COMMANDER 300
Universal
Process Controller

Operating Guide

MODBUS (RTU)
Communications Option
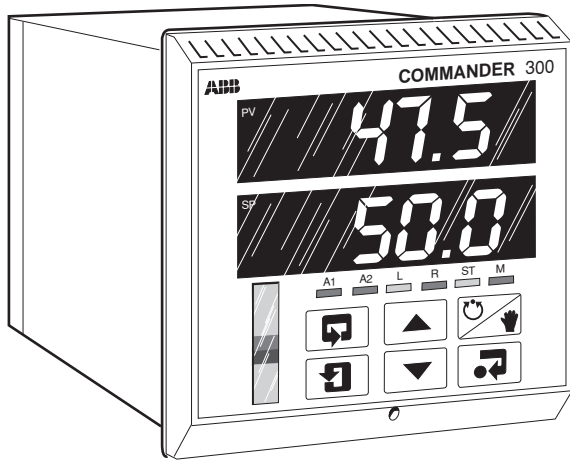

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Use of Instructions

⚠ **Warning.**
An instruction that draws attention to the risk of injury or death.

⚠ **Caution.**
An instruction that draws attention to the risk of damage to the product, process or surroundings.

✳ **Note.**
Clarification of an instruction or additional information.

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Further reference for more detailed information or technical details.

Although **Warning** hazards are related to personal injury, and **Caution** hazards are associated with equipment or property damage, it must be understood that operation of damaged equipment could, under certain operational conditions, result in degraded process system performance leading to personal injury or death. Therefore, comply fully with all **Warning** and **Caution** notices.

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To ensure that our products are safe and without risk to health, the following points must be noted:

1. The relevant sections of these instructions must be read carefully before proceeding.

2. Warning labels on containers and packages must be observed.

3. Installation, operation, maintenance and servicing must only be carried out by suitably trained personnel and in accordance with the information given.

4. Normal safety precautions must be taken to avoid the possibility of an accident occurring when operating in conditions of high pressure and/or temperature.

5. Chemicals must be stored away from heat, protected from temperature extremes and powders kept dry. Normal safe handling procedures must be used.

6. When disposing of chemicals ensure that no two chemicals are mixed.

Safety advice concerning the use of the equipment described in this manual or any relevant hazard data sheets (where applicable) may be obtained from the Company address on the back cover, together with servicing and spares information.

CONTENTS

1 INTRODUCTION

2 ELECTRICAL INSTALLATION

2.1 Selection of Serial Communication Adaptors for Personal Computers

An RS422/485 communications adaptor is required for serial links. It is strongly recommended that the card used has galvanic isolation to protect the computer from lightning damage and increase immunity from noise pick-up.

2.2   Recommended OPTO22 Boards

The following OPTO22 boards are recommended for use with the COMMANDER 300 Series of instruments:

Part No.	Computer Type
AC24 AT	AT Bus IBM PC compatible
AC34	Microchannel IBM PC

2.3   Pull-up and Pull-down Resistors – Fig. 2.1

To prevent false triggering of the slave (COMMANDER 300) by the presence of noise when the master (host computer) is inactive, 1.8K pull-up and pull-down resistors must be fitted to the RS422/485 adaptor card – see Fig. 2.1.
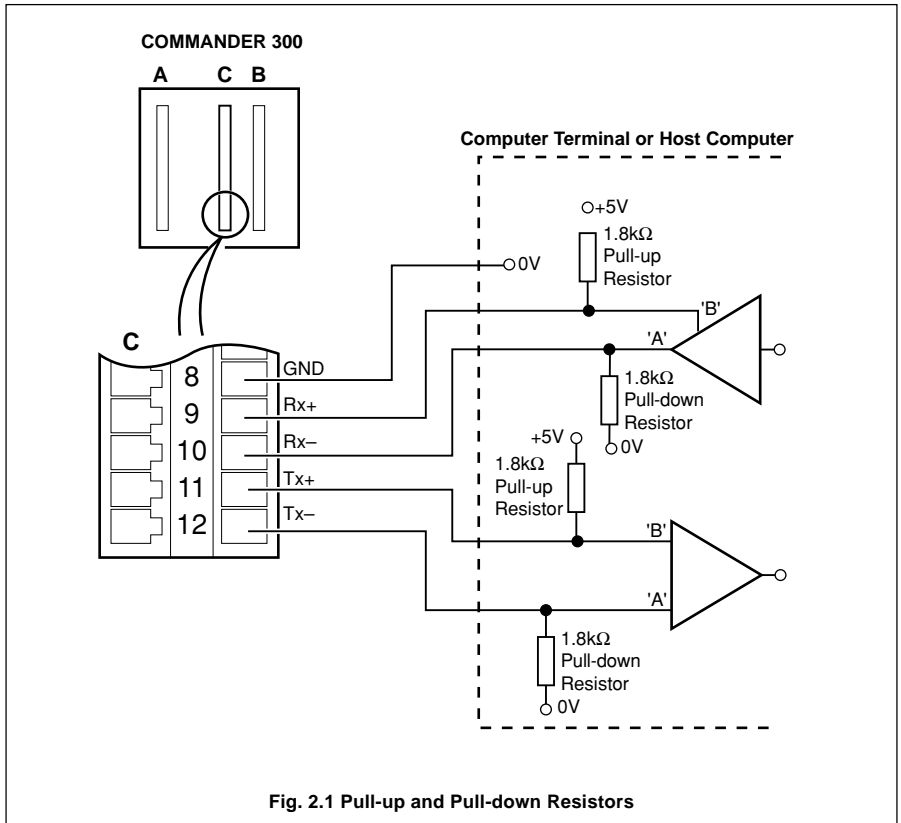
Fig. 2.1 Pull-up and Pull-down Resistors

2.4   Termination Resistors – Fig. 2.2

For long transmission lines, termination resistors are required on the last slave in the chain – see Fig. 2.2A. The slave termination resistors are selected using plug-in links (PL1) on the serial board – see Fig. 2.2B.

2.5   RS485/422 Standard

The RS485 standard quotes connection of thirty two slaves maximum, to any single driver (computer terminal or host computer); the RS422 standard quotes connection of up to ten slaves. However, these numbers can be increased if the driver's serial port permits.

A – Schematic Diagram

B – Termination Resistor Link Positions

Fig. 2.2 Selecting the Slave Termination Resistor

2.6   Serial Connections – Fig. 2.3

⌐i¬ **Information.**
- Up to **10 slaves** can be connected to a single **RS422** adaptor card on a PC.

- Up to **32 slaves** can be connected to a single **RS485** adaptor card on a PC.

- The maximum serial data transmission line length for both **RS422** and **RS485** systems is 1200m.

All connections, apart from those for serial data communication, are made as shown in *Section 4 of the Installation Guide*.

Make serial data connections as shown in Fig. 2.3. The type of cable used is dependent on the cable length:

Up to 6m	–	standard screened or twisted pair cable.
Up to 300m	–	twin twisted pair with overall foil screen and an integral drain wire, e.g. Belden 9502 or equivalent.
Up to 1200m	–	twin twisted pair with separate foil screens and integral drain wires for each pair, e.g. Belden 9729 or equivalent.
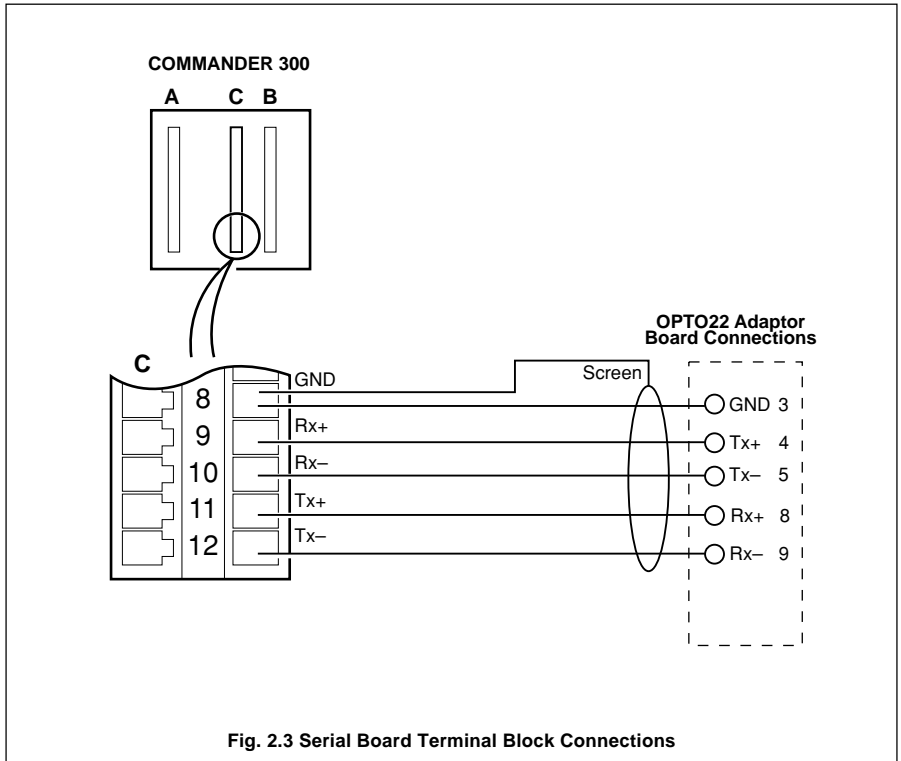
Fig. 2.3 Serial Board Terminal Block Connections
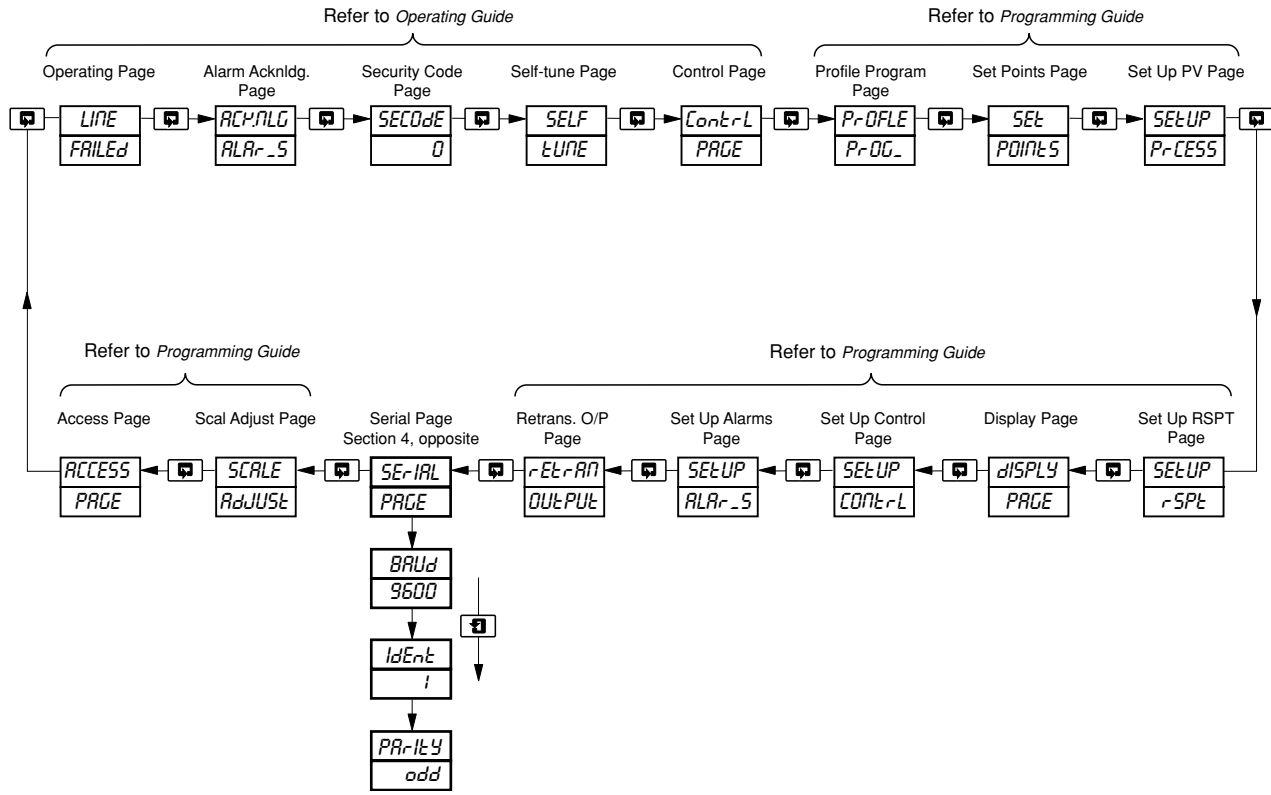
Fig. 3.1 Location of Serial Data (RS485) Communications Page

3.1   Serial Data Communication Page

┌─ i **Information.**
- Programmable baud rate (1200 to 9600 baud).

- Odd or even parity.

The general programming procedure is as detailed in the *Operating Guide*. In this Section, parameters in the lower display denoted ■ are Company Standard Settings. The instrument is dispatched programmed with these settings.
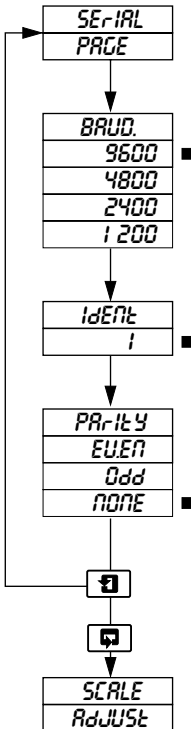
SErIAL **PAGE**	Page Header – **Serial Page**.
BAUD. **9600** ■ **4800** **2400** **1200**	**Transmission Rate** Select the transmission rate required (1200 slowest, 9600 fastest).
IdEnt **1** ■	**Controller Identification** Assign the controller an identification number between 1 and 99.
PArItY **EU.En** **Odd** **nOnE** ■	**Parity** Select the appropriate parity to match the computer terminal or host computer.
⊟ ⊡	Return to **Serial Page** frame or advanced to **Scale Adjust Page** – see *Operating Guide*.
SCALE **AdJUSt**	

7

4   MODBUS PROTOCOL

> i **Information.**
>
> • The COMMANDER 300 operates as a Modbus, Remote Terminal Unit (RTU) slave.
>
> • Parity checking – used to detect transmission errors in individual characters.
>
> • Cyclic redundancy checking – used to detect errors in the master messages and slave responses.
>
> • Non-volatile memory save command.

4.1   Introduction to Modbus Protocol

Modbus communication is based on a master and a slave arrangement. The master sends a message to one slave at a time and waits for a reply.

The slave cannot accept a new message until the existing message is processed and a reply sent to the master (maximum response time 180 milliseconds). The slave monitors the elapsed time between receipt of characters. If the elapsed time without a new character is $3^{1}/_{2}$ character times, the slave assumes the next character received is the start of a new message.

To allow the master to differentiate between more than one slave in a system, each slave is given a unique identity address (between 1 and 99).

A broadcast address (address zero) can be used to access all slave devices with one command. This is limited to write messages only and there is no slave acknowledgment.

> ✳ **Note**. Modbus RTU requires 1 start bit, 8 data bits, 1 parity bit (optional) and 1 or 2 stop bits.

4.1.1   Non-volatile Memory Limitations

> ⚠ **Caution.** If the number of write cycles to any particular non-volatile memory register exceeds 10^4 cycles, the data stored may not be retained.

Any changes made to a parameter via the serial link, e.g. Control Set Point value, are stored in a non-volatile memory register assigned to that parameter.

The number of write cycles to a particular register can be reduced by disabling non-volatile memory access when making changes to parameters which do not need to be retained following a power-down. This is done using the **Non-volatile Save State (NV) Coil 181** – see Section 7.1, Coils.

When the **Non-volatile Save State** is set to 'Enable', any parameter changes made via the serial link are written to non-volatile memory and are retained on power-down. If the **Non-volatile Save State** is set to 'Disable', parameter changes made via the serial link are not retained on power down.

The **Non-volatile Save State** must be adjusted only when necessary and must be reset to the required state each time the instrument is powered down, replaced with another instrument or the host computer is powered down.

4.2   Modbus Function Codes

The function code field instructs the addressed slaves what function to perform. Table 4.1 shows the function codes, their meaning, and the action they initiate.

Modbus Function Code	Modbus Mesage Name	MODCELL 2050 Definition
01	Read Coil Status	Read up to 16 consecutive discrete (boolean) points from a specific starting point. The COMMANDER 300 returns zeros for points which do not contain defined data and NAKs* any request for point numbers greater than 200.
03	Read Holding Register	Read up to 8 consecutive registers from a specific starting register. The COMMANDER 300 returns zeros for points which do not contain defined data and NAKs* any request for point numbers greater than 250.
05	Force Single Coil	Write one discrete (boolean) point. The COMMANDER 300 NAKs* this if the point is not currently writeable.
06	Preset Single Register	Write one register. The COMMANDER 300 NAKs* if the register is not currently writeable. This function code also applies to any currently applicable limits the value before storage in the database.
08	Loop Back Diagnostic Test	Echo the message, only 'Return of Query' is supported.
16	Preset Multiple Registers	Write up to 8 consecutive registers from a specified starting register. The COMMANDER 300 NAKs* if any of the registers are not currently writeable, but still carries out all the writes which are still valid, applying any current applicable limits to the value before storage in the database. This function code is only available if 'write to non-volatile memory' is disabled – see coil number 181.

*NAK = Negative Acknowledgement

Table 4.1 Modbus Function Codes

5   MODBUS FUNCTIONS

This section shows typical examples of Modbus function codes 01, 03, 05, 06, 08 and 16.

5.1   Read Coil Status – Function Code 01

5.1.1   Read Coil Status Query
This function allows the user to obtain the ON/OFF status of logic coils used to control discrete outputs from the addressed slave only. Broadcast mode is not supported with this function code. In addition to the slave address and function fields, the message requires that the information field contain the initial coil offset address to be read (starting address) and the number of locations to be interrogated must obtain status data.

> ✳ **Note**. The coil offset address is the coil number minus one, e.g. to start at coil 31 the data start value must be set to 30 (1EH).

Example – a read coil status request to read 16 coils from slave (01) starting at coil 31 (alarm A status) is shown below.

Address	Function	Coil Start Offset High	Coil Start Offset Low	Number of Coils High	Number of Coils Low	Error Check Field	(CRC-16)
01	01	00	1E	00	10	5D	C0

5.1.2   Read Coil Status Response
The data is packed one bit for each coil (1 = ON, 0 = OFF). The response includes the slave address, function code, quantity of data characters, the data characters and error checking. The low order bit of the first character contains the first addressed coil and the remainder follow. For coil quantities that are not even multiples of eight, the last characters are filled in with zeros at high order end.

Example – the response to the read coil status query shows the following:
Alarm A status ON
Alarm B status OFF
Alarm C status ON
Alarm D status OFF
Alarm E,F,G,H,J, K status all OFF
Alarm 1 Relay to Alarm 4 Relay status all OFF
Logic Input 1 and 2 status ACTIVE

Address	Function	Byte Count	Data Coil Status 31 to 38	Data Coil Status 39 to 46	Error Check Field	(CRC-16)
01	01	02	05	00	BA	AC

5.2   Read Holding Register – Function Code 03

5.2.1   Read Holding Register Query

The Read holding registers allow the user to obtain the binary contents of holding registers in the addressed slave.

> ✱ **Note**. The data start register must contain the offset address of the first register to be accessed, e.g. to start at register 121 the data start register must contain 120 (78H).

Broadcast mode is not allowed.

Example – a read holding register request to read 6 holding registers from slave (01) starting at holding address 121 (alarm A trip value) is shown below.

Address	Function	Register Start Offset High	Register Start Offset High	Data Number of Registers High	Data Number of Registers Low	Error Check Field	(CRC-16)
01	03	00	78	00	06	45	D1

5.2.2   Read Holding Register Response
The addressed slave responds with its address and function code, followed by the information field. The information field contains 1 byte describing the quantity of data bytes to be returned. The contents of each register requested (DATA) is two bytes, the first byte includes the high order bits and the second the low order bits.

Example – the response to the read holding register query shows the following:

Alarm trip A	–	150
Alarm trip B	–	50
Alarm trip C	–	100
Alarm trip D	–	400
Alarm trip E	–	0
Alarm trip F	–	0

Address	Function	Byte Count	Holding Register 121 High Low	Holding Register 121 High Low	Holding Register 123 High Low
01	03	0C	00 96	00 32	00 64

Holding Register 124 High Low	Holding Register 125 High Low	Holding Register 126 High Low	Error Check Field	(CRC-16)
01 90	00 00	00 00	D9	91

5.3   Force Single Coil – Function Code 05

5.3.1   Force Single Coil Query

This message forces a single coil either ON or OFF. The data value 65,280 (FF00 HEX) sets the coil ON and the value zero turns it OFF. All other values are illegal and do not affect the coil.

> ✳ **Note**. To write to a coil the coil offset address must be used, e.g. to write to coil 149, the coil address 148 (94H) is transmitted.

The use of slave address zero (broadcast mode) forces all attached slaves to modify the desired coil.

Example – a force single coil request to switch ON coil address 149 (auto/manual state, channel 1) in slave 01 is shown below.

Address	Function	Coil Offset High	Coil Offset Low	Data Value High	Data Value Low	Error Check Field	(CRC-16)
01	05	00	94	FF	00	CD	D6

5.3.2   Force Single Coil Response

The response is confirmation of the query after the coil state has been altered.

Example:

Address	Function	Coil Offset High	Coil Offset Low	Data Value High	Data Value Low	Error Check Field	(CRC-16)
01	05	00	94	FF	00	CD	D6

5.4   Preset Single Register – Function Code 06

5.4.1   Preset Single Register Query

The preset single register allows the user to modify the contents of a holding register.

> ✳ **Note**. Function codes 5, 6 and 16 are the only messages that are recognized as valid for broadcast.

Example – a preset single register request to write the value 500 to holding register address 121 (alarm A trip value) in slave 01 is shown below.

> ✳ **Note**. To write to a register, the register's offset address must be used, e.g. to write to register 121, the offset address 120 (78H) is transmitted.

Address	Function	Register Offset High	Register Offset Low	Data Value High	Data Value Low	Error Check Field	(CRC-16)
01	06	00	78	01	F4	09	C4

5.4.2   Preset Single Register Response
The normal response to a preset single register request is to retransmit the query message after the register has been altered.

Example:

Address	Function	Register Offset High	Register Offset Low	Data Value High	Data Value Low	Error Check Field	(CRC-16)
01	06	00	78	01	F4	09	C4

5.5   Loopback Test – Function Code 08

5.5.1   Loopback Test Query

The purpose of the loopback test is to test the Modbus system, it does not affect the content of the controller. Variations in the response may indicate faults in the Modbus system. The information field contains 2 bytes for the designation of the diagnostic code followed by 2 bytes to designate the action to be taken.

Example:

Address	Function	Data Diagnostic Code High	Data Diagnostic Code Low	Data *	Data *	Error Check Field	(CRC-16)
01	08	00	00	A5	37	DA	8D

*These are considered to be the information fields for diagnostic mode.

5.5.2   Loopback Test Response

The response always echoes the query, only diagnostic code 0 (bytes 3 and 4) can be used.

Example:

Address	Function	Data Diagnostic Code High	Data Diagnostic Code Low	Data	Data	Error Check Field	(CRC-16)
01	08	00	00	A5	37	DA	8D

5.6   Write Multiple Registers – Function Code 16

5.6.1   Write Multiple Registers Query

Holding registers existing within the controller can have their contents changed by this message (a maximum of 8 registers). When used with slave address zero (broadcast mode) all slave controllers load the selected registers with the contents specified.

Example – a write multiple register request to write the value 10 to the register address 121 (alarm A trip value) and the value 100 to the register address 122 (alarm B trip value) in slave 01 is shown below.

Address	Function	Register Start Offset High	Register Start Offset Low	Number of Registers		Byte Count
01	10	00	78	00	02	04

Holding Register 121 High	Holding Register 121 Low	Holding Register 122 High	Holding Register 122 Low	Error Check Field	(CRC-16)
00	0A	00	64	D4	C4

5.6.2   Write Multiple Registers Response

The response confirms slave identification, function code, starting register address and quantity only.

Example:

Address	Function	Register Start Offset High	Register Start Offset Low	Number of Registers			Error Check Field	(CRC-16)
01	10	00	78	00	02	00	10	90

6   EXCEPTION RESPONCES

The exception response codes sent by the slave are shown in Table 6.1. When a slave detects one of these errors, it sends a response message to the master consisting of slave address, function code, error code and error check fields.

Exception Response Code	Exception Response Name	Exception Response Definition
01	Illegal Function	The message function received is not an allowable action for the C200.
02	Illegal Data Address	The address reference in the data field is not an allowable address for the C200.
03	Illegal Data Value	The value referenced in the data field is not allowable in the addressed slave location.
07	Negative Acknowledgement	The function just requested cannot be performed.
08	Memory Parity Error	Parity check indicates an error in one or more of the characters received.

Table 6.1 Exception Response Codes

6.1   Examples

A read register request to read holding register address 251 of slave 01 (undefined address for slave, beyond address limit) is shown below.

Address	Function	Register Start Offset High	Register Start Offset Low	Number of Registers High	Number of Registers Low	Error Check Field	(CRC-16)
01	03	00	FA	00	06	E5	F9

The response is an exception response sighting 'illegal data address'. To indicate that the response is a notification of an error, the most significant bit of the function code is set to 1.

Slave Address	Function	Exception Code	Error Check Field	(CRC-16)
01	83	02	C0	F1

7   MODBUS REGISTERS

7.1   Coils

Coil Number	Read/Write	Description	Response/Entry
		Input Failure States	
011	R	Process Variable	
012	R	Position Feedback	0 = Active, 1 = Failed
013	R	Remote Set Point	
		Alarm Status	
031	R	Alarm A	
032	R	Alarm B	
033	R	Alarm C	
034	R	Alarm D	
035	R	Alarm E	
036	R	Alarm F	
037	R	Alarm G	0 = Inactive
038	R	Alarm H	1 = Active
039	R	Alarm J	
040	R	Alarm K	
041	R	Alarm 1Relay	
042	R	Alarm 2 Relay	
043	R	Alarm 3 Relay	
044	R	Alarm 4 Relay	
		Digital Input States	
051	R	Logic Input 1	
052	R	Logic Input 2	0 = Active
053	R	Logic Input 3	1 = Inactive
054	R	Logic Input 4	
		Multiple Read Group	
061	R	Alarm A	
062	R	Alarm B	
063	R	Alarm C	
064	R	Alarm D	
065	R	Alarm E	0 = Inactive
066	R	Alarm F	1 = Active
067	R	Alarm G	
068	R	Alarm H	
069	R	Alarm J	
070	R	Alarm K	
071	R	Logic Input 1	0 = Active, 1 = Inactive
072	R	Logic Input 2	0 = Active, 1 = Inactive
073	R	Control Action	0 = Direct,1 = Reverse
074	R	Auto/Manual	0 = Auto, 1 = Manual
075	R	Control Action for Output 2	0 = Direct,1 = Reverse
076	R	Process Variable Failure	0 = Active, 1 = Failed

…7.1 Coils

Coil Number	Read/Write	Description	Response/Entry
		Control States	
148	R/W	Control Action	0 = Direct, 1 = Reverse
149	R/W	Auto/Manual	0 = Auto, 1 = Manual
150	R/W	Control Action for Output 2	0 = Direct, 1 = Reverse
		Save Modbus	
181	R/W	Enable Writes to Non-Vol Memory	0 = Disable, 1= Enable

7.2 Holding Registers

$\boxed{i}$ **Information.**
Holding registers which have a response entry of 0 to 4095 are numbers scaled over the display range.

Example – scaling process variable to display range:
- Process variable display high = 1000
- Process variable display low = 0
- Process variable response (011) = 2047

Scaled value = $\left\lceil \dfrac{\text{Response}}{4095} \times (\text{Display High} - \text{Display Low}) \right\rceil$ + Display Low

Process Variable = $\left\lfloor \dfrac{2047}{4095} \times (1000 - 0) \right\rfloor$ + 0

Process Variable = 500

Register No.	Read/Write	Description	Response/Entry
		Process Variable Inputs	
011	R	Process Variable	
012	R	Remote Set Point	Scaled 0 to 4095
013	R	Postion Feedback	of Display Range
019	R	Process Variable Display Decimal Point Position	0 to 3 Decimal Places
041	R	Process Variable Display Span	
042	R	Process Variable Display Zero	−9999 to +9999
043	R	Remote Set Point High	
044	R	Remote Set Point Low	

7.3   Controller Settings/Outputs

Register No.	Read/Write	Description	Response/Entry
		Controller Settings	
051	R	Process Variable	
052	R/W	Control Set Point	0 to 4095
053	R/W	Control Output*	
054	R	Position Feedback Input	0 to 4095
055	R	Position Feedback Failure State	0 = Active, 1 = Failed
057	R/W	Cycle Time	10 to 3000
058	R/W	Proportional Band	1 to 9999
059	R/W	Integral Action Time	0 to 7201
060	R/W	Manual Reset Value	0 to 4095
061	R/W	Derivative Action Time	1 to 9999
062	R/W	Approach Band	1 to 30
063	R/W	Control Output Heat	0 to 4095
064	R/W	Control Output Cool	0 to 4095
065	R/W	Proportional Band Cool	1 to 9999
066	R/W	Intregral Action Time Cool	0 to 7200
067	R/W	Manual Reset Cool	0 to 4095
068	R/W	Cycle Time Cool	10 to 3000
069	R/W	Crossover Value	0 to 4095
070	R/W	Transition Band	0 to 4095
071	R	Remote Set Point Input	
074	R/W	Ratio Value for Remote Set Point	10 to 9999
075	R/W	Bias Value for Remote Set Point	± Display Range)
		Controller Settings for Position Feedback	
094	R/W	Ratio Value for Position Feedback	0 to 999
095	R/W	Bias Value for Position Feedback	± 100
		Set Points	
101	R/W	Local Set Point	
102	R/W	Dual Set Point	0 to 4095
103	R/W	Remote Set Point (without Ratio/Bias)	(Display Range)
104	R/W	Remote Set Point (with Ratio/Bias)	
105	R/W	Remote Set Point Failure State	0 = Active, 1= Failed
106	R/W	Set Point Selection	0 = Local,1 = 2nd SP

* Only applicable for time proportioning and current proportioning. NOT position proportioning or boundless.

7.4 Alarm Settings

Register No.	Read/Write	Description	Response/Entry
		Alarms	
121	R/W	Alarm A Trip Value	
122	R/W	Alarm B Trip Value	
123	R/W	Alarm C Trip Value	
124	R/W	Alarm D Trip Value	
125	R/W	Alarm E Trip Value	
126	R/W	Alarm F Trip Value	0 to 4095
127	R/W	Alarm G Trip Value	
128	R/W	Alarm H Trip Value	
129	R/W	Alarm J Trip Value	
130	R/W	Alarm K Trip Value	
			0 = Alarm Off
141	R	Alarm A Type	1 = High Process
142	R	Alarm B Type	2 = Low Process
143	R	Alarm C Type	3 = High Deviation
144	R	Alarm D Type	4 = Low Deviation
145	R	Alarm E Type	5 = High Output
146	R	Alarm F Type	6 = Low Output
147	R	Alarm G Type	7 = Fast Rate
148	R	Alarm H Type	8 = Slow Rate
149	R	Alarm J Type	9 = Mode Alarm
150	R	Alarm K Type	10 = Program Event
			11 = Segment Event

7.5 Ramp/Soak Settings

Register No.	Read/Write	Description	Response/Entry
		Ramp Soak Settings	
171	W	Ramp Soak Run State	1 = Run Profile
172	W	Ramp Soak Hold Command	1 = Hold Profile
173	W	Ramp Soak Skip	1 = Skip
175	W	Ramp Soak Reset	1 = Reset Profile
			0 = Stop
			1 = Ramp
			3 = Soak
			4 = Countdown
176	R	Profile Status	5 = Operator Hold
			6 = Not Used
			7 = Manual Hold
			8 = Holdback Hold
			9 = End
178	R	Remaining Segment Time	0 to 9999
179	R/W	Selected Program	1 to10

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Client Warranty

Prior to installation, the equipment referred to in this manual must be stored in a clean, dry environment, in accordance with the Company's published specification. Periodic checks must be made on the equipment's condition.

In the event of a failure under warranty, the following documentation must be provided as substantiation:

1. A listing evidencing process operation and alarm logs at time of failure.

2. Copies of operating and maintenance records relating to the alleged faulty unit.

ABB

The Company's policy is one of continuous product improvement and the right is reserved to modify the information contained herein without notice.