RS485 Modbus RTU Supplemental Manual

GC Series
Mass Flow Controllers

BROOKS® INSTRUMENT

Beyond Measure

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Introduction

The GC Series of Mass Flow Controllers from Brooks Instrument® utilizes the Modbus RTU protocol over RS-485, offering a robust and standardized method of digital communication. This protocol provides a reliable, transaction-oriented service between a master device—such as a PLC, DCS, or PC—and one or more GC Series instruments. Modbus RTU allows a centralized controller to acquire real-time process data (e.g., flow rate, temperature, valve status) and, for controller models, to transmit setpoint values and configuration parameters.

Unlike proprietary or hybrid protocols, the GC Series follows the standard Modbus RTU register-based architecture, supporting both read and write access to a wide array of operational, calibration, and diagnostic parameters. The implementation includes a comprehensive register map, covering device identity, gas properties, control loop settings, and user-defined configuration options.

Refer to the device specification and IOM manuals for more information.

Device Configuration

All Brooks® GC Series devices come standard with an RS-485 Modbus RTU communication interface. No hardware setup or jumper configuration is required for communication. Each unit is preconfigured from the factory with the following default settings:

- **Baud Rate:** 38400
- **Modbus Address:** 1

These parameters can be reconfigured via Modbus registers (0x0082 for baud rate and 0x0081 for address) to suit system requirements.

Wiring

The GC Series RS485 is a multidrop Modbus connection. It allows a maximum of 10 devices devices to be connected to a computer system (for multi-device networks, custom cabling required – contact Brooks Instrument Customer Service for support). Personal computers are not equipped with RS485 ports as standard. An RS232/USB to RS485 converter or RS485 interface board is therefore required to connect an RS485 network to a standard personal computer. An adapter can be purchased to power the device with simultaneous connection to PC via USB for 1 device. Brooks Instrument offers such an adapter – part number 778Z024AAA. The GC Series BCAT Adapter is designed to power a single GC device while enabling seamless data transmission between the device and a computer. It includes a 110V AC power supply, a USB cable, and a 9-pin D-sub connector for reliable connectivity. Specific driver software is required to be installed for this device.

Protocol

The GC series utilizes the Modbus RTU protocol for communications. The Modbus RTU protocol is a de facto standard maintained by the Modbus Organization. The protocol syntax is not covered here.

PLC (Programmable Logic Controller)

A PLC is an industrial digital computer used to automate electromechanical processes, such as control of machinery on factory assembly lines. It is designed for real-time control and can be programmed to perform a wide range of tasks using input/output signals.

DCS (Distributed Control System)

A DCS is a control system used in industrial processes where control functions are distributed throughout the system rather than centralized. It integrates multiple controllers and field devices to manage complex processes, offering high reliability and scalability.

MFC (Mass Flow Controller)

An MFC is a device used to measure and control the flow of gases or liquids in a precise and repeatable manner. It is commonly used in applications requiring accurate flow regulation, such as semiconductor manufacturing, chemical processing, and laboratory research.

Address

The unique numeric device ID assigned to the MFC, used by a PLC or host computer to communicate over RS-485. Functions like a network address. All GC devices are shipped from the factory with the address set to 1 by default. To connect multiple devices in the same network, each device in the network must have a unique address. The address can be changed via a register as specified below. Valid addresses are 1 to 247 except 157.

Serial Number

A permanent, read-only identifier embedded in the device. Used for traceability, technical support, and retrieving calibration records.

Flow Rate

The current gas flow measured by the MFC. Expressed in device units (sccm), scaled ×1000 for enhanced decimal precision.

Gas Temperature

The real-time temperature of the gas flowing through the device. Crucial for accurate thermal mass flow measurements.

Baud Rate

Defines the communication speed over RS-485. This setting must match the PLC or host system for reliable data exchange. All GC devices are shipped from the factory with the baud rate set to 38400 by default, but it can be changed via a register as specified below.

Gas Correction Factor (GCF)

Devices are configured based on the customer-selected gas at the time of ordering. All devices are calibrated using either air or CO_2. Users may change the device to operate on a different gas by setting the appropriate gas correction factor. The gas correction factor corresponds to the value in the register divided by 1000. Reference the IOM manual for more details about GCF.

Filter Depth

Applies signal averaging to reduce noise in flow readings. A higher setting smooths output but reduces response speed. 0-9 settable. Sets the number of samples to average in 2^x, where x is the value. Factory default is 3.

Setpoint Source

Selects the control input method:

- 0 = Analog (voltage or current)
- 1 = Digital (Modbus command)

Setpoint (Ratio)

Defines flow command as a percentage of full scale. A value of 32000 represents 50% of full scale (32000 ÷ 64000).

Setpoint (Read-Only)

Shows the commanded setpoint in device flow units (e.g., sccm), useful for monitoring and validation. Flow rate in Device Units * 1000.

Valve Preload Offset

Sets the baseline opening valve position to improve control responsiveness, especially at low flows or startup.

Exhaust Mode

Switches the MFC into alternate operating states such as open-loop control or purge for maintenance, leak testing, or shutdown.

Exhaust Value

Determines the valve position (in % ×100) when in exhaust mode. Used to control purge rates during open-loop operation.

Valve Status

Indicates the current valve drive signal (0–65535), reflecting the valve's opening effort in either control mode.

Offset Calibration

Command to zero the flow sensor. Instructs the device to treat the current (no-flow) condition as zero.

Offset Calibration Value

The stored offset value subtracted from the raw ADC signal. Helps with diagnostics and zero verification.

Write Protection

Prevents unintentional changes to sensitive parameters. Write protection must be disabled to modify key registers.

ADC Value

The raw analog-to-digital converter (ADC) reading, post-offset. Used for deep diagnostics or factory calibration.

Calibration Write Protection

Protects the internal calibration table. Calibration write protection must be explicitly unlocked with a secure key to permit certain calibration changes.

Calibration Table

Device’s internal lookup table that maps raw sensor values to flow. Configured during production and rarely modified directly in the field.

DUT Calibration Info

Describes calibration structure: compression factor, number of data frames, and frame length. Used in calibration tooling.

Unit Full Scale

Defines the full-scale flow rate in engineering units ×1000 (e.g., 500000 = 500 SLPM). Critical for interpreting flow and setpoint values.

Device Units

Specifies engineering unit format:

- 8 = sccm

Write protection must be disabled to change.

Model Code

Describes the complete device configuration (e.g., gas, flow range, I/O type). Used for service, spares, or replacement. Up to 32 characters (16 registers) in length. Reference the device specification document for the full model code format.

Set Model Code

Used to write or update the model code.

Firmware Version

Current firmware version, formatted as 0.abc, where each letter represents a revision digit.

Gas Used for Calibration (Read-Only)

Identifies the factory calibration gas (e.g., H_2, He). Immutable without recalibration. Semi gas code (SEMI E52-0703).

Gas Used for Calibration (Read/Write)

Allows authorized users to update the calibration gas code, typically during dual-gas setups or rework. Semi gas code (SEMI E52-0703).

Minimum Analog Value

The analog input value representing 0% setpoint.

- Voltage: in mV (e.g., 1000 = 1V)
- Current: in 0.01 mA (e.g., 400 = 4 mA)

Maximum Analog Value

The analog input value representing 100% setpoint.

- Voltage: in mV (e.g., 5000 = 5V)
- Current: in 0.01 mA (e.g., 2000 = 20 mA)

Bin Size

Categorizes the hardware's flow capacity. Internally used to apply correct scaling and calibration.

Heater Drive Circuit Value

Controls heater intensity based on gas properties.

- Typical: 90 for N_2/Air, 60 for H_2/He

Current Amplification Factor

Amplifies sensor signal for low-mass gases.

- Typical: 32 for N_2/Air, 128 for H_2/He

Gas Calibration Temperature

Sets the temperature during gas calibration. Write 0xAA55 to update with current temp.

PD Control I Gain

Defines how aggressively the controller reacts to flow errors. Higher values improve response speed.

PD Control P Gain

Applies damping to prevent overshoot. Smooths control action in dynamic systems.

Calibration Unit

Sets the engineering unit used during calibration:

- 0 = sccm

Heater Voltage

Live reading of the voltage applied to the flow sensor's heater (in mV). Useful for system health checks.

Zero Cutoff Analog Input

Defines the threshold below which analog inputs are treated as zero. Enhances turndown and low-flow performance.

If voltage, value is in mV

If current, value is in mA

For current, value is 100*I (e.g. 15 = 0.15mA)

RH Offset

Factory-set offset for thermal resistance measurement. Part of calibration for flow accuracy.

RH Value

Live reading of the sensor’s thermal bridge resistance. Used for sensor diagnostics and performance trending.

Analog Input Voltage/Current

Displays the current analog signal to the MFC:

- Voltage in mV
- Current in mA (e.g., 200 = 2 mA)

Park Position

A known valve position used during valve leak testing or parking. Typically, a percentage of preload.

Output Flow Filter Depth

Averages the output flow signal using 2^x samples (x = register value). A factory setting of 5 is used for flows >1000 sccm.

Table 1-1 Register List

Register Name	Data Type	Access	Default Value	Range / Notes	Register (Hex)
Address	UINT16	R/W	—	Accepts 1 to 247 (except 157)	0x0081
Serial Number	UINT8	R	—	string	0x0030–0x0035
Flow Rate	UINT32	R	—	Flow * 1000 in Device Units (see 0x0090 for units)	0x003A–0x003B
Gas Temperature	SINT16	R	—	ABCD = AB.CD °C	0x0040
Baud Rate	Enum	R/W	3 (38400 baud)	0=4800, 1=9600, 2=19200, 3=38400	0x0082
Gas Correction Factor	UINT16	R/W	1000	Any value; value = GCF × 1000. Write protection must be disabled to write	0x008B
Filter Depth	UINT16	R/W	3	0–9; samples averaged = 2^x. Write protection must be disabled to write	0x008C
Setpoint Source	UINT16	R/W	1 (digital)	0–analog, 1–digital	0x00BA
Setpoint ratio	UINT16	R/W	—	Value/64000 = ratio of full scale. Not affected by Device Units (0x0090)	0x00BB
Setpoint (flow units)	UINT32	R	—	Flow rate in Device Units * 1000. Affected by Device Units (0x0090)	0x00BC–0x00BD
Valve Preload Offset	UINT16	R/W	—	0 to 9999. Sets valve opening point	0x00C0
Exhaust Mode	UINT16	R/W	—	See Table 1-2 below	0x00C1
Exhaust Value	UINT16	R/W	—	Sets valve position for open-loop control only; value ÷ 100 = %; range 0–10000	0x00C2
Valve Status	UINT16	R	—	Valve drive value; applies to open-loop and closed-loop; range 0–65535	0x00C3
Offset Calibration	UINT16	W	—	Write 0xAA55 to zero the device	0x00F0
Offset Calibration Value	SINT16	R	—	Value subtracted from raw ADC	0x008E
Write Protection	UINT16	W	—	Write 0xAA55 to disable write protection	0x00FF
ADC Value	UINT16	R	—	Raw ADC value minus zero offset	0x82F2
Calibration Write Protect	UINT32	W	—	Write 0x53494152 (SIAR) to enable calibration write; write anything else to lock	0x8200
Calibration Table	—	R/W	—	Address 0xE000; length = value in 0x820A ÷ 2; index = ADC bit value	0xE000
DUT Calibration Info	UINT16	R	—	0x820A, length 3: 1. Compression factor 2. Number of data frames 3. Data frame length	0x820A

Table 1-1 Register List (Cont.)

Unit Full Scale	UINT32	R/W	—	Full-scale value * 1000 in Device Units; changes when Device Units is changed. Write protection must be disabled to change.	0x0085–0x0086
Device Units	UINT16	R/W	—	Enum: 8 – sccm; 7 – slpm Note: Only changeable if full scale between 1000–5000 sccm; requires protection disabled	0x0090
Model Code	Char	R	—	32-character string; read from 0x016D–0x017C	0x016D–0x017C
Set Model Code	Char	R/W	—	32-character string; write to 0x816D–0x817C	0x816D–0x817C
Firmware Version	UINT16	R	—	Encoded format: 0x0abc = v0.a.b.c. Example: 0x0130 = v0.1.3.0	0x007F
Gas Used for Calibration	UINT16	R	—	SEMI E52-0703 gas code	0x005E
Gas Used for Calibration	UINT16	R/W	—	Write protected; SEMI E52-0703 gas code; sets value of 0x005E	0x831D
Minimum Analog Value	UINT16	R/W	—	Minimum analog voltage/ current value: Example: 4mA → 400 (0x0190), 1V → 1000 (0x03E8)	0x0087
Maximum Analog Value	UINT16	R/W	—	Sets max analog voltage/ current: 20mA → 2000 (0x07D0); 5V → 5000 (0x1388)	0x0089
Bin Size	UINT16	R	—	Integer defining size/flow configuration based on internal binning table	0x0060
Heater Drive Circuit Value	UINT8	R/W	—	Set 90 for N_2/Air; 60 for H_2/He	0x830F
Current Amplification Factor	UINT8	R/W	—	Enum values: 1, 2, 4, 8, 16, 32 (N_2/Air), 128 (H_2/He)	0x8305
Gas Calibration Temperature	SINT16	R/W	—	Read ABCD = AB.CD °C. Write 0xAA55 to save current temp at calibration	0x8307
PD Control I Gain	UINT16	R/W	—	Sets PD controller I gain; range: 0–9999	0x00BE
PD Control P Gain	UINT16	R/W	—	Sets PD controller P gain; range: 0–9999	0x00BF

Table 1-1 Register List (Cont.)

Calibration Unit	—	R/W	—	Enums: 0 – sccm; 1 – slpm	0x8320
Heater Voltage	UINT16	R	—	Voltage in mV	0x8302
Zero Cutoff Analog Input	UINT16	R/W	—	In mV (voltage) or 100×I (current). E.g., 15 = 0.15mA	0x831C
RH Offset	UINT16	R/W	—	Value in Ohms	0x830D
RH Value	UINT16	R	—	Value in Ohms	0x82F9
Analog Input Voltage/Current	UINT16	R	—	Value in mV (voltage) or 100×I (current). E.g., 200 = 2mA	0x831B
Park Position	UINT16	R/W	—	Example: Value of 80 means 80% of preload value	0x00E5
Output Flow Filter Depth	UINT16	R/W	5 (size 0 flow ≥1000 sccm), 0 (all other sizes)	0–9; sets number of averaged samples: 2^x. Write protection must be disabled	0x008D

Table 1-2 Exhaust Modes

Enum Name	**Enum Value**	**Heater Enabled**	**Valve Control Mode**	**Drive Value to Exhaust Valve**
Closed Loop	0	Yes	Closed Loop	Exhaust valve value is live and can change
Open Loop	1	Yes	Open Loop	Exhaust value is live and can be changed (via register 0x00C2)
Open Loop Heater Disabled	2	No	Open Loop	Exhaust value is live and can be changed (via register 0x00C2)
I/O Leak Check	3	No	Open Loop	10000 (decimal, (fixed)
Pedestal Leak Check	4	No	Open Loop	0x00C2 value = park position (copied from register 0x00E5 at the time this mode is entered), (fixed)

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