate vs. Volumetric Flow Rate

Since thermal flow sensors are sensitive to changes in air density and air velocity, all thermal flow meters indicate flow rates with reference to a set of standard conditions. For TSI® instruments, standard conditions are defined as 21.1° C (70° F) and 101.3 kPa (14.7 psia). Other manufacturers may use different values.

Standard flow rate is the flow rate the air would be moving if the temperature and pressure were at standard conditions. It is usually the most useful measure of airflow because it defines the heat-carrying capacity of the air.

Volumetric flow rate is the true volume flow of the gas exiting the flow meter.

In some instances, volumetric flow rate rather than standard flow rate may be of interest. To display volumetric flow rate, the Model 4140/4143 will multiply the standard flow measurement by the following density correction factor:

$$\text{VolumetricFlow} = (\text{Standard Flow}) \left[\frac{273.15 + T_m}{273.15 + 21.11} \right] \frac{101.3}{P_m}$$

Where

T_m = Gas temperature measured in flow tube in units of degrees Celsius

P_m = Absolute pressure measured in flow tube in units of kPa

To demonstrate the difference in output, consider the following.

Measured flow displays 10 Std L/min at 15C and 117kPa. The volumetric flow as calculated by the Model 4140/4143 would be as follows.

$$\text{VolumetricFlow} = (10) \left[\frac{273.15 + 15}{273.15 + 21.11} \right] \frac{101.3}{117} = 8.478 \text{ L / min}$$

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Appendix C

Optimal Use of the 4000/4100 Series Analog Out Capability

Introduction

TSI® Incorporated's 4000/4100 series flow meters have a feature that allows you to determine the flow rate based on a 0-10 Volt Analog out signal. This feature has programmable options that can improve its use accuracy.

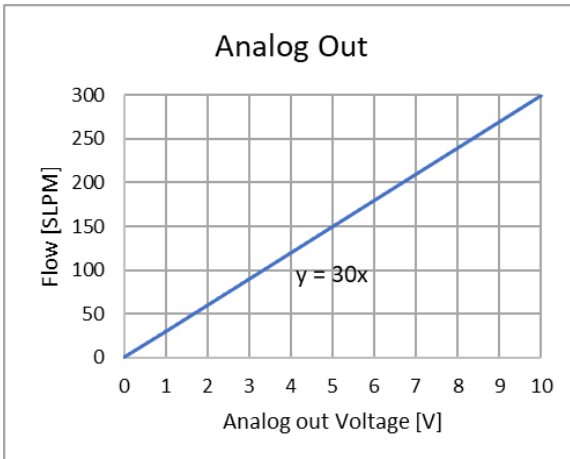
Function of the Analog Out Feature

The 4000/4100 series meter has an analog out circuit that outputs a voltage signal that is linearly proportional to the flow measurement displayed on the front screen. The voltage signal has a 0-10 volt range. This output is configurable so the user can change the voltage output at zero flow and at the span flow.

The factory defaults for the analog out are as follows:

- 0 volts at zero flow
- 10 volts at span flow (300 SLPM for 4000 Series meters, 20 SLPM for 4100 Series meters)

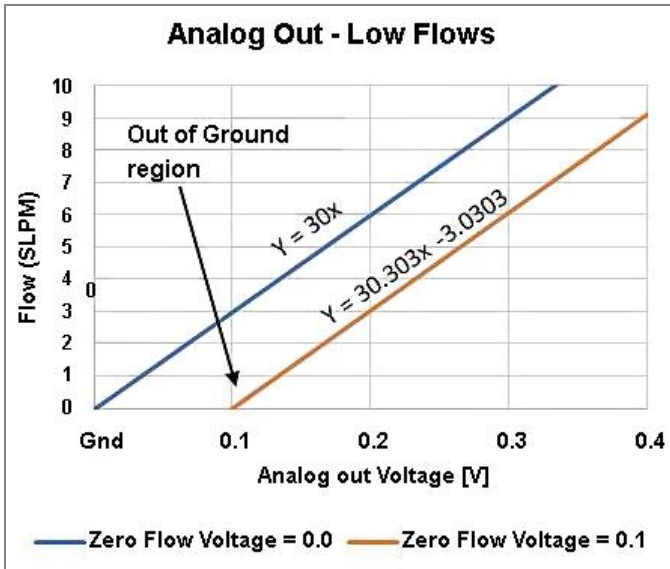
The graph below shows the factor default relationship. This relationship results in an easy conversion from voltage to flow.



Considerations When Needing to Read Zero and Low Flow Accurately

If the application requires accurate flow measurement at or near zero flows then it is recommended that the zero flow voltage be changed from its factory default of 0 volts to 100 mV. This is due to noise and slight offset of the ground voltage that could be interpreted as a low-level flow.

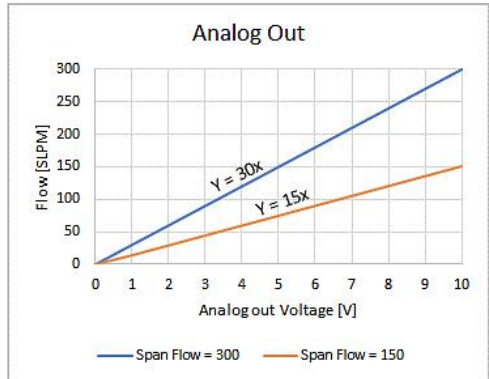
By setting 100 mV (0.1 V) to be the zero-flow voltage, this gets out of the region around 0 volts (ground) where noise and a slight offset can shift the reading. The graphic below shows the change in zero voltage to move out of the ground region.



NOTE: The conversion equation changes if the zero is change to 100 mV.

Considerations for Setting the Span Flow Voltage

If the application does not require the flow meter to read up to its span flow then it is recommended that the analog span be set to the maximum limit that is required by the application. This will make for a better voltage to flow conversion due to more resolution per change in measured flow. The



graphic compares examples with a span flow set to 300 SLPM (factory default for 4000 Series meters) and a 150 SLPM example.

For the factor default settings, each 1 SLPM change in flow will cause a 0.0333 change in voltage. If the application allows for the setting of 150 SLPM span, then for each 1 SLPM change in flow will cause a 0.0666 change in voltage. This will allow the voltage measurement device employed by the customer to be less precise.

Process for Changing the Analog Zero and Span

The TSI® setup program, provided free of charge, makes changing the analog zero and span easy. The graphic below shows where to enter the analog zero and span in the TSI® setup program.

The screenshot shows the TSIsetup application window. The 'Analog Span (L/min)' and 'Analog Zero (mV)' input fields are highlighted with a pink rectangular box. The interface includes various configuration options and control buttons.

Reference the instrument manual for more details on how to use the TSI® setup program.



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