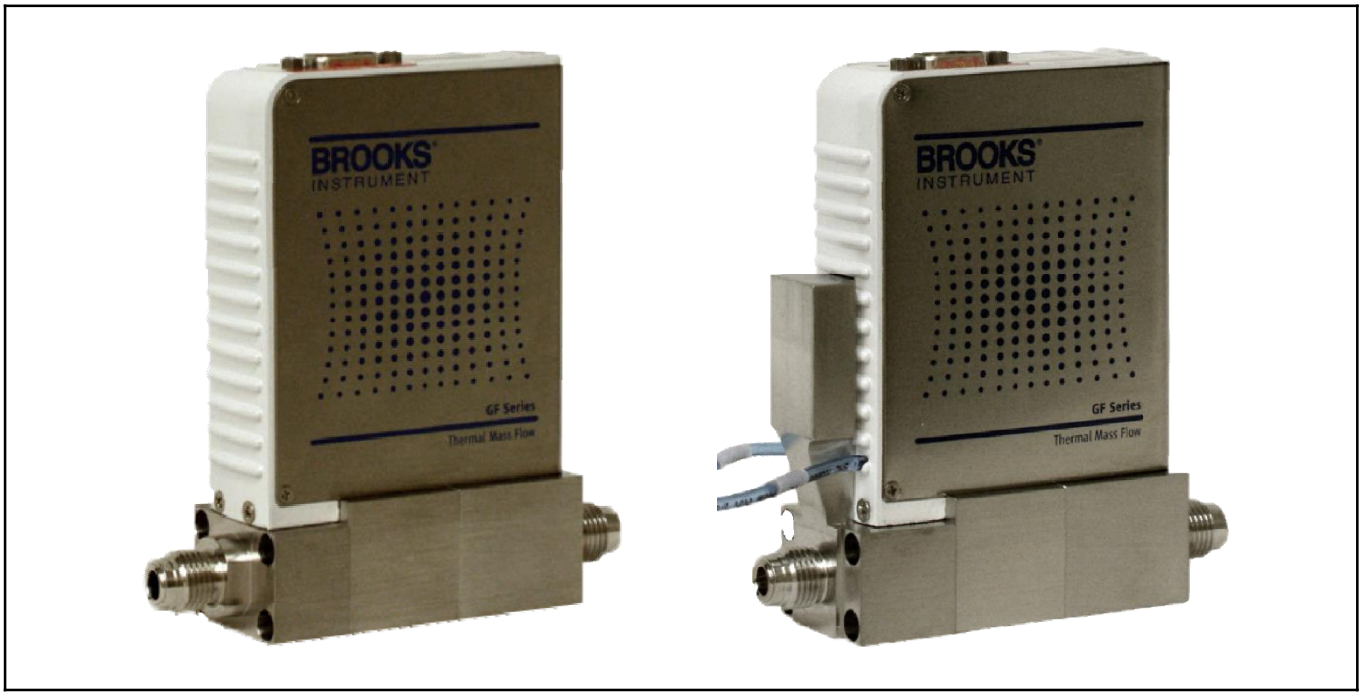
Installation and Operation Manual
X-DPT-RS485-GF100-Series-MFC-eng
Part Number: 541B183AAG
March, 2020

RS485 L-Protocol Supplemental Manual for GF100 Series Mass Flow Controllers and Meters



Brooks® GF125 Series and GF135 Series

Dear Customer,

We recommend that you read this manual in its entirety as this will enable efficient and proper use of the RS485 L-Protocol Mass flow controllers and meters. Should you require any additional information concerning the RS485 L-Protocol Mass flow controllers and meters, please feel free to contact your local Brooks Sales and Service Office; see back cover for contact information, or visit us on the web at www.BrooksInstrument.com. We appreciate this opportunity to service your fluid measurement and control requirements, and trust that we will be able to provide you with further assistance in future.

Yours sincerely,

Brooks Instrument

Contents

1. Introduction

1.1. Purpose

The purpose of this document is to outline the generic RS485 multi-drop communication protocol for UNIT digital MFC.

1.2. Scope

This protocol is intended to serve all digital MFCs. Only the following messages are supported:

- Query for MAC – Master controller will use this message to query the existence of a MFC controller.
- Digital mode selection – Master controller will use this message to set a MFC controller to digital mode.
- Freeze Follow – Master controller will use this message to configure a MFC controller to act upon a new set point when received.
- Set Point – Master controller will use this message to send a new set point to a MFC controller.
- Ramp Time – Master controller will use this message to send a ramp time to a MFC controller.
- Filtered Set Point – Master controller will use this message to get the current set point from a MFC controller.
- Indicated Flow - Master controller will use this message to get the current flow reading from a MFC controller.
- Valve Drive Current - Master controller will use this message to get the valve drive current.
- Calibration Instance (Process Gas) Selection - Master controller will use this message to select which calibration instance is to be used for flow metering.
- Query for Calibration Instance (Process Gas) Selected - Master controller will use this message to query the selected calibration instance, which is currently being used for flow metering.

- Query for Available Calibration Instances (Process Gases) - Master controller will use this message to query available number of calibration instances.
- Auto Zero Enable/Disable - Master controller will use this message to enable auto zero function.
- Requested Zero Enable - Master controller will use this message to enable requested function.
- Query for Requested Zero Status – Master controller will use this message to query if the requested zero function has been completed.
- Query for Sensor Current Zero - Master controller will use this message to query the current sensor zero offset.
- Query for Sensor Reference Zero - Master controller will use this message to query the sensor reference zero offset.
- Set Sensor Reference Zero - Master controller will use this message to set sensor reference zero offset.
- Query for Inlet Pressure (GF125 only) – Master controller will use this message to query the pressure transducer reading.
- Query for Temperature – Master Controller will use this message to query the temperature reading

2. Background

2.1. Topology

The controller acts as a Master device on an RS-485 multi-drop bus. It controls all transactions on the bus.

The digital MFC controller (up to 31 acts as a slave device on an RS-485 multi-drop bus. It continually listens for transaction requests from the Master controller, processes requests addressed to it, and sends replies as needed.

2.2. Communication Parameters

- BAUD rate: 9600, 19200, 38400, 57600
    - Data bits: 8 ✡ Start bit: 1 ✡ Stop bit: 1 ✡ Parity: none
    - Byte order: LSB first
    - MAC(Address) assignment:
    - Master controller: 0
        - Digital MFC controller 1-31: 0x21(33) – 0x3F(63)
        - Broadcast packet address: 0xFF(255)
        - Addresses 0x01 to 0x1f are reserved for bus control characters
            - ACK – 0x06
            - NAK – 0x16

2.3. Message Format

Messages on the bus are sent as packets with a fixed format, illustrated as the following diagram. Each packet begins with the target digital MFC controller MAC ID (address), an STX character (0x02), a service (command) code (0x80 for read and 0x81 for write), a packet length character, a variable identifier (consisting of Class ID, Instance ID, Attribute ID) and a data count between 0 to 2. Each packet ends with a pad byte of 0, and a 1-byte checksum, which is the sum of all of the bytes in the packet, other than the target MAC ID, modulo 256. The checksum calculation discards the carry from the byte summation calculation. This message structure resembles with the one used by DeviceNet protocol.

MAC ID (Targeted MFC Controller Address)
STX(0x02)
Command Code(0x80 for read, 0x81 for write)
Packet Length
Class ID
Instance ID
Attribute ID
Data(0 - 2 bytes)
Pad(0x00)
Checksum

All communication on the bus is done by service requests (from Master controller to a specified MFC slave controller), each addressed to a specific MAC ID, Class ID, Instance ID and Attribute ID. Currently this protocol supports only 2 services – Read and Write.

All communication on the bus is done by service requests (from Master controller to a specified MFC slave controller), each addressed to a specific MAC ID, Class ID, Instance ID and Attribute ID. Currently this protocol supports only 2 services – Read and Write.

The following table summarizes the specification of Class ID, Instance ID and Attribute ID for each supported message:

Message	Class ID	Instance ID	Attribute ID
Query for MAC ID	0x03	0x01	0x01
Digital Mode Selection	0x69	0x01	0x03
Query for Present Control Mode	0x69	0x01	0x03
Freeze Follow	0x69	0x01	0x05
New Setpoint	0x69	0x01	0xA4
Ramp Time	0x6A	0x01	0xA4
Filtered Setpoint	0x6A	0x01	0xA6
Indicated Flow	0x6A	0x01	0xA9
Valve Drive Current	0x6A	0x01	0xB6
Calibration Instance	0x66	0x00	0x65
Query for Calibration Instance	0x66	0x00	0x65
Query for Available # of Calibration Instances	0x66	0x00	0xA0
Auto Zero Enable/Disable	0x68	0x01	0xA5
Requested Zero Enable	0x68	0x01	0xBA
Query for Requested Zero Status	0x68	0x01	0xBA
Query for Sensor Current Zero	0x68	0x01	0xA9
Query for Sensor Reference Zero	0x68	0x01	0xAA
Set Sensor Reference Zero	0x68	0x01	0xAA
Set Default Control Mode	0x69	0x01	0x03
Query for Default Control Mode	0x69	0x01	0x03
Query for Inlet Pressure	0x31	0x02	0x06
Query for Temperature	0x31	0x03	0x06
Set MAC ID (Hardware Dependent): See Appendix	0x03	0x01	0x01

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3. Message Protocol Details

The following sub-sections describe in detail the supported messages.

3.1. Query for MAC ID

Master controller will use this message to query the existence of a MFC controller.

Query message from Master controller to a digital MFC controller

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x03)
Class ID(0x03)
Instance ID(0x01)
Attribute ID(0x01)
Pad(0x00)
Checksum(0x8A)

Response message from a digital MFC controller to Master controller

MAC ID (0 – Master controller)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x04)
Class ID(0x03)
Instance ID(0x01)
Attribute ID(0x01)
MFC MAC ID
Pad(0x00)
Checksum

3.2. Digital Mode Selection

Master controller will use this message to set a MFC controller to digital or analog mode.

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x81 for write)
Packet Length(0x04)
Class ID(0x69)
Instance ID(0x01)
Attribute ID(0x03)
Mode(1 – digital, 2 - analog)
Pad(0x00)
Checksum

3.3. Query Present Control Mode

Master controller will use this message to query the present control mode.

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x03)
Class ID(0x69)
Instance ID(0x01)
Attribute ID(0x03)
Pad(0x00)
Checksum(0xF2)

Response message from a digital MFC controller to Master controller

MAC ID (0-Master Controller)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x04)
Class ID(0x69)
Instance ID(0x01)
Attribute ID(0x03)
Mode(1 – digital, 2 - analog)
Pad(0x00)
Checksum

3.4. Freeze Follow

Master controller will use this message to configure a MFC controller to act upon, or ignore, a new set point when received.

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x81 for write)
Packet Length(0x04)
Class ID(0x69)
Instance ID(0x01)
Attribute ID(0x05)
FreezeFollow(1–Act on new set point immediately-(default)) **(0-Ignore change in set point)**
Pad(0x00)
Checksum

3.5. New Setpoint

Master controller will use this message to send a new set point to a MFC controller.

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x81 for write)
Packet Length(0x05)
Class ID(0x69)
Instance ID(0x01)
Attribute ID(0xA4)
Data Byte#1(LSB)*
Data Byte#2(MSB)*
Pad(0x00)
Checksum

**See New Setpoint conversion Table, pg. 51*

3.6. Ramp Time

Master controller will use this message to send a ramp time to a MFC controller. The ramp time is how long the MFC controller should take to reach the final set point from the current set point. The unit is millisecond. A zero ramp time effectively disables the ramping.

Request message from Master controller to a digital MFC controller

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x81 for write)
Packet Length(0x05)
Class ID(0x6A)
Instance ID(0x01)
Attribute ID(0xA4)
Data Byte#1(LSB)
Data Byte#2(MSB)
Pad(0x00)
Checksum

Ramp time (msec)	Ramp Time value (hex)
0	**0000**
65535	**FFFF**

3.6.1 Query for Ramp Time Setting

Master controller will use this message to query the ramp time setting

Request message from Master controller to a digital MFC controller

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x03)
Class ID(0x6A)
Instance ID(0x01)
Attribute ID(0xA4)
Pad(0x00)
Checksum (0x94)

Request message from Master controller to a digital MFC controller

MAC ID (0 - controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x07)
Class ID(0x6A)
Instance ID(0x01)
Attribute ID(0xA4)
Data Byte #1(LSB)
Data Byte #2(MSB)
Reserved Byte #1
Reserved Byte #2
Pad(0x00)
Checksum

3.7. Filtered Setpoint

Master controller will use this message to get the current set point from a MFC controller. This is the current set point after ramping has been applied.

Request message from Master controller to a digital MFC controller

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x03)
Class ID(0x6A)
Instance ID(0x01)
Attribute ID(0xA6)
Pad(0x00)
Checksum (0x96)

Response message from a digital MFC controller to Master controller

MAC ID (0 – Master controller)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x05)
Class ID(0x6A)
Instance ID(0x01)
Attribute ID(0xA6)
Data Byte #1(LSB)*
Data Byte #2(MSB)*
Pad(0x00)
Checksum

**See New Setpoint Conversion Table Pg. 51*

3.8. Indicated Flow

Master controller will use this message to get the current flow reading from a MFC controller.

Request message from Master controller to a digital MFC controller

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x03)
Class ID(0x6A)
Instance ID(0x01)
Attribute ID(0xA9)
Pad(0x00)
Checksum (0x99)

Response message from a digital MFC controller to Master controller

MAC ID (0 – Master controller)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x05)
Class ID(0x6A)
Instance ID(0x01)
Attribute ID(0xA9)
Data Byte #1(LSB)*
Data Byte #2(MSB)*
Pad(0x00)
Checksum

**See New Setpoint Conversion Table Pg. 51*

3.9. Valve Drive Current

Master controller will use this message to get the valve drive current.

Request message from Master controller to a digital MFC controller

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for re ad)
Packet Length(0x03)
Class ID(0x6A)
Instance ID(0x01)
Attribute ID(0xB6)
Pad(0x00)
Checksum (0xA6)

Response message from a digital MFC controller to Master controller

MAC ID (0 – Master controller)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x05)
Class ID(0x6A)
Instance ID(0x01)
Attribute ID(0xB6)
Data Byte #1(LSB)*
Data Byte #2(MSB)*
Pad(0x00)
Checksum

*

% Valve Drive	Valve Drive value (Hex)
0.0	0000
100.0	FFFF

3.10. Calibration Instance (Process Gas) Selection

Master controller will use this message to select which calibration instance is to be used for flow metering.

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x81 for write)
Packet Length(0x04)
Class ID(0x66)
Instance ID(0x00)
Attribute ID(0x65)
Calibration Instance ID(#)
Pad(0x00)
Checksum

3.11. Query for Calibration Instance (Process Gas) Selection

Master controller will use this message to query the selected calibration instance, which is currently being used for flow metering.

Request message from Master controller to a digital MFC controller

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x03)
Class ID(0x66)
Instance ID(0x00)
Attribute ID(0x65)
Pad(0x00)
Checksum (0x50)

Response message from a digital MFC controller to Master controller

MAC ID (0 – Master controller)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x05)
Class ID(0x66)
Instance ID(0x00)
Attribute ID(0x65)
Calibration Instance ID(#)
Reserved Byte
Pad(0x00)
Checksum

3.12. Query for Available Calibration Instances (Process Gases)

Master controller will use this message to query available number of calibration instances.

Request message from Master controller to a digital MFC controller

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x03)
Class ID(0x66)
Instance ID(0x00)
Attribute ID(0xA0)
Pad(0x00)
Checksum (0x8B)

Response message from a digital MFC controller to Master controller

MAC ID (0 – Master controller)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x04)
Class ID(0x66)
Instance ID(0x00)
Attribute ID(0xA0)
Available # Of Calibration Instances
Pad(0x00)
Checksum

3.13. Auto Zero Enable/Disable

Master controller will use this message to enable auto zero function.

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x81 for write)
Packet Length(0x04)
Class ID(0x68)
Instance ID(0x01)
Attribute ID(0xA5)
>0 for enable, = 0 for disable
Pad(0x00)
Checksum

3.14. Requested Zero Enable

Master controller will use this message to enable requested function.

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x81 for write)
Packet Length(0x04)
Class ID(0x68)
Instance ID(0x01)
Attribute ID(0xBA)
1 for enable
Pad(0x00)
Checksum

3.15. Query for Requested Zero Status

Master controller will use this message to query if the requested zero function has been completed.

Request message from Master controller to a digital MFC controller

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x03)
Class ID(0x68)
Instance ID(0x01)
Attribute ID(0xBA)
Pad(0x00)
Checksum (0xA8)

Response message from a digital MFC controller to Master controller

MAC ID (0 – Master controller)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x04)
Class ID(0x68)
Instance ID(0x01)
Attribute ID(0xBA)
0: completed, 1: in progress
Pad(0x00)
Checksum

3.16. Query for Sensor Current Zero

Master controller will use this message to query the current sensor zero offset.

Request message from Master controller to a digital MFC controller

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x03)
Class ID(0x68)
Instance ID(0x01)
Attribute ID(0xA9)
Pad(0x00)
Checksum (0x97)

Response message from a digital MFC controller to Master controller

MAC ID (0 – Master controller)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x07)
Class ID(0x68)
Instance ID(0x01)
Attribute ID(0xA9)
Data Byte #1(LSB)
Data Byte #2(MSB)
Reserved Byte #1
Reserved Byte #2
Pad(0x00)
Checksum

3.17. Query for Sensor Reference Zero

Master controller will use this message to query the sensor reference zero offset.

Request message from Master controller to a digital MFC controller

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x03)
Class ID(0x68)
Instance ID(0x01)
Attribute ID(0xAA)
Pad(0x00)
Checksum (0x98)

Response message from a digital MPC controller to Master controller

MAC ID (0 – Master controller)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x05)
Class ID(0x68)
Instance ID(0x01)
Attribute ID(0xAA)
Data Byte #1(LSB)
Data Byte #2(MSB)
Pad(0x00)
Checksum

3.18. Set Sensor Reference Zero

Master controller will use this message to set sensor reference zero offset.

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x81 for write)
Packet Length(0x05)
Class ID(0x68)
Instance ID(0x01)
Attribute ID(0xAA)
Data Byte#1(LSB)
Data Byte#2(MSB)
Pad(0x00)
Checksum

3.19. Set Default Control Mode

Master controller will use this message to set MFC control mode when first powered up.

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x81 for write)
Packet Length(0x04)
Class ID(0x69)
Instance ID(0x01)
Attribute ID(0x04)
Mode(1 – digital, 2 - analog)
Pad(0x00)
Checksum

3.20. Query Default Control Mode

Master controller will use this message to query the MFC wakeup control mode.

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x03)
Class ID(0x69)
Instance ID(0x01)
Attribute ID(0x04)
Pad(0x00)
Checksum (0xF3)

Response *message from Digital MFC controller to Master controller*

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x04)
Class ID(0x69)
Instance ID(0x01)
Attribute ID(0x04)
Mode(1 – digital, 2 - analog)
Pad(0x00)
Checksum

3.21. Query for Inlet Pressure (GF125 Only)

Master Controller will use this message to query the current pressure transducer reading.

Request message from Master controller to digital MFC controller

MAC ID (Targeted MFC Controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x03)
Class ID(0x31)
Instance ID(0x02)
Attribute ID(0x06)
Pad(0x00)
Checksum (0xBE)

Response message from a digital MFC controller to Master Controller

MAC ID (0 – Master controller))
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x05)
Class ID(0x31)
Instance ID(0x02)
Attribute ID(0x06)
Data Byte #1(LSB)
Data Byte #2(MSB)
Pad(0x00)
Checksum

Actual Pressure Reading (psia)	Output Value (hex)	Output Value (decimal)
0	0000	0
100	6000	24576

The actual pressure reading is calculated from the output value:

Actual Pressure Reading = (Output_Value/Full_scale_output_value)*100

Where Full_scale_output_value = 24576 (0x6000)

3.22. Query for Temperature

Master controller will use this message to query the current temperature reading.

Request message from Master controller to a digital MFC controller

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x03)
Class ID(0x31)
Instance ID(0x03)
Attribute ID(0x06)
Pad(0x00)
Checksum(0xBF)

Response message from a digital MFC controller to Master Controller

MAC ID (0 – Master controller))
STX(0x02)
Command Code(0x80 for read)
Packet Length(0x05)
Class ID(0x31)
Instance ID(0x03)
Attribute ID(0x06)
Data Byte #1(LSB)
Data Byte #2(MSB)
Pad(0x00)
Checksum

Actual Temperature Reading (psia)	Output Value (hex)	Output Value (decimal)
0	0000	0
500	6000	24576

The actual temperature reading is calculated from the output value:

Actual Temperature Reading (^{0}K) = (Output_Value/Full_scale_output_value)*500

Where Full_scale_output_value = 24576 (0x6000)

Actual Temperature Reading (^{o}C) = ((Output_value/Full_scale_output_value)*500) - 273.15

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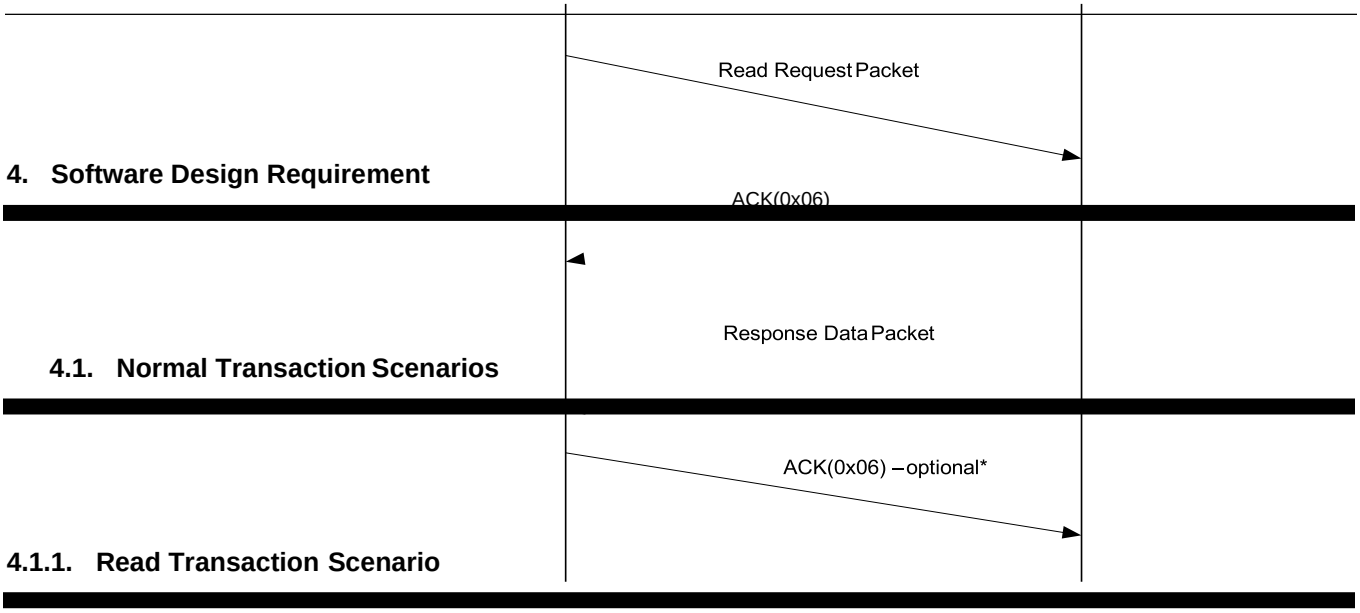
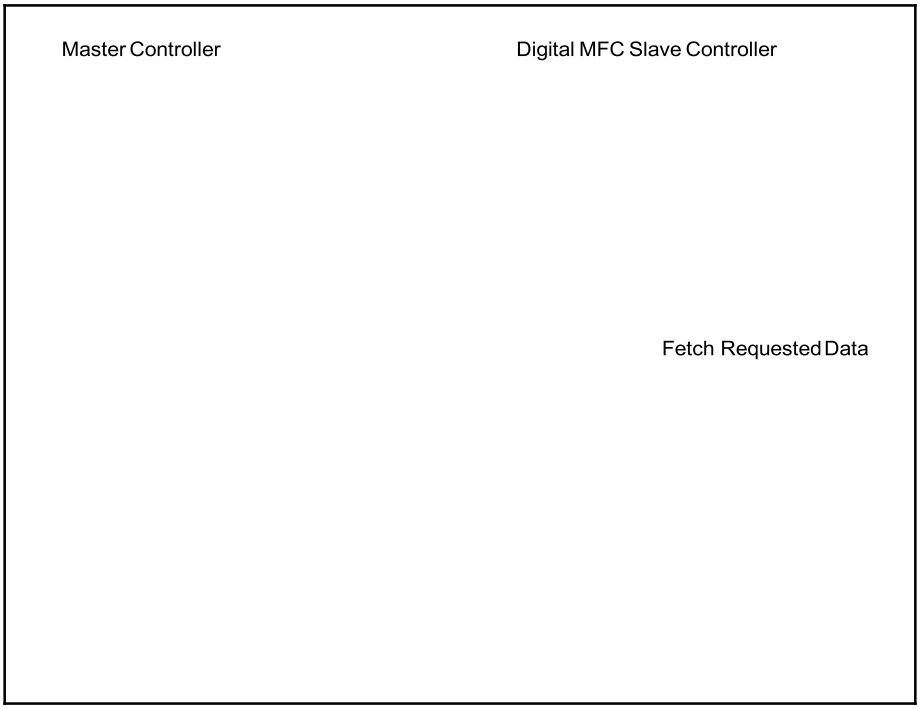
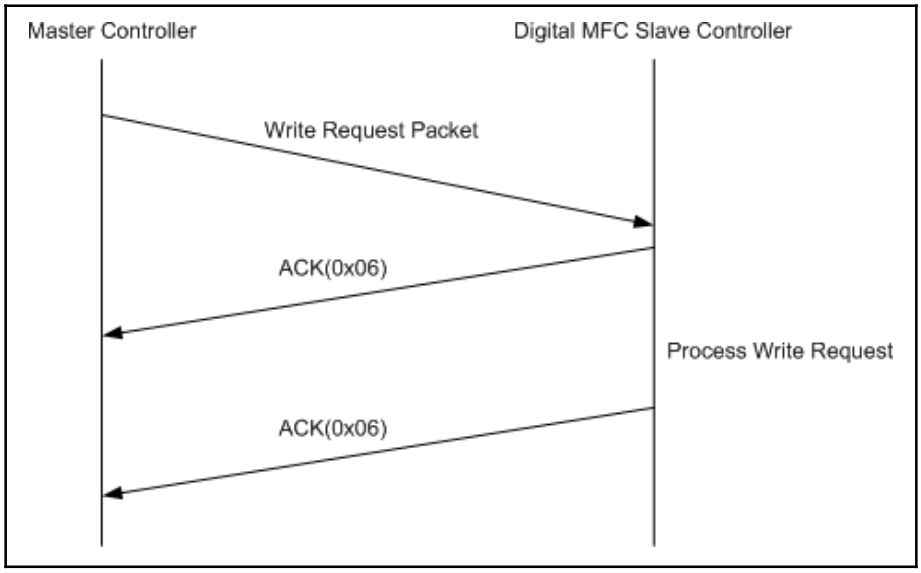




* If the slave controller does not receive any response within a reasonable time (18-20 character times) after sending a message, it behaves as though it received an ACK. If the slave controller receives an invalid response, it behaves as though it received an ACK, and assumes that the invalid character is the target address for a new message.

4.1.2. Write Transaction Scenario



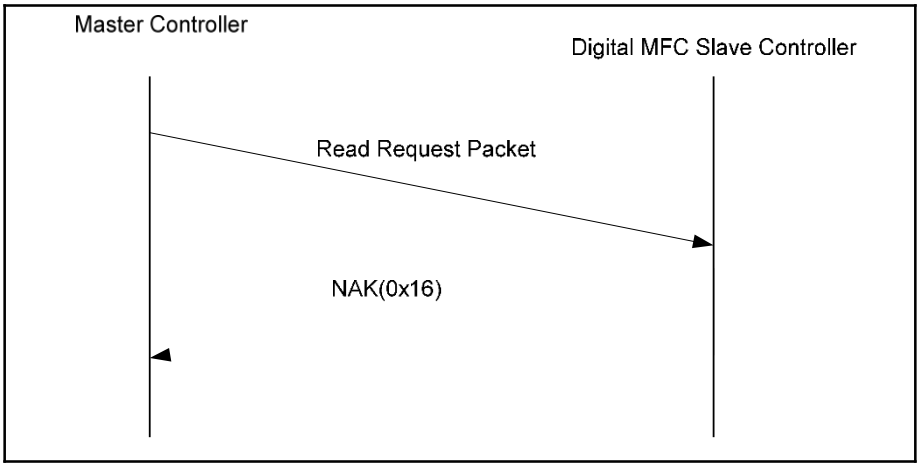
4.2. Abnormal Transaction Scenarios

4.2.1. Read Transaction Scenario

There are two different types of abnormal read transaction scenarios: packet error or read error within the MFC controller.

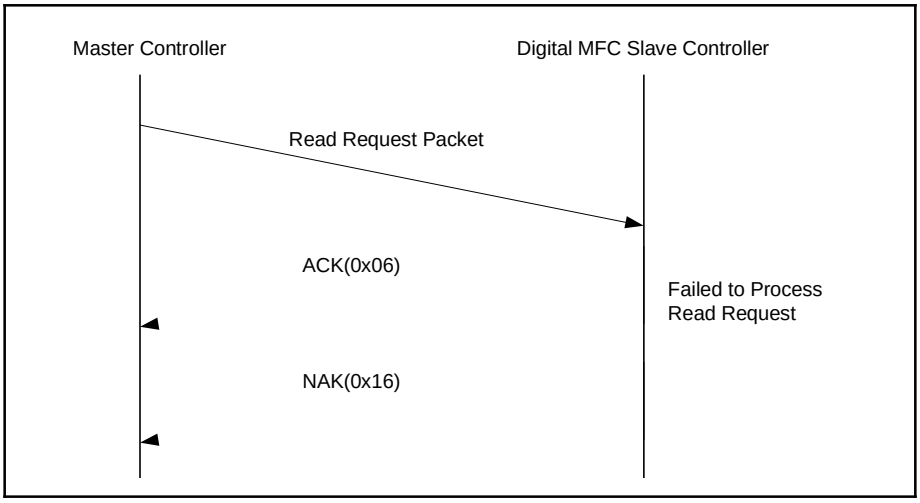
4.2.1.1. Packet Error

If the Class, Instance, or Attribute ID is invalid in the Read Request Packet, the digital MFC controller responds with a NAK(0x16) character.



4.2.1.2. Read Error

If any errors occur within the MFC controller after the first ACK is sent (no packet errors), a NAK (0x16) will be sent to indicate an execution error.

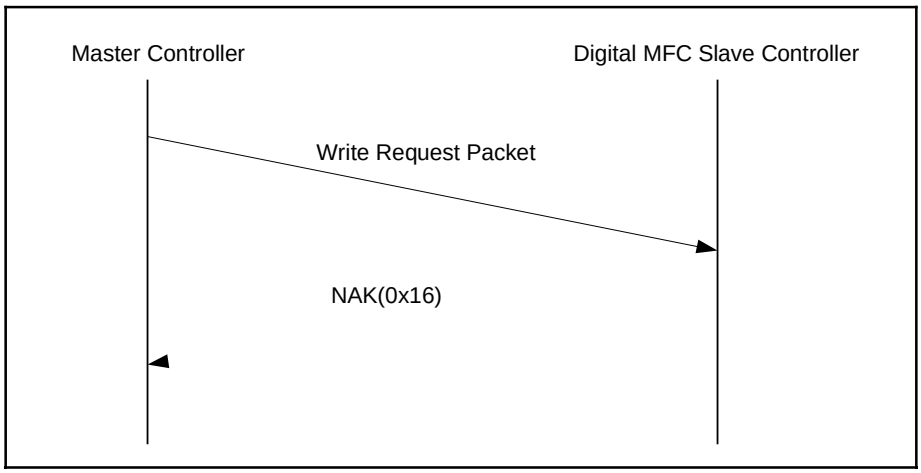


4.2.2. Write Transaction Scenario

There are two different types of abnormal write transaction scenarios: packet error or write error within the MFC controller.

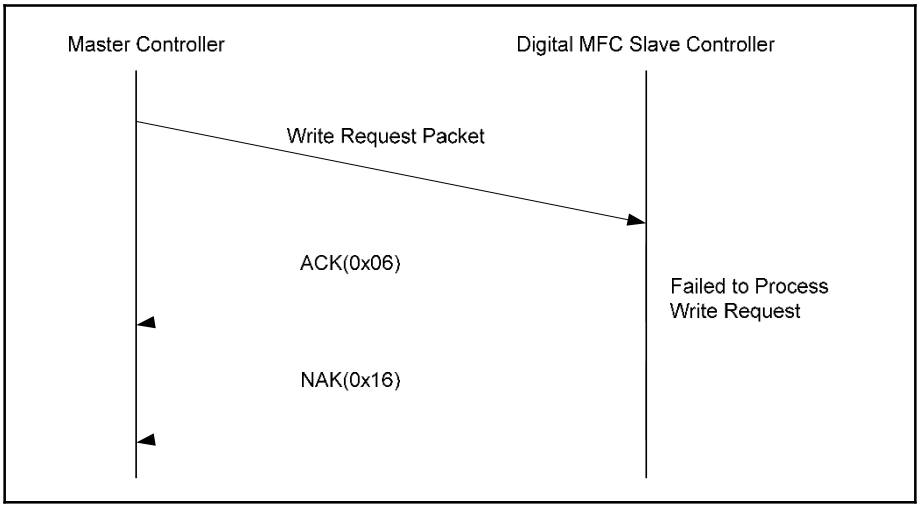
4.2.2.1. Packet Error

If the Class, Instance, or Attribute ID is invalid in the Write Request Packet, the digital MFC controller responds with a NAK(0x16) character.



4.2.2.2. Write Error

If any errors occur within the MFC controller after the first ACK is sent (no packet errors), a NAK (0x16) will be sent to indicate an execution error.



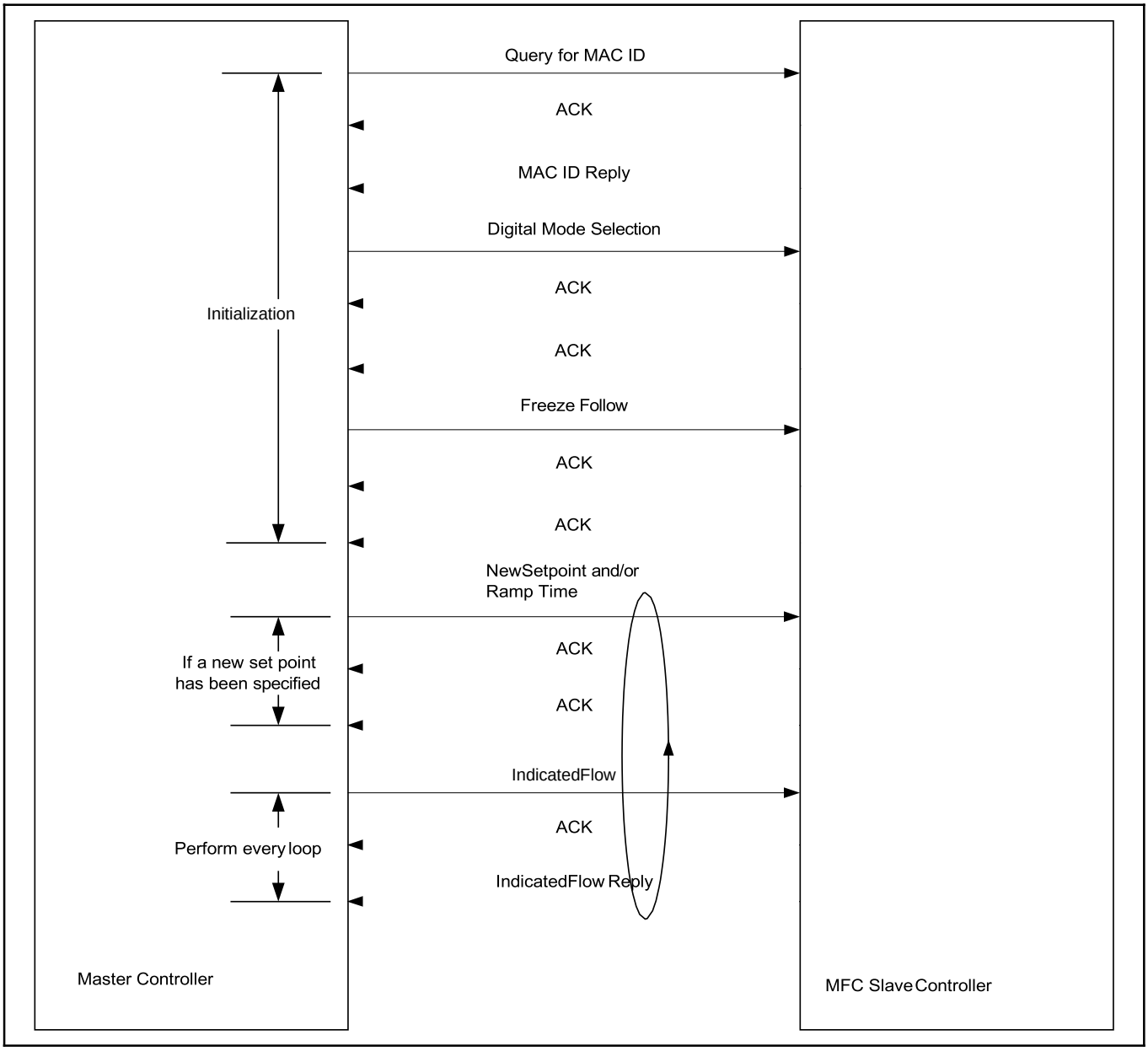
4.3. Protocol Timing

Devices on the RS485 bus distinguish address characters from other packet characters by maintaining an idle timer. This timer is started at the end of each received character, and expires if the next character does not arrive within two bytes times (20 bit times). If the timer expires, the device assumes that the message has ended, and the next character received will be either a target address, or a response indicating the acceptance of the previous packet (ACK or NAK). **Thus it is vital that devices on the bus not insert idle gaps of 1 character time or more within a packet.** A target device can also assume that an error has occurred if a new character is expected and does not arrive within 2 character times of the preceding character's arrival.

Each transaction on the bus begins when the Master controller transmits a request packet on the bus, following an idle gap of at least 1 character time. The specified slave MFC controller replies quickly with an ACK character (0x06) to indicate that it has received the packet correctly. After the request message is processed, the specified controller responds with a reply message or an ACK.

Since the current supported messages are simple and small, the Master controller expects that the entire response to the request message to be completed by the MFC controller within 5 ms. If the Master controller does not receive all response characters (ACK+ACK (2 bytes) for write request, ACK + response packet (11 or 12 bytes)) within 5ms, it assumes that an error has occurred and up to 3 retries are performed automatically.

4.4. Message Sequence between Master Controller and a MFC Slave Controller



4.5. MFC New Setpoint Conversion

The NewSetpoint request takes values in the range of 0x4000 to 0xC000 which represent set points between 0% and 100% full scale. The linear relationship between Full Scale set points and NewSetpoint is demonstrated in the following table:

Full Scale % set point	NewSetpoint Value(Hex)
0.0	4000
25.0	6000
50.0	8000
75.0	A000
99.0	BEB8
100.0	C000

The “NewSetpoint” value may be calculated from the full scale percent value by:

“NewSetpoint” = (327.68 * full scale %) + 16,384

or

“NewSetpoint” = ((0xC000-0x4000)/100 * full scale %) + 0x4000

Note that at the communication level all values are sent in binary format. The decimal and hexadecimal formats shown above are for convenience.

- Other commands that use this scaling are: Filtered Setpoint, Indicated flow, Sensors Zero, and Sensor Reference Zero

4.6. Sensor Zero Filter

The digital MFC controller should provide sensor zero filter to support correction for reasonably stable offsets in the gas flow sensor. The actual flow reading (IndicatedFlow) should be derived by subtracting **SensorCurrentZero** from each sensor measurement. **SensorCurrentZero** can be updated under two conditions, described in the following sub-sections.

4.6.1. Requested Zero

When the requested zero command is issued by Master controller, the digital MFC controller should close the flow meter valve and wait until the sensor output is stabilized (typically 90 seconds). Then the requested zero function can be started and the **SensorCurrentZero** is to be updated through the entire process. At the end of the process, **SensorReferenceZero** is to be set to **SensorCurrentZero**. If Auto Zero function is never enabled, the **SensorCurrentZero** is always equal to **SensorRe ferenceZero** . For flexibility the **SensorReferenceZero** can also be set by the Master controller.

Due to the long duration to execute the "Enable requested Zero" command, the MFC will not return an ACK when process is completed. Instead, an ACK is sent to acknowledge start of execution. During the process time, the MFC is in an "In Progress" state. While in the "In Progress" state, the MFC will only accept commands from the "Query Requested Zero Status" command, all other request to the MFC can be ignored

4.6.2. Auto Zero

Auto zero process can be started under the following condition:

- Auto Zero Enable has been issued by Master controller
- The digital MFC is in OFF mode

Once the above condition has been true for a specified delay (typically 90 seconds), auto zero process can be started at the specified rate (typically 10 times per second) and the **SensorCurrentZero** is to be updated through the entire process.

During the auto zero calculations, the digital MFC controller can use **SensorReferenceZero** to check against the calculated results. If the difference between **SensorReferenceZero** and the calculated result is beyond a specified limit, exception can be raised within the digital MFC controller.

4.7. Calibration Instances

Each calibration instance contains values needed by flow meter to calculate the actual gas flow rate for a particular process gas and flow range from sensor readings. This protocol allows Master controller to query for number of available calibration instances supported by the digital MFC controller and select a calibration instance for digital MFC operation and calculation. The detailed calibration instance internal setup is not supported through this interface and must be programmed through local MFC controller.

4.8. Analog / Digital Mode

The default mode for the MFC is set to Analog Mode. MFC's can be switch to Digital Mode with the "Digital Mode Selection" command as soon as communication is established

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5. Advanced Diagnostics (GF135 Only)

5.1. New Communication Protocol Overview

5.1.1. Objectives and Problem Statement

Through the years, issues found in the field on Brooks MFCs have been very difficult to troubleshoot due to lack of information given to failure analysis teams. Issues that are random in occurrence and are specific to the field setup are the most difficult to reproduce therefore troubleshooting takes longer.

This new communication capability will enable the device to perform a series of self validation at regular interval and report its status to the tool software. Some of the self validation will require at least knowing the state of certain part of the tool over which the device typically had neither control nor access. The capabilities of the GF135 will enable short interval control of the upstream isolation valve in a manner consistent with good safety practices.

Those capabilities do not exist in any protocol currently in use in the field.

5.1.2. Protocol Description

The communication protocol shall be implemented over RS485 physical layer.

The protocol shall be able to handle the following type of communications between the device and the tool:

- Tool request for Commissioning status
- Tool request for valve leak status, ROD measurements

These are the minimum requirements to support advanced diagnostics.

5.2. Specific Requirements

5.2.1. Introduction

The following requirements are a subset of Brooks' new communication protocol definition.

5.2.2. Advanced Protocol

The advanced communication protocol is more fully defined in GF135-SRS-011.

5.2.3. New Attributes

Note: Those attributes are valid as of the date of writing. Attribute ID are subject to change and new attributes will likely be added by the time this document is finalized.

New attributes for the advanced diagnostic:

Attribute	Access	Class	Instance	Att. ID	Values
isolation valve status	READ ONLY	177	1	3	0: Upstream open 1: Upstream closed
ROD delay	Read/Write	177	1	20	Delay before first ROD measurement after a setpoint change (seconds). Minimum = default = 4 sec.
ROD interval	Read/Write	177	1	21	Interval between ROD measurement when setpoint is constant (seconds). Minimum = 5 sec. Default = 10 sec.
ROD enable Default flag	Read/Write	177	1	55	0: ROD is disabled 1: ROD is enabled Non Volatile. Copied to Attribute 62 at power up. Default = Enabled

Attribute	Access	Class	Instance	Att. ID	Values
ROD Error Status	READ ONLY	177	1	56	0: ROD Error (attribute 11) is not valid 1: ROD Error (attribute 11) is valid
Valve Leak status	READ ONLY	177	1	57	0: Valve Leak Meas. is not valid 1: Valve Leak Meas. is valid
Valve Leak value	READ ONLY	177	1	59	Float, fraction of configured range
ROD Current Setpoint	READ ONLY	177	1	60	Current setpoint at which the ROD is being measured (see attribute 11) (fraction of configured range)
ROD error	READ ONLY	177	1	61	ROD measured flow change (from baseline) in % SP for the current setpoint. Same as ROD error N.
ROD enable flag	Read/Write	177	1	62	0: ROD is disabled 1: ROD is enabled Volatile
Commissioning status	Read/Write	103	n	132	0: Not done or failed 1: Commissioning was successful
ROD 0 Status	READ ONLY	177	1	70	0: ROD Error 0 is not valid 1: ROD Error 0 is valid
ROD 1 Status	READ ONLY	177	1	71	0: ROD Error 1 is not valid 1: ROD Error 1 is valid
ROD 2 Status	READ ONLY	177	1	72	0: ROD Error 2 is not valid 1: ROD Error 2 is valid
ROD 3 Status	READ ONLY	177	1	73	0: ROD Error 3 is not valid 1: ROD Error 3 is valid
ROD 4 Status	READ ONLY	177	1	74	0: ROD Error 4 is not valid 1: ROD Error 4 is valid
ROD 5 Status	READ ONLY	177	1	75	0: ROD Error 5 is not valid 1: ROD Error 5 is valid
ROD 6 Status	READ ONLY	177	1	76	0: ROD Error 6 is not valid 1: ROD Error 6 is valid
ROD 7 Status	READ ONLY	177	1	77	0: ROD Error 7 is not valid 1: ROD Error 7 is valid
ROD 8 Status	READ ONLY	177	1	78	0: ROD Error 8 is not valid 1: ROD Error 8 is valid
ROD 9 Status	READ ONLY	177	1	79	0: ROD Error 9 is not valid 1: ROD Error 9 is valid
ROD 10 Status	READ ONLY	177	1	80	0: ROD Error 10 is not valid 1: ROD Error 10 is valid

Attribute	Access	Class	Instance	Att. ID	Values
ROD 11 Status	READ ONLY	177	1	81	0: ROD Error 11 is not valid 1: ROD Error 11 is valid
ROD 12 Status	READ ONLY	177	1	82	0: ROD Error12 is not valid 1: ROD Error 12 is valid
ROD 13 Status	READ ONLY	177	1	83	0: ROD Error 13 is not valid 1: ROD Error 13 is valid
ROD 14 Status	READ ONLY	177	1	84	0: ROD Error 14 is not valid 1: ROD Error 14 is valid
ROD 15 Status	READ ONLY	177	1	85	0: ROD Error 15 is not valid 1: ROD Error 15 is valid
ROD 16 Status	READ ONLY	177	1	86	0: ROD Error 16 is not valid 1: ROD Error 16 is valid
ROD 17 Status	READ ONLY	177	1	87	0: ROD Error 17 is not valid 1: ROD Error 17 is valid
ROD 18 Status	READ ONLY	177	1	88	0: ROD Error 18 is not valid 1: ROD Error 18 is valid
ROD 19 Status	READ ONLY	177	1	89	0: ROD Error 19 is not valid 1: ROD Error 19 is valid
ROD Error 0	READ ONLY	177	1	90	Float, Avg. error for setpoint 0-5%
ROD Error 1	READ ONLY	177	1	91	Float, Avg. error for setpoint 5-10%
ROD Error 2	READ ONLY	177	1	92	Float, Avg. error for setpoint 10-15%
ROD Error 3	READ ONLY	177	1	93	Float, Avg. error for setpoint 15-20%
ROD Error 4	READ ONLY	177	1	94	Float, Avg. error for setpoint 20-25%
ROD Error 5	READ ONLY	177	1	95	Float, Avg. error for setpoint 25-30%
ROD Error 6	READ ONLY	177	1	96	Float, Avg. error for setpoint 30-35%
ROD Error 7	READ ONLY	177	1	97	Float, Avg. error for setpoint 35-40%
ROD Error 8	READ ONLY	177	1	98	Float, Avg. error for setpoint 40-45%
ROD Error 9	READ ONLY	177	1	99	Float, Avg. error for setpoint 45-50%
ROD Error 10	READ ONLY	177	1	100	Float, Avg. error for setpoint 50-55%
ROD Error 11	READ ONLY	177	1	101	Float, Avg. error for setpoint 55-60%
ROD Error 12	READ ONLY	177	1	102	Float, Avg. error for setpoint 60-65%
ROD Error 13	READ ONLY	177	1	103	Float, Avg. error for setpoint 65-70%
ROD Error 14	READ ONLY	177	1	104	Float, Avg. error for setpoint 70-75%
ROD Error 15	READ ONLY	177	1	105	Float, Avg. error for setpoint 75-80%
ROD Error 16	READ ONLY	177	1	106	Float, Avg. error for setpoint 80-85%

Attribute	Access	Class	Instance	Att. ID	Values
ROD Error 17	READ ONLY	177	1	107	Float, Avg. error for setpoint 85-90%
ROD Error 18	READ ONLY	177	1	108	Float, Avg. error for setpoint 90-95%
ROD Error 19	READ ONLY	177	1	109	Float, Avg. error for setpoint 95-100%

The following set of attributes is required for the data logging and trending:

Attribute	Access	Class	Instance	Att. ID	Values
Time Synchronization	WRITE ONLY	0x43 (67)	1	TBD	Time and date information Not implemented
Data Request	READ ONLY	0x41 (65)	1	TBD	Trending information Not implemented

5.3. Tool – Device Communication

The following items need to be addressed with the customer to define the new advanced diagnostic protocol:

Tool to provide status (e.g. isolation valve status upstream and downstream)

Some operations require knowing the status of the isolation valves on both sides of the device. The tool shall provide this information by writing to the isolation valve status attribute whenever the status changes.

Note: At this time, this is not implemented on the customer tool software.

Request from the device to the tool to modify the tool status (e.g. Operating the isolation valves at the request of the MFC)

Some operations require a specific state of the isolation valves on both sides of the device. The tool shall read the isolation valve request attribute on a schedule TBD and satisfy the request of the MFC.

Note: At this time, this is not implemented on the customer tool software.

Time synchronization

In order to provide accurate data logging for the trending diagnostic, the tool will need to provide accurate time synchronization. The MFC is capable of running a real time clock, so only occasional synchronization is required (at least once per power on cycle)

Note: At this time, this is not implemented on the customer tool software.

Request from the tool for some trending information

Data can be logged at regular interval and time stamped using the time information

Data can be retrieved by the customer to provide long term trend (e.g. zero information logged once per week)

Note: At this time, this is only supported via the diagnostic port.

6. Appendix: Tool - Device Communication

MFC's can have software configurable MAC ID's by sending the "Set MAC ID" command to the current MFC controller address or the default address (0xFF).

Master controller will use this message to set the MAC ID of a MFC.

Set message from Master controller to a digital MFC controller

MAC ID (Targeted MFC controller address)
STX(0x02)
Command Code(0x81 for write)
Packet Length(0x04)
Class ID(0x03)
Instance ID(0x01)
Attribute ID(0x01)
Data(0x33~0x47)
Pad(0x00)
Checksum

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Brooks RS485 L-Protocol MFCs

LIMITED WARRANTY

Seller warrants that the Goods manufactured by Seller will be free from defects in materials or workmanship under normal use and service and that the Software will execute the programming instructions provided by Seller until the expiration of the earlier of twelve (12) months from the date of initial installation or eighteen (18) months from the date of shipment by Seller. Products purchased by Seller from a third party for resale to Buyer ("Resale Products") shall carry only the warranty extended by the original manufacturer.
All replacements or repairs necessitated by inadequate preventive maintenance, or by normal wear and usage, or by fault of Buyer, or by unsuitable power sources or by attack or deterioration under unsuitable environmental conditions, or by abuse, accident, alteration, misuse, improper installation, modification, repair, storage or handling, or any other cause not the fault of Seller are not covered by this limited warranty, and shall be at Buyer's expense.
Goods repaired and parts replaced during the warranty period shall be in warranty for the remainder of the original warranty period or ninety (90) days, whichever is longer. This limited warranty is the only warranty made by Seller and can be amended only in a writing signed by an authorized representative of Seller.

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