ALICAT SCIENTIFIC

A Halma company

OPERATING MANUAL

DIGITAL MASS FLOW CONTROLLERS

BC-Series

Thank you for purchasing your OEM Mass Flow Controllers.

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This device comes with a NIST traceable calibration certificate.

This device conforms to the European Union's Restriction of Use of Hazardous Substances in Electrical and Electronic Equipment (RoHS) Directive 2011/65/EU.

This device complies with the requirements of the Low Voltage Directive 2014/35/EU and the EMC Directive 2014/30/EU and carries the CE Marking accordingly.

This device complies with the requirements of the European Union's Waste Electrical & Electronic Equipment (WEEE) Directive 2002/96/EC

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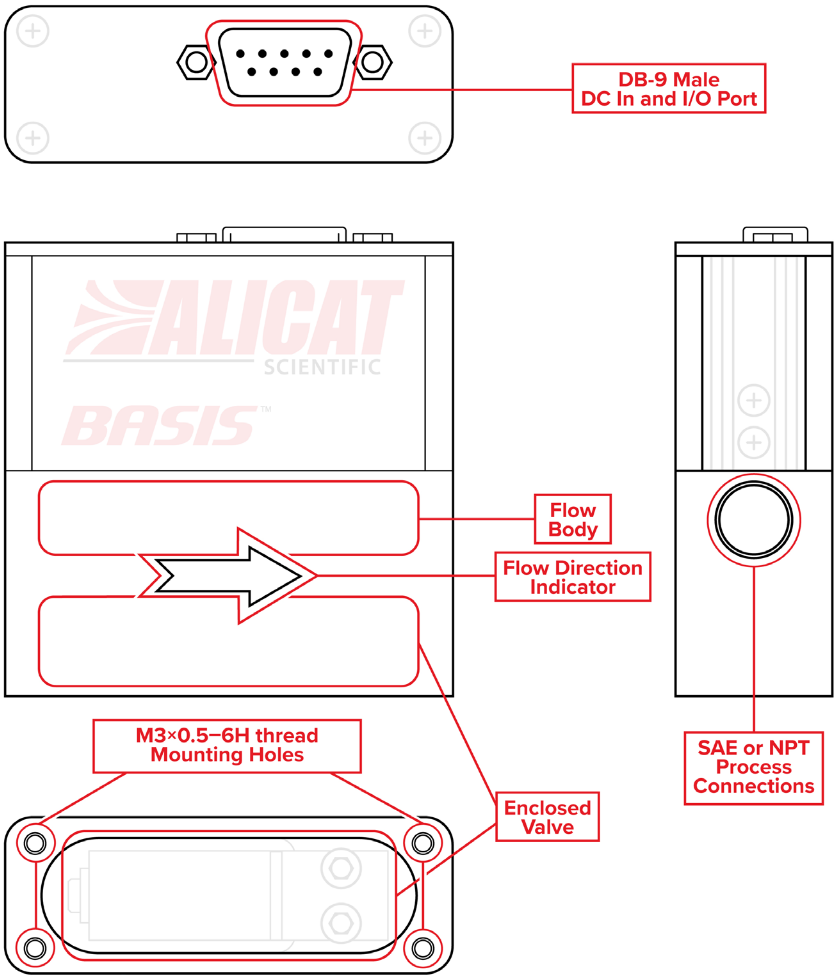
Contents

Getting Started

Mounting

No straight runs of pipe are required upstream or downstream of the flow controller. BASIS (BC-Series) Mass Flow Controllers have mounting holes on the bottom for convenient mounting to flat panels. The thread size of these holes is M3. These controllers are position insensitive and can be mounted in any orientation.



Plumbing

Process Ports

Your instrument is shipped with plastic plugs fitted in the port openings. To lessen the chance of contaminating the flow stream do not remove these plugs until you are ready to install the device.

- If you are using a fitting that does not have a face seal, use thread-sealing Teflon tape to prevent leakage around the port threads, but do not wrap the first two threads. This will minimize the possibility of getting tape into the flow stream and flow body.
- If you are using a fitting that has a face seal, there is no need to apply Teflon tape to the threads.

! *Warning: Do not use pipe dopes or sealants on the process connections, as these compounds can cause permanent damage to the controller should they get into the flow stream.*

When changing fittings, carefully clean any tape or debris from the port connections.

Maximum Pressure

Using the flow controller above the maximum specified internal line pressure will result in permanent damage to the internal sensors. If the line pressure is above this, please use a pressure regulator upstream of the flow controller to reduce the pressure to below the maximum internal pressure. See the chart below for pressure limits.

Model	Max Common Mode Pressure
BC-C0100	145 PSIG
BC-C1000	145 PSIG
BC-L0020	60 PSIG

Flow Controller Operation

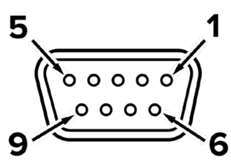
Your flow controller can measure and control flow generated by positive pressure and/or suction. Connect the controller so that the flow travels in the same direction as the flow arrow, from left to right, as you look at the front of the device.

Alicat Scientific BC-Series Mass Flow Controllers incorporate a digital sensor with a single control valve and circuitry. The integrated control algorithm measures the mass flow, compares it with the setpoint, and adjusts the valve accordingly at 400 times per second.

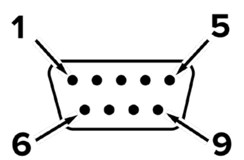
The response time of the system will depend on the operating conditions and the PID tuning of the device.

Power and Signal Connections

Power must be supplied through the 9-pin D-Sub connector located on top of your BASIS device. BASIS controllers require a power supply capable of delivering 10–30 Vdc at 200 mA.



Female Connector



Male Connector

Pin	Function	Cable
1	Not Connected	Black
2	Not Connected	Brown
3	Serial RS-232 RX / RS-485 B Input Signal (receive)	Red
4	0–5 Vdc Analog Setpoint Input	White
5	Serial RS-232 TX / RS-485 A Output Signal (send)	Yellow
6	0–5 Vdc Analog Output Signal	Green
7	Power In (as described above)	Blue
8	Ground (common for power, digital communications, and analog signals)	Orange
9	Ground (common for power, digital communications, and analog signals)	Orange

Caution: Do not apply power to pins 3, 4, 5, or 6. Permanent damage can occur.

RS-232 or RS-485 Digital Signals

To use the RS-232 or RS-485 input signal, connect the RS-232 / RS-485 Output Signal (Pin 5), the RS-232 / RS-485 Input Signal (Pin 3), and Ground (Pin 8) to your computer serial port as shown below.

9-Pin Serial Connection		9-Pin Alicat Connection	
Pin	**Function**	**Pin**	**Function**
5	Ground	**8**	Ground
3	Transmit	**3**	Receive
2	Receive	**5**	Transmit

Analog Signals

These devices include a primary analog output signal, which is 0–5 Vdc and linear over its entire range. A zero-flow condition is indicated at approximately 0.010 Vdc and full scale flow is indicated at 5.0 Vdc. The output voltage is linear over its entire range. Ground for this signal is common on pin 8.

Serial Communication

The device supports both ASCII-based serial commands and Modbus/RTU IO over either a RS-232 or RS-485 serial port. The supported physical serial protocol will be specified in the device model number. Connecting your flow controller to a computer allows you to log the data that it generates. This section of the manual shows you how to operate the flow controller using ASCII commands.

Establishing Communications

After connecting your flow controller using a communications cable, you will need to establish serial communications through a real or virtual COM port on your computer or programmable logic computer (PLC).

- If you have connected your device to a serial port, note its COM port number. This can be found in Windows® Device Manager.
- If you have a serial to USB adapter, plug it into your computer, ensure the proper driver is installed, and note the COM port number.
- The controller will be configured with the following settings:
  - **Baud:** 38400 (default; others can be used if the computer, its software and the controller are set for the same rate)
  - **Data bits:** 8
  - **Parity:** None
  - **Stop bits:** 1
  - **Flow control:** None

Alicat devices use ASCII commands which are easily used in a serial terminal or integrated into a PLC.

✓ ***Note**: In what follows, ↵ indicates an ASCII carriage return (decimal 13, hexadecimal D). Serial commands are not case-sensitive.*

Serial Terminal Application

Alicat's proprietary Serial Terminal is a preconfigured program for serial communications that functions much like Windows' old HyperTerminal program. Download Serial Terminal at alicat.com/drivers for free. Once downloaded, simply run SerialTerminal.exe. Enter the COM port number to which your device is connected and the baud rate of the flow controller. The default baud rate is 38400.

✓ ***Note***: *Some features of the serial terminal, such as the dump all command, are not available for BASIS devices. All serial commands specified in this manual will function as intended.*

Unit ID and Modbus ID

The device is addressed with a single letter unit ID from A through Z, with A being the default. All serial commands must be preceded by the unit ID, and followed by a carriage return ↵ before they take effect. The * character will address all devices on the serial line and can be used to query the unit ID, if it is unknown. This should only be used if a single device is connected, otherwise the responses will be corrupted from multiple devices trying to write at the same time.

You can change the unit ID by typing:

Change the unit ID:	`[current unit ID]`**`@=`**`[desired unit ID]`↵
Example:	**`a@=b`**↵ (changes unit A to unit B)

! *Warning: Care should be taken not to assign the same unit ID to more than one device on a single COM port.*

This device supports the Modbus/RTU device address from 1–247, and this is separate from the unit ID. The factory default Modbus ID is 1.

You can read and change the Modbus ID by typing:

Read the Modbus ID:	`[unit ID]`**`rm`**↵
Example:	**`arm`**↵ (reads Modbus ID on unit A)
Change the Modbus ID:	`[unit ID]`**`wm=`**`[desired Modbus ID]`↵
Example:	**`awm=7`**↵ (changes Modbus ID to 7 on unit A)

✓ ***Note***: *When changing to a new Modbus ID, any values above the maximum of 247 will result in the ID changing to 1.*

Changing the Baud Rate

BASIS units can communicate over bauds rates of 4800, 9600, 19200, 38400, 57600, or 115200. 38400 is the default baud rate.

You can read the current baud rate as well as change it by typing:

Read the baud rate:	`[unit ID]`**`rb`**↵
Example:	**`arb`**↵ (reads baud rate on unit A)
Change the baud rate:	`[unit ID]`**`wb=`**`[desired baud rate, see table]`↵
Example:	**`awb=2`**↵ (changes baud rate on unit A to 19200)

Value	Corresponding Baud Rate
0	4800
1	9600
2	19200
3	38400
4	57600
5	115200

***Note**: When changing the device's baud rate, your COM port must change its own baud rate in time to successfully receive the response confirming the new baud rate. If it does not, then the baud rate will change on the device, but the response from the serial terminal will be incomprehensible. Since the serial terminal is set to communicate at a specific baud rate during the initial configuration, you will have to redefine the terminal baud rate to continue communications. This can be done using the baud [value]↵ command, where [value] equals the baud rate.*

Taring

Before collecting data, be sure to tare your flow controller. If auto-tare is enabled, this can be accomplished by providing a setpoint of zero for at least 2 seconds. Taring flow sets the zero-flow reading and must be done when no flow is passing through the flow controller:

Tare Flow: `[unit ID]`**`v`**↵

Example: **`av`**↵ (sets flow reading to zero)

To determine if auto-tare is enabled, use the following command:

Read auto-tare setting: `[unit ID]`**`re`**↵

Example: **`are`**↵

The response from the controller will be **`ENABLE=value`**, where a value of **`0`** indicates that auto-tare is disabled, and a value of **`1`** indicates that auto-tare is enabled. If auto-tare is disabled, then you can enable it using the following command:

Enable auto-tare: `[unit ID]`**`we=1`**↵

Example: **`awe=1`**↵ (turn on auto-tare on unit A)

Likewise, auto-tare can be disabled by using the same command but replacing the **`1`** with a **`0`**.

Collecting Flow Data

The unit measures flow normally, but will only output data when it is polled. Polling the flow controller returns a single line of data each time you request it. To poll the flow controller, simply enter its unit ID.

Poll the device: `[unit ID]`↵

Example: **`a`**↵ (polls units A)

Whenever you enter this command, a line of data will appear in the following format:

`A`	**`32.1C`**	**`0454.2SCCM`**	**`0454.0SP`**	**`Air`**
Unit ID	Temperature	Standard (Mass) Flow	Setpoint	Gas

If the device is in exhaust mode, an additional column with an EXH status code will be present to the right of the gas label column.

Commanding a New Setpoint

Before attempting to send setpoints to your BASIS flow controller serially, confirm that it's configured to receive serial setpoints. If not, the device will respond with **`SETPOINT SOURCE IS ANALOG`**. This can be done by typing:

Read setpoint source: `[unit ID]`**`rs`**↵

Example: **`ars`**↵ (reads setpoint source on unit A)

Change setpoint source: `[unit ID]`**`rs=`**`[desired setpoint source, see table]`↵

Example: **`aws=A`**↵
(setpoint source on unit A changed to unsaved serial)

Valid Values	Meaning
A	0–5 Vdc analog input
D	Digital serial value saved to flash
U	Digital serial value not saved to flash

If a digital setpoint is saved to the flash, it will be restored after a power cycle of the device. The default power-up setpoint is zero. If a non-zero power-up setpoint is desired, this can be set by giving a setpoint while the setpoint source is saved to the flash, and then changing the setpoint source to unsaved.

! *Warning: If you are frequently changing the setpoint as part of your system, you can quickly wear out the flash memory. If your process is like this, it is highly recommended to not save the serial value to the flash.*

Sending Setpoints as Floating Point Numbers

This is how to send the desired setpoint value as a floating point number:

New setpoint: `[unit ID]s[floating point number setpoint]`↵

Example: **`as50`**↵ (setpoint of 50.0 SCCM)

Sending Setpoints as Integers

In this method, your controller's full scale range (FS) is represented by a value of 4000, and a zero setpoint is represented by 0. To calculate your intended setpoint, use the following formula:

Integer value = 4000 × `[desired setpoint]/[device FS]`

Example: A desired setpoint of +760 SCCM on a 1000-SCCM BASIS mass flow controller with unit ID A is calculated as 4000 x 760/1000 = **3040**. The command to assign a setpoint based on this integer value is:

New setpoint: `[unit ID][setpoint as integer where 4000 is FS]`↵

Example: **`a3040`**↵ (setpoint of 760 SCCM)

If you don't know your device's full scale range, you can find out by typing the following command:

Query Full Scale: `[unit ID]`f↵

Example: **`af`**↵ (query full scale on unit A)

Creating a Setpoint Watchdog

A setpoint watchdog is a communication watchdog timeout which is user-settable. If no serial communication is received by the device after an amount of chosen time, the device will force a zero setpoint and close its valve. The time is set in milliseconds, and valid values are 0–5000. The commands to set a watchdog and read the current watchdog are as follows:

Read current watchdog: `[unit ID]`rw↵

Example: **`arw`**↵ (read watchdog time on unit A)

Set a new watchdog: `[unit ID]`ww=`[new watchdog time, ms]`↵

Example: **`aww=10`**↵ (create watchdog with 10 ms timeout)

✓ ***Note**: The setpoint source must be unsaved digital serial value for the setpoint watchdog to take effect. If the setpoint source is saved digital serial value, then the watchdog value can be read and written, but it will not take effect.*

Flow Averaging

Flow averaging governs how the flow sensor reports its data. The higher the flow averaging setting, the greater a smoothing effect will be applied. This is most useful on rapidly-fluctuating flow readings. Allowed values are integers from 0–9, which correspond to the following settings:

Setting	0	1	2	3	4	5	6	7	8	9
Averaging (ms)	0	5	10	20	40	80	160	320	640	1280

Read current averaging: `[unit ID]ra↵`

Example: **`ara↵`** (read averaging on unit A)

Set new averaging values: `[unit ID]wa=[integer value]↵`

Example: **`awa=5↵`**
(set averaging on unit A to 80 ms)

Changing the Gas

BASIS units calibrated with air have built-in correction equations that allow flow with up to 8 different gases. To reconfigure your flow controller to flow a different gas, look up its Gas Number in the table below. Then type:

Change the gas: `[unit ID]g[gas number]↵`

Example 1: **`ag2↵`** (reconfigures to flow CO_2)

Example 2: **`ag6↵`** (reconfigures to flow H_2)

✓ ***Note**: BASIS units with a 1000 SCCM full scale that are calibrated to carbon dioxide or nitrous oxide are limited to a maximum flow rate of 750 SCCM instead of 1000 SCCM due to the correction factor equations used for these gases.*

Gas Number	0	1	2	3	4	5	6	7
Gas (long name)	Air	Argon	Carbon Dioxide	Nitrogen	Oxygen	Nitrous Oxide	Hydrogen	Helium
Gas (short name)	Air	Ar	CO2	N2	O2	N2O	H2	He

✓ ***Note**: Units that are calibrated with Hydrogen or Helium can only function with that gas.*

PID Tuning

Your flow controller uses a closed-loop algorithm to determine how to actuate its valve in order to achieve the commanded setpoint. We have tuned these settings to work for most operating conditions, but sometimes your process requires on-site adjustments to maintain optimal control performance. If you encounter issues with control stability, oscillation, or speed of response, fine-tuning your closed-loop control may help.

Changing Gain Values

Before you begin any PID tuning, it's a good idea to write down your current values so you can return to the factory settings if necessary:

Read I value:	`[unit ID]`ry↵
Example:	**`ary`**↵ (read current I value on unit A)
Read P value:	`[unit ID]`rx↵
Example:	**`arx`**↵ (read current P value on unit A)

To write new I and P values to the controller, type:

Change I value:	`[unit ID]`wy=`[desired I value]`↵
Example:	**`awy=150`**↵ (change I value to 150 on unit A)
Change P value:	`[unit ID]`wx=`[desired P value]`↵
Example:	**`awx=450`**↵ (change P value to 450 on unit A)

Tuning the PDF Control Algorithm

Alicat's control algorithm employs pseudo-derivative feedback (PDF) control, which uses two editable variables:

• The larger the integral (I) gain, the faster the controller will correct for offsets based on the size of the errors and amount of time they have occurred.

• The larger the proportional (P) gain, the slower the controller will correct errors between the commanded setpoint and the measured process value.

Troubleshooting Valve Performance with PID Tuning

The following issues can often be resolved by adjusting the PID gain values for your flow controller.

Fast oscillation around setpoint / Overshooting setpoint

- Reduce the integral gain in decrements of 10%.

Delayed or unattained setpoint

- Increase the integral gain in increments of 10%, and then decrease the P gain by small amounts to fine-tune.

✓ ***Note****: Valve tuning can be complex. Please give us a call, and we'll be happy to guide you through the process.* *See page 2.*

Quick Command Guide

✓ ***Note**: Serial commands are not case-sensitive. For simplicity, we assume that the unit ID of the flow controller when not streaming is **a** in the listing that follows.*

Change unit ID:	`a@=[desired unit ID]↵`
Change Modbus ID:	`awm=[desired Modbus ID]↵`
Change baud rate:	`awb=[baud rate, see page 10]↵`
Poll the live data frame:	`a↵`
Tare flow:	`av↵`
Flow averaging:	`awa=[value, see page 14] ↵`
Set setpoint source:	`aws=[setpoint source, see page 12]↵`
New setpoint:	`as[setpoint as floating point #]↵`
New setpoint:	`a[setpoint as integer where 4000 is full scale]↵`
Query full scale:	`af↵`
Create setpoint watchdog:	`aww=[desired watchdog time in ms]↵`
Change the gas:	`ag[gas number, see table on page 14]↵`
Exhaust*:	`ae↵`
Cancel exhaust:	`ac↵`
Firmware version:	`arv↵`
Serial number:	`arn↵`
Change I Gain:	`awy=[desired gain value]↵`
Change P Gain:	`awx=[desired gain value]↵`

* *When the valve is in exhaust mode, the EXH status code will appear to the right of the gas in the data frame whenever the device is polled.*

If you have need of more advanced serial communication commands, please contact support (page 2).

Modbus/RTU Communication

All BASIS devices support input and output using the Modbus/RTU protocol. The following Modbus commands are supported:

Function Code	Function
3	Read holding register
6	Write single register
16	Write multiple registers

***Note**: All function codes and registers listed in this manual are base 10.*

Modbus Registers

BASIS devices use the Modbus PLC numbering convention such that all registers begin at index 0. The table below lists the data addresses of each holder register, where the register number is offset by 1 from the address. For example, holding register 1 will have a data address of zero.

All 32-bit values are handled in consecutive Modbus registers in big-endian format. This means bits 31:16 are in the lower numbered Modbus register and bits 15:0 are in the higher register. All floating-point values are IEEE 32-bit floats.

***Note**: All values are unsigned shorts (2-bytes), unless otherwise specified.*

***Note**: Many addresses on the table on page 19 are applicable only to BASIS firmware greater than 2.4.0. If you have an older BASIS unit, please contact Alicat for information on legacy data addresses.*

Configuration Registers

Data Address	Access	Description
21	R/W	The baud rate. See baud table on page 10 for valid values.
25	R	The firmware version. This is encoded as 256 × a + 16 × b + c where the version is Va.b.c. For example, V2.1.3 would read as 2 × 256 + 1 × 16 + 3 = 531.
26–31	R	The serial number. This is a string of characters, with two characters per register.
39	W	Perform a tare. To do this, write 43605 (0xAA55) to this register.
40	R/W	The time constant for flow averaging, as an integer from 0–9. Time (ms) ≈ $2.5 \times 2^{(value)}$
45	R/W	Modbus Device ID (1–247)
46	R/W	Serial unit ID in ASCII (e.g. A=65)
47–48	R	The full scale of the device (4-byte unsigned integer) in current engineering units. The full scale can be calculated using: Full Scale = value/1000
49	R	The flow engineering units 0: SCCM 1: SLPM
52	R/W	The STP temperature. Valid values are 0–3000 (0–30°C) STP Temperature (°C) = value / 100
512	R/W	Exhaust mode 0: Valve under PD control 1: Valve in full-open exhaust
513	R/W	Exhaust valve-drive percentage Valve-drive is an integer such that 0 is fully closed and 10000 is full open. Only applicable if the valve is in exhaust mode.
514	R/W	The setpoint watchdog (0–5000) in milliseconds. If zero, then the watchdog is disabled.
516	R/W	Setpoint source 0: Analog input 1: Digital serial value saved to flash 2: Digital serial value not saved to flash
519	R/W	The proportional (P) gain value as an integer (0–65534)
520	R/W	The integral (I) gain value as an integer (0–65534)

Data Registers

Data Address	Access	Description
2048	R/W	The currently selected gas, returned as the gas number. See gas table on page 14 to view available gases.
2049	R	Temperature in degrees Celsius. Value is presented as hundredths of a degree. For example, 2850 = 28.5°C
2050–2051	R	Current mass flow rate (4-byte signed integer) in flow units. Register 2050 is the MSB (31:16), register 2051 is the LSB (15:0). The mass flow can be calculated using the following formula: Flow = value/1000
2052	R	The instantaneous valve drive. The valve drive indicates by how much the valve is open. Valve drive (%) = value/100
2053–2054	R/W	Setpoint (4-byte signed integer) in flow units. The setpoint can be calculated as: Setpoint = value/1000. The setpoint is updated when the lower register is written.

Maintenance

Cleaning

This device requires minimal maintenance. If necessary, the outside of the device can be cleaned with a soft dry cloth. Avoid excess moisture or solvents.

The single most important thing that affects the life and accuracy of these devices is the quality of the gas being measured. The instruments are designed to measure clean, dry, non-corrosive gases.

Recalibration

The BASIS series is an OEM product calibrated to NIST traceable standards at the time of manufacture. As an OEM device, there is not a factory recommended periodic recalibration cycle. Recalibration can be requested at the user's discretion/requirement. A recalibration can be requested with your serial number at alicat.com/service.

For repair, recalibration, or recycling of this product contact us (page 2).

Technical Specifications and Dimensional Drawings

Please visit alicat.com/specs to find complete operating specifications and dimensional drawings.