BCT SERIES CONTROLLERS (VERSION 3.0)
RS-485 COMMUNICATION INSTRUCTION MANUAL
MODBUS Protocol Reference Guide

1. COMMUNICATION FUNCTIONS

1.1 General

- □ BCT series provides a communication function by RS-485 interface, by which it can transmit and receive data to and from host computer, programmable controller, graphic display panel, etc.
- □ The communication system consists of master station and slave stations. Up to 255slave station can be connected per master station.
- □ In order that the master station and slave station can communicate, the format of the transmit/receive data must coincide. For the BCT series, the format of the communication data is determined by the MODBUS protocol (RTU mode).
- □ Please use an RS-232C→RS-485 converter in case of designating a personal computer or other devices which have an RS-232C interface as a master station.

2. SPECIFICATIONS

2.1 Communication Specifications

Item	Specification	
Electrical specification	Based on EIA RS-485	
Transmit system	2-wire, semi-duplicate	
Synchronizing system	Asynchronous mode	
Connection format	1 : N	
Number connection unit	Up to 255 units	
Transmission distance	500m max	
Transmission speed	2400 / 4800 / 9600 / 19200 selectable	
Data format	Start bit	1 bit
	Data length bit	8 bits
	Parity bit	None
	Stop bit	2 bits
Transmission code	HEX value (MODBUS RTU mode)	
Error detection	CRC-16 bits	
Isolation	Functional isolation between transmission circuit and others (with stand voltage: 500V AC).	

A typical MODBUS protocol character is shown below:

1	2	3	4	5	6	7	8	9	10	11
Start bit	Data bits								Stop bits	

One character is including 1 Start bit and 8 Data bits and 2 Stop bits.

3. CONNECTION

△ WARNING
For avoiding electric shock and malfunctions, don't turn on the power supply until all wiring has been completed.

3.1 Terminal Allocation

◆ BCT38

Terminal number	Signal name
1	+
2	-

3.2 Wiring

- □ Use twisted pair cables with shield.
  Recommended cable: UL2464, UL2448, etc.

- The total extension length of the cable is up to 500m. A master station and up to 255 units of the BCT series can be connected per line.
- Both ends of the cable should be connecting with terminate resistors 100Ω 1/2W.
- The shield wire of the cable should be grounded at one place on the master station unit side.

4. SETTING OF COMMUNICATION CONDITION

In order that the master station and BCT series can correctly communicate, following settings are required.

- All communication condition settings of the master station are the same as those of BCT series.
- All BCT series connected on a line are set to address (ADDR), which are different from each other.

4.1 Set Items

The parameters to be set are shown in the following table. Set them by operating the front panel keys.

Parameter	Item	Value at delivery	Setting range	Remarks
BAUD	Transmission speed	9600	2400/4800/9600/19200	Set the same communication condition to the master station and all slave station.
---------	Data length	8 bits	Fixed (can't be changed)	
---------	Stop bit	2 bit	Fixed (can't be changed)	
---------	Parity setting	None	Fixed (can't be changed)	
ADDR	Address	1 byte	1 to 255	Set a different value to each station.

4.2 Setting Operation Method

The following example shows how to set the communication condition.
Example: Setting a transmission speed is 9600 bps and address at 12 on a station.

Key operation	Indication	Description
Power ON	25/100	Power on running state (PV/SV indication)
SET (5 seconds)	PB	Press SET key simultaneously for approximately 5 seconds to get level parameter.
SET (5 seconds)	TYPE	Press SET key simultaneously for approximately 5 seconds to get level parameter.
SET		Press SET key to go into level.
SET	ADDR	Press SET key repeatedly until ADDR is display.
△ or ▽	ADDR/12	Press △ or ▽ key to setting "ADDR=12"
SET	BAUD	Press SET key again to select next parameter "BAUD"
△ or ▽	BAUD/9.6K	Press △ or ▽ key to setting "BAUD=9.6K"
SET	BAUD	Press SET key to save "BAUD".
SET + ▽	25/100	Press SET +▽ one time to return the normal indication (PV/SV indication).

5. MODBUS COMMUNICATION PROTOCOL

5.1 General

The communication system by the MODBUS protocol is that the communication is always started from the master station and a slave station responds to the received message.

Transmission procedures is as shown below.

1. The master station sends a command message to a slave station.

2. The slave station checks that the address in the received message matches with the own address or not.
3. If matched, the slave station executes the command and sends back the response message.
4. If mismatched, the slave station leaves the command message and wait for the next command message.
5. The master station can individually communicate with any one of slave stations connected on the same line upon setting the address in the command message.

5.2 Composition of Message

Command message and response message consist of 4 fields; Address, Function code, Data and CRC check code. And these are sends in this order. The allowable character transmitted for all fields are hexadecimal 0-9,A-F

RTU mode framing

START	ADDRESS	FUNCTION	DATA	CRC CHECK	END
T1-T2-T3-T4	8 BITS	8 BITS	N × 8 BITS	16 BITS	T1-T2-T3-T4

In the following, each field is explained.

1. **Start**
   In RTU mode, messages start with a silent interval of at least 3.5 character times. This is most easily implemented as a multiple of character times at the baud rate that is being used on the network (shown as T1-T2-T3-T4 in the figure above). The first field then transmitted is the device address.

2. **Address**
   Address is the number specifying a slave station. Valid slave device addresses are in the range 0f 1-255 decimal. A master addresses a slave by placing the slave address in the address field of the message. When the slave sends its response, it places its own address in this address field of the response to let the master know which slave is responding.
   Address 0 is used for the broadcast address, which all slave stations recognize. When the broadcast address (address 0) is applied on the command message, no any response message will be sent from the slave stations.
3. **Function**
   This is a code to designate the function executed at a slave station. When a message is sent from a master to a slave device the function code field tells the slave what kind of action to perform. When the slave responds to the master, it uses the function code field to indicate either a normal response or that some kind of error occurred. For normal response, the slave simply echoes the original function code. For an exception response, the slave returns a code that is equivalent to the original function code with its most-signification bit set to a logic 1.
4. **Data**
   Data are the data required for executing function codes. The composition of data varies with function codes. Refer to chapter 6 for details.
   A data address is assigned to each data in the temperature controller. For reading/writing the data by communication, designate the data address.
5. **CRC check**
   This is the code to detect message errors (change in bit) in the signal transmission.
   On the MODBUS protocol (RTU mode), CRC-16 (Cyclical Redundancy Check) is applied.
   For CRC calculation method, refer to section 5.5.
6. **End**
   Following the last transmitted character, a similar interval of at least 3.5 character times marks the end of message. A new message can begin after this interval.

5.3 Response of Slave Station

1. Response for normal command

To a relevant message, the slave station creates and sends back a response message, which corresponds to the command message. The composition of message in this case is the same as in section 5.2. Content of the data field depend on the function code. For details, refer to Chapter 6.

2. Response for abnormal command

If contents of a command message have an abnormality (for example, non-actual function code is designated) other than transmission error, the slave station does not execute that command but creates and sends back a response message at error detection.

The composition of response message at error detection is shown on below, the value used for function field is function code of command message plus 80H.

ADDRESS	FUNCTION (Function code + 80H)	ERROR CODE	CRC CHECK
8 BITS	8 BITS	8 BITS	16 BITS

Error Code	Contents	Description
01	Illegal function	The function code received is not an allowable action for the slave.
02	Illegal data address	The data address received is not an allowable address for the slave.
03	Illegal data value	A value contained in the data field is not an allowable value for the slave.

5.4 Function Code

The listing below shows the function codes supported by VT20 series controllers.

Function code		
Code	Function	Object
03	Read-out	Holding Register
04	Read-out	Input Register
05	Write-in	Coil
06	Write-in	Holding Register

5.5 Calculation of Error Check Code (CRC-16)

CRC-16 is the 2-bytes (16-bits) error check code. From the top of the message (address) to the end of the data field are calculated.

The slave station calculates the CRC of the received message, and does not respond if the calculated CRC is different from the contents of the received CRC code.

A procedure for generating a CRC is:

1. Load a 16-bits register with FFFF hex (all 1's). Call this the CRC register.
2. Exclusive OR the first 8-bit byte of the message with the low-order byte of the 16-bit CRC registers, putting the result in the CRC register.
3. If the LSB is 0: Shift the CRC register one bit to the right (toward the LSB), Zero-filling the MSB.
   If the LSB is 1: Shift the CRC register one bit to the right (toward the LSB), Zero-filling the MSB. Exclusive OR the CRC registers with the polynomial value A001 hex.
4. Repeat step 3 until 8 shifts have been performed. When this is done, a complete 8-bit byte will have been processed.
5. Repeat step 2 through 5 for the next 8-bit byte of the message. Continue doing this until all bytes have been processed.
6. The final content of the CRC register is the CRC value. The CRC field is appended to the message as the last field in the message. When this is done,

the low-order byte of the field is appended first, followed by the high-order byte. The CRC high-order byte is the last byte to be sent in the message.

5.6 Transmission Control Procedure

1. Transmission procedure of master station

The master station must proceed to a communication upon conforming to the following items.

1-1. Before sending a command message, provide 44 bits time or more vacant status.

1-2. For sending, the interval between bytes of a command message is below 22 bits time.

1-3. Within 22 bits time after sending a command message, the receiving status is posted.

1-4. Provide 44 bits time or more vacant status between the end of response message reception and beginning for next command message sending (same as in 1-1).

1-5. For ensuring the safety, make a confirmation of the response message and make an arrangement so as to provide 3 or more retries in case of no response, error occurrence, etc.

Note: The above definition is for most unfavorable value. For ensuring the safety, it's recommended the program of the master to work with safety factors of 2 to 3. Concretely, it is advised to arrange the program for 9600 bps with 10ms or more for vacant status (1-1), and within 1ms for byte interval (1-2) and changeover from sending to receiving (1-3).

2. Description

(1). Detection of the message frame

Since the communication system uses the 2-write RS-485 interface, there may be 2 statuses on a line below.

(a) Vacant status (no data on line)

(b) Communication status (data is existing)

Instruments connected on the line are initially at a receiving status and monitoring the line. When 22 bits time or more vacant status has appeared on the line, the end of preceding frame is assumed and, within following 22 bits time, a receiving status is posted. When data appears on the line, instruments receive it while 22 bits time or more vacant status is detected again, and the end of that frame is assumed. Data, which appeared on the line from the first 44ms time or more vacant status to the next 44 bits time or more vacant status is fetched as one frame.

1-1. 44 bits time or more vacant status precedes the command message sending.

1-2. Interval between bytes of 1 command message is smaller than 22 bits time.

(2). Response of this instrument (VT-20)

After a frame detection (22 bits time or more vacant status), this instrument carries out-processing with that frame as a command message. If the command message is destined to the own station, a response message is returned. Its processing time is 1 to 10ms (depends on contents of command message). After sending a command message, therefore, the master station must observe the following.

1-3. Receiving status is posted within 22 bits time after sending a command message.

5.7 Fix Processing (Cautions at write-in of data)

The instrument is provided inside with a non-volatile memory (EEPROM) for holding the setting parameters. Data written in the non-volatile memory is not lost even if

turning off the power. Data written in via communication are not written in this non-volatile memory but stored in the internal memory (RAM). If it is desired to hold the parameters written in via communication even after turning off the power, FIX processing must be carried out.
FIX execution writes the parameters stored in the internal memory into the non-volatile memory. See 6.3 for further detail.

Cautions:

- FIX processing lasts approximately 0.1 seconds.
- The non-volatile memory (EEPROM) is a device where the number of write-in times is limited. The guaranteed number of write-in times of the non-volatile memory used on the instrument is 10000 minimums. Don't carry out the FIX processing except when absolutely necessary such as after rewriting the setting the parameters. Refrain from carrying out of FIX processing periodically for example or while such is not absolutely required.

6. DETAILS OF MESSAGE

6.1 Read-out of Word Data [Function Code: 03]

Read the contents of holding registers (0000~ 007D) in the slave.
Broadcast is not possible.

1. Message composition

Command message composition

Address	Function	Starting Address	Word Number*	CRC-16	
01~FF	03	0xxx	0001~007E	Low-order byte	High-order byte
1 byte	1 byte	2 byte	2 bytes	2 bytes	

* Maximum word number = 7E

Response message composition

Address	Function	Byte Number *	Word Data	CRC-16	
01 ~ FF	03	02~FC		Low-order byte	High-order byte
1 byte	1 byte	1 bytes	N bytes	2 bytes	

* Byte number = Word number × 2

2. Message transmission (example)

The following show an example of reading the Setpoint Value (1000) from address No.1 controller.

Command message composition

Address	Function	Starting Address	Word Number	CRC-16
01	03	0000	0001	840A

Response message composition

Address	Function	Byte Number	Word Data	CRC-16
01	03	02	03E8	B8FA

6.2 Read-out of Read-Only Word Data [Function Code: 04]

Read the contents of input registers (1000~1002) in the slave.
Broadcast is not possible.

1. Message composition

Command message composition

Address	Function	Starting Address	Word Number	CRC-16	
01~FF	04	1xxx	0001~007E	Low-order byte	High-order byte

1 byte	1 byte	2 bytes	2 bytes	2 bytes

Response message composition

Address	Function	Byte Number	Word Data	CRC-16	
01 ~ FF	04	02~FC		Low-order byte	High-order byte
1 byte	1 byte	1 byte	N bytes	2 bytes	

2. Message transmission (example)

The following show an example of reading the Process Value (27) from address No.1 controller.

Command message composition

Address	Function	Starting Address	Word Number	CRC-16
01	04	1000	0001	350A

Response message composition

Address	Function	Byte Number	Word Data	CRC-16
01	04	02	001B	F93B

6.3 Write-in of Bit Data [Function Code: 05]

Fix processing, store the holding register data into EEPROM. When broadcast, the function affects all attached slaves.

1. Message composition

Command message composition

Address	Function	Data Address	Data	CRC-16	
01~FF	05	0xxx	FF00	Low-order byte	High-order byte
1 byte	1 byte	2 bytes	2 bytes	2 bytes	

Response message composition

Address	Function	Data Address	Data	CRC-16	
01~FF	05	0xxx	FF00	Low-order byte	High-order byte
1 byte	1 byte	2 bytes	2 bytes	2 bytes	

2. Message transmission (example)

The following show an example of storing the Setpoint Value of address No.1 controller into EEPROM.

Command message composition

Address	Function	Data Address	Data	CRC-16
01	05	0000	FF00	8C3A

Response message composition

Address	Function	Data Address	Data	CRC-16
01	05	0000	FF00	8C3A

6.4 Write-in of Word Data (1 word) [Function Code: 06]

1. Message composition

Command message composition

Address	Function	Starting Address	Word Data	CRC-16	
1 ~ FF	06	0xxx	0xxx	Low-order byte	High-order byte
1 byte	1 byte	2 bytes	2 bytes	2 bytes	

Response message composition

Address	Function	Starting Address	Word Data	CRC-16	
1 ~ FF	06	0xxx	0xxx	Low-order byte	High-order byte
1 byte	1 byte	2 bytes	2 bytes	2 bytes	

2. Message transmission (example)

The following show an example of writing the Setpoint Value to address No.1 controller.

Command message composition

Address	Function	Starting Address	Word Number	CRC-16

01	06	0000	01F4	89DD

Response message composition

Address	Function	Starting Address	Word Number	CRC-16
01	06	0000	01F4	89DD

7. ADDRESS MAP AND DATA FORMAT

7.1 Data Format

1. Transmission data format

The MODBUS protocol used in this instrument (VT-20) is RTU (Remote Terminal Unit) mode.

Transmitted data is “numeric value” and not “ASCII code”.

2. Internal calculation value and engineering unit

There are 3 different kinds of set value in the BCT series controllers.

1. Normal value:
   The data value is transfer into Hexadecimal regardless of decimal. For example: 1000 ℃ will be transfered to 03E8(hex), However, such as output percentage and Pb (proportional band), 100.0 % will be transfered to 03E8(hex).
2. English code:
   Some parameters value are set by index code. For example, to change the unit to ℃ via communication. The data value would be 0017(hex).

Code	English	Code	English	Code	English	Code	English
00	J	**0F**	ENG	**1E**	9.6K	**2D**	1101
01	K	**10**	0000	**1F**	19.2K	**2E**	1110
02	T	**11**	000.0	**20**	0000	**2F**	1111
03	E	**12**	00.00	**21**	0001	**30**	HI
04	B	**13**	0.000	**22**	0010	**31**	LO
05	R	**14**	REV	**23**	0011	**32**	DIF.H
06	S	**15**	DIR	**24**	0100	**33**	DIF.L
07	N	**16**	NONE	**25**	0101	**34**	BD.HI
08	C	**17**	STDY	**26**	0110	**35**	BD.LO
09	D-PT	**18**	LATH	**27**	0111	**36**	T.ON
0A	J-PT	**19**	ST.LA	**28**	1000	**37**	T.OFF
0B	LINE	**1A**	HH.MM	**29**	1001	**38**	NONE
0C	℃	**1B**	MM.SS	**2A**	1010	**39**	LO
0D	℉	**1C**	2.4K	**2B**	1011	**3A**	HI
0E	ENG	**1D**	4.8K	**2C**	1100	**3B**	HI.LO

7.2 Data Address Map

■ Word data (read-out/write-in) : Function code [03,,05,06]

Data Address	Parameter	Range	Unit
0000	SV	HiLt~LoLt	℃/℉
0001	SPOF	-1000~1000	℃/℉
0002	PVOF	-1000~1000	℃/℉
0003	A1SP	-1000~1000	℃/℉
0004	A2SP	-1000~1000	℃/℉
0005	A3SP	-1000~1000	℃/℉
0006	PB	0.0~300.0	%
0007	TD	900	Sec
0008	CT	0~100	Sec
0009	HYST	0~2000	℃/℉
000A	A1HY	0~2000	℃/℉

000B	A2HY	0~2000	℃/℉
000C	A3HY	0~2000	℃/℉
000D	LOCK	0000~1111	
000E	TYPE	J/K/B/R/S/T/E/N/C/DPT/JPT/LINE (English code)	
000F	UNIT	℃ / ℉ / ENG (English code)	
0010	DP	0000/000.0/00.00/0.000 (English code)	
0011	ACT	REV / DIR(English code)	
0012	LOLT	-1999~9999	℃/℉
0013	HILT	-1999~9999	℃/℉
0014	FILT	0.0~-100.0	
0015	A1FU	None/Hi/Lo/dif.H/dif.L/bd.Hi/bd.Lo/T.SNL (English code)	
0016	A1MD	None/Stdy/Lath/St.La/T.End (English code)	
0017	A2FU	None/Hi/Lo/dif.H/dif.L/bd.Hi/bd.Lo/T.SNL (English code)	
0018	A2MD	None/Stdy/Lath/St.La/T.End (English code)	
0019	A3FU	None/Hi/Lo/dif.H/dif.L/bd.Hi/bd.Lo/T.SNL (English code)	
001A	A3MD	None/Stdy/Lath/St.La/T.End (English code)	
001B	ADDR	0~255	0
001C	BAND		
001D	CH01	0~2000	
001E	CL01	0~2000	
001F	RTSH	0~3000	
0020	RTSL	0~3000	
0021	MR	0.0~100.0	%

■ Word data (read-out only) : Function code [04]

Data Address	Parameter	Contents	Unit
1000	PV	Process value	

8. TROUBLESHOOTING

8.1 Troubleshooting

If the communication is unavailable, check the following items.

- ☐ Whether all devices related to communication are turned on.
- ☐ Whether connections are correct.
- ☐ Whether the number of connected instruments and connection distance are as specified.
- ☐ Whether communication conditions coincide between the master station (host computer) and slave station (BCT).
  - ☐ Transmission speed : ☐ 2400 bps ☐ 4800 bps ☐ 9600 bps ☐ 19200 bps
  - ☐ Address :01 ~ FF (master and slave station must be match)
- ☐ Whether send/receive signal timing conforms to Section 5.4 in the manual.
- ☐ Whether more than one instrument connected on the same transmission line share the same address.