PR212/D-M Modbus™ System Interface

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1. General

This document describes the Modbus™ interface regarding:

- Network Management of the device (installation, configuration, …)
- Application Objects and Slave Variables

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Modbus	984	P190	SM85
ModConnect	BM85	RR85	SQ85
Modcom	BP85	SA85	

1.1 Applicability

This document applies to the Communication Unit of the PR212/D-Modbus™ (also called PR212/D-M) device connected to the Protection Unit PR212/P only.
It could be used as a starting point for other Modbus™ device too.

1.2 Applicable Documents

[1] Schneider Automation Inc., '*Modicon MODBUS Protocol Reference Guide*', June 1996, rev. J, PI-MBUS-300

1.3 Acronyms and Definitions

1.3.1 Acronyms

AI	**Analog Input**
AO	**Analog Output**
AppObj	**Application Object**
CB	**Circuit Breaker (MCCB ISOMAX family)**
CP	**Configuration Parameter**
CT	**Current Transformer**
CU	**Communication Unit (PR212/D-M)**
DI	**Digital Input**
DCP	**Dialogue (CU) Configuration Parameter**
DO	**Digital Output**
ETT	**Electronic Trip Test**
In	**Nominal current**
LSb	**Least Significant bit**
LSB	**Least Significant Byte**
MSb	**Most Significant bit**
MSB	**Most Significant Byte**
MTT	**Mechanical Trip Test**
PCP	**Protection Configuration Parameter**
PU	**Protection Unit (PR212/P)**
OR	**(Main) Opening Release**
SOR	**Shunt Opening Release**
UVR	**Under Voltage Release**

1.3.2 Definitions

ALARM there are two types of alarm:

Alarm Type	Definition
Alarm	It's similar to a status. It will be frozen after a protection trip. A Trip Reset is NOT necessary to reset it. Ex. L Pre-Alarm, S Alarm, ...
Trip	Only a command can reset it, i.e. a new alarm won't be signalled until the reset. Ex. L Tripped, S Tripped, ...

Trips are reset after a Trip Reset command.

BUFFER Meaningful part of a Modbus™ Map section.

It's defined by the device Modbus™ Map.

CB RESET command equal to a Trip Reset.

COIL the least digital information container (i.e. one bit)

COMMUNICATION UNIT PR212/D-M electronic board that implements the Modbus™ interface

DEVICE Communication Unit (i.e. the PR212/D-M)

EVENT information that signals a normal (foreseen) device behaviour.

Typically, the producer of an event is the device, while the consumer (who resets it) is the system.

Reset of an event is automatically done after a read operation from the system.

ITEM a Digital (coil) or an Analog (register) Modbus™ data type

OPERATION every CB status transition toward OPEN state. It doesn't matter which is the starting state (TRIPPED or CLOSED).

OTHER TRIPS sum of CB status transitions toward the TRIPPED state, either from the OPEN or CLOSED starting state, but not caused by the protection.

So they are all the transitions caused by an electronic / mechanical trip test, under voltage release and secondary shunt opening release.

PARAMETER information that allows configuration of a device functionality (e.g. a protection algorithm).

PERSISTENCE 'volatile/non-volatile' attribute concerning information, i.e. the information is/is not still available after a power fail/HW reset/...

PERSISTENCE	Description
Temporary (default)	Information is NOT still available after a power fail/HW reset/...
Permanent	Information is still available after a power fail/HW reset/...

For example, parameters and trip data have this attribute set to PERMANENT, while states/events/alarms settings are TEMPORARY.

PROTECTION TRIPS	sum of real protection trips (Σ LSIG trips). 'Real' means 'not caused by the Test Unit PR010/T. Trips that come up when: – Test Unit connected – CB closed and/or currents NOT equal to zero are considered 'real'. In fact, in his case the Test Unit can only read values and can NOT simulate a trip.
PROTECTION UNIT	PR212/P electronic board that implements protection algorithms
PROTECTION X TRIPS	sum of trip of protection X (e.g. L, S, I, G).
REGISTER	the least analogue information container (one word = 2 bytes)
STATUS	information that represents the dynamics of a functionality (e.g. the CB or a protection algorithm). It can be managed (i.e. set/reset) only by the device itself.
TRIP COMMAND FAIL	after a protection trip, with relevant opening command to the release, CB stays in CLOSED state. In this case, the CU tries to open the CB using the YO.
TRIP RESET	event (Any Alarm) /alarm reset of any information related to the (last) trip. It doesn't change the 'real' CB status (i.e. the CB is OPEN) but it changes the 'virtual' CB status from TRIPPED to OPEN.
(PROCESS) VARIABLE	information strictly connected to device functionality. Examples are: – commands – states/events – alarms – measurements – historical/statistical data – ...

2. Introduction

It has been decided to describe the device according to the Modbus™ protocol [1] and a high level description for different functionality called *Application Object (AppObj)*.
These AOs manage the reporting of the Protection Unit information to the remote system. This information is polled by the Communication Unit to the Protection Unit according to the Internal Bus Protocol.
Moreover the Communication Unit manages the Internal Bus sharing with the Test Unit (e.g. PR010/T) according to the Master Token Protocol.

2.1 Modbus™ Protocol and Map Organisation

2.1.1 Communication parameters

1. Transmission mode: RTU (2 four bits hexadecimal chars for each byte).

2. Serial parameters:

Start Bit	Data Bits	Parity Bit	Stop Bit
1	8 (LSb first)	1 (even | odd)	1

Table 1. Serial parameters

Please note that mode and serial parameters MUST be the same for all devices on a Modbus™ network.
Only the parity parameter is modifiable.

3. Baud Rate: [9600 | 19200].

DEFAULT VALUES: Even Parity, Baud Rate = 19200

2.1.2 Device RTU Framing

START	SLAVE ADDRESS	FUNCTION	DATA	CRC CHECK	END
T1 – T2 – T3 – T4	8 bits	8 bits	n * 8	16 bits	T1 – T2 – T3 – T4

Figure 1. Modbus™ message

Up to 256 bytes can be sent.

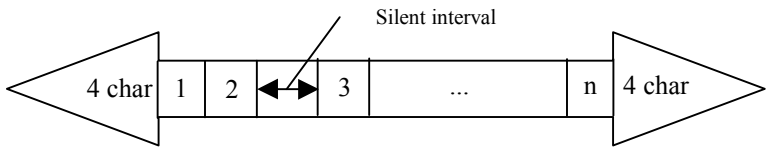
The allowed inter-character silent interval is been relaxed from ‘at least 2 characters’ to ‘at least 4 characters’ (the same silent interval to recognise the end of a message). This means:

2.1.2.1 Silent interval < 4 char between two characters inside the message

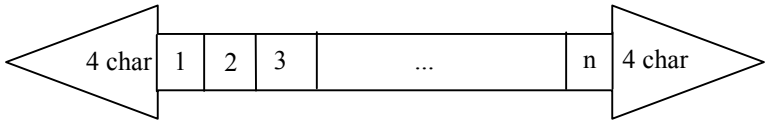
In this case the receiver filters the silent interval and the following characters will be appended to those already received.
The difference from the protocol specification is:

1. Silent interval < 2 char between two characters inside the message

Transmitter



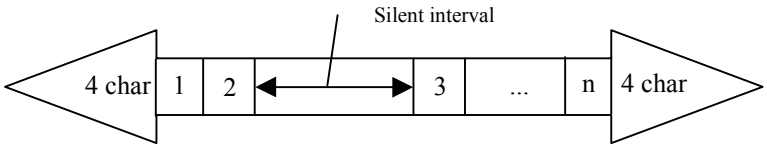
Receiver



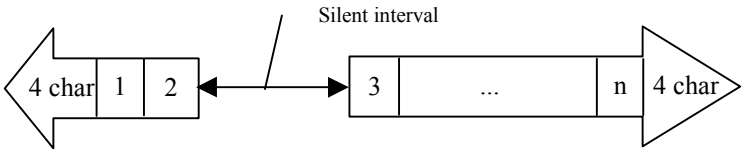
The behaviour is exactly as specified by the protocol.

2. Silent interval ≥ 2 char and < 4 char between two characters inside the message
The received characters are NOT flushed and the following ones will be appended.

Transmitter



Receiver



Note that after flushing, the standard protocol specification allows:

- reception of the remaining characters of a partially received message;
- reception of a completely new message.

The device behaviour **doesn't cover the second case** because it always appends new incoming characters to the previous ones, leading to a CRC error.
So the behaviour is exactly the same if and only if the incoming characters are NOT a new message. In this case the received packet will lead to a CRC error and the CRC error counter will be incremented.

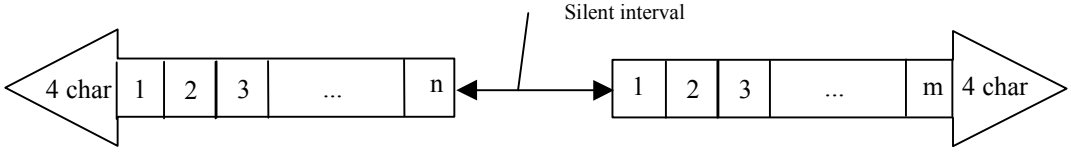
2.1.2.2 Silent interval ≥ 4 char between two characters inside the message

If the message transmission is NOT ended, all the previously received characters are managed as a message because this is exactly the protocol specification regarding the end of a message.

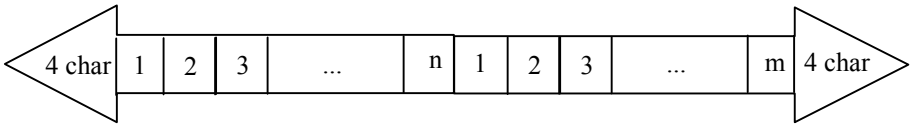
2.1.2.3 New frame before 4 character silent interval at the end of a frame

In this case the receiver filters the silent interval and the following characters (of the new frame) will be appended to those already received (see case 2 of par. 2.1.2.1).
This will lead to a CRC error.

Transmitter



Receiver



So the CRC error counter will count both the 'real' CRC errors and the inter-character errors.

2.1.3 Response Timeout

The reported timeouts have been measured over more than 100 samples (normal responses) in the following conditions:

- device in 'normal' status, i.e. only measurements are periodically updated and NO alarm conditions are satisfied

	Minimum (ms)	Medium (ms)	Maximum (ms)
Single COIL Read	16.62	17.81	19.02
Multiple COILS (29) Read	19.71	20.8	22.39
Single REGISTER Read	18.16	18.16	20.1
Multiple REGISTERS (52) Read	76.86	78.21	80.36

Table 2. Response Timeout

Please note that the multiple items read has been performed on maximum number of items allowed by the device map, in particular:

- 29, status / events, alarms, trips
- 52, present parameters in use

The minimum suggested response timeout for **periodically polled information** is 25 ms.

2.1.4 Reception checks

After reception, the device performs the following checks:

- CRC,
- Max Message Length allowed (256 bytes),
- Slave Address.

If any of this information is not correct, the received message is discarded and no response message is sent back to the Master.

2.1.5 Function Codes

The following standard functions have to be supported:

Code	HEX Code	Name	Applies to
01	0x01	Read Coil Status	DO
02	0x02	Read Input Status	DI
03	0x03	Read Holding Register	AO
04	0x04	Read Input Register	AI
05	0x05	Force Single Coil	DO
06	0x06	Preset Single Register	AO
08	0x08	Diagnostic Sub-function: 0 (0x00)	
15	0x0F	Force Multiple Coils	DO
16	0x10	Preset Multiple Registers	AO
17	0x11	Report Slave ID	

Table 3. PR212/D-M function codes

All other NOT supported function codes lead to an Exception response 'ILLEGAL_FUNCTION'.

These functions can be grouped into two different categories:

1. Data Management functions.
   Functions applied to device data into the Modbus™ Map (codes 01, 02, 03, 04, 05, 06, 15 and 16).

2. Network / Device Management functions.
   Functions applied to device that can:
   - request / setting general information
   - change the device behaviour / status
   - …

   Function codes 08 and 17 belong to this category.

2.1.5.1 08 (0x08) Diagnostic

The function uses a two-byte sub-function code field in the query to define the type of test to be performed.
Most of the diagnostic queries use a two-byte data field to send diagnostic data or control information to the slave.

Sub-function Hi	Sub-function Lo	Data Hi	Data Lo

Figure 2. 'Diagnostic' query data field structure

where the only supported sub-function code is:

Sub-function code	HEX code	Name	Description
00	0x00	Return Query Data	The data passed in the information field will be returned to the Master via the addressed Modbus™ Slave. The entire message returned should be identical to the message transmitted by the Master, field-per-field.

NOTE: the protocol specification on data field ('Any', pages 74 – 75, 77) is NOT clear. The device allows both a generic field length (i.e. more than two bytes) and a generic value range.

2.1.5.2 17 (0x11) Report Slave ID

A normal response has some fields defined and others device dependent:

Byte Count	Slave ID	Run Indicator Status	Additional Data ...

Figure 3. 'Report Slave ID' response data field structure

where:

- 'Byte Count' depends on 'Additional Data'. Its minimum value is 2.
- 'Slave ID' is the identifier of the device of a specific manufacturer (i.e. devices from different manufacturers could have the same 'Slave ID'):

Slave ID	Device
22 = 0x16	PR212/D-M

Table 4. Slave ID

- 'Run Indicator Status' reports the current Slave Run status, fixed to ON (0xFF).

2.1.6 Data Addressing (Map organisation)

Two different data addressing types are implemented:

1. Standard Modbus™ addressing
2. ABB SACE addressing (old ABB SACE Modbus™ Communication Units)

Standard			**ABB**	
Starting Address	**Item Address**	**Data Type**	**Starting Address**	**Item Address**
0 … 9999	1 … 10000	DO	1 … 10000	1 … 10000
0 … 9999	10001 … 20000	DI	10001 … 20000	10001 … 20000
0 … 9999	30001 … 40000	AI	30001 … 40000	30001 … 40000
0 … 9999	40001 … 50000	AO	40001 … 50000	40001 … 50000

It is possible to configure it using the 'Network Info' menu of the HMI.

The organisation of every section of the map (i.e. DO, DI, AI, AO) can be partitioned into different areas, called '*buffers*', containing a contiguous number of item. For example

Item Address	**Item Value**
1	
…	
27	
28	
29	
30	
31	
…	
…	
10000	

defines a DO buffer starting at 27 and with length 5 (grey cells are map items not defined for the device).

Please note that:

Item Address	Item Value
1	
…	
27	
28	
29	
30	
31	
32	
…	
10000	

defines two different DO buffers. The first one starts at 27 with length 2, while the second one starts at 30 with length 3.

It's possible to query a buffer as a whole or a portion of it, but **it's NOT possible to query two buffers within the same message: an exception response will rise up.**

2.1.6.1 Standard Modbus™ Addressing

In Modbus™ messages Start Address is always referred to zero.

Every single item in these sections is identified by a LOGICAL ABSOLUTE ADDRESS in the following ranges:

Data	Logical Absolute Address Range	Offset / Reference (decimal)	Offset / Reference (hex)
DO	00001 – 10000 (MAX_DO_ADDR)	00000 (DO_OFFSET)	0x0000
DI	10001 – 20000 (MAX_DI_ADDR)	10000 (DI_OFFSET)	0x2710
AI	(MIN_AI_ADDR) 30001 – 40000 (MAX_AI_ADDR)	30000 (AI_OFFSET)	0x7530
AO	40001 – 50000 (MAX_AO_ADDR)	40000 (AO_OFFSET)	0x9C40

Table 5. Modbus™ logical memory map

Please note that when the Master specifies the 'Starting Address' into the Modbus™ message, it uses a LOGICAL RELATIVE ADDRESS, calculated from the LOGICAL ABSOLUTE ADDRESS:

Starting Address = LOGICAL RELATIVE ADDRESS
= LOGICAL ABSOLUTE ADDRESS – XX_OFFSET –1
= Item Address – XX_OFFSET –1 **Equation 1.**

So the Logical Relative Address Range is 00000 – 09999 (= 0x270F, MAX_RELATIVE_ADDR) for all data types.

Moreover, items like 10005, 40001, ... are addressed like 0005, 0001, ... because the function code uniquely identifies the portion of Modbus map they belong to.

Example
Coil with LOGICAL ABSOLUTE ADDRESS = 13 will be addressed by the Master with the LOGICAL RELATIVE ADDRESS = 12.

Register with LOGICAL ABSOLUTE ADDRESS = 32475 will be addressed by the Master with the LOGICAL RELATIVE ADDRESS = 32475 – 30000 – 1 = 2474.

So the device performs the following check on the Starting Address field:

- Starting Address range between 0 and 9999
- Starting Address belongs to a valid part of the section pointed by the Function Code

2.1.6.2 ABB SACE Addressing

The item address is:

Starting Address = LOGICAL ABSOLUTE ADDRESS = Item Address

The device performs the following check on the Starting Address field:

- Starting Address congruency with the section pointed by the Function Code (see Table 5).
- Starting Address belongs to a valid part of the pointed section

2.1.7 Data Field

The data field is formed by an 'header' part and a data value part: following points consider only the header part of this field.

In some function, there could be a 0 length data field (i.e. the message contains only the function code like in the 'Report Slave ID' function).

There is no restriction to max data length except the maximum message length (256 bytes).

2.1.7.1 Query

Number of items [2 bytes] (except writing functions 5 and 6)	**Byte Count (only for writing functions 15 and 16) [1 byte]**
How many items to read/write	How many data bytes follow

Figure 4. Query data field structure

Function Code	Data Type	Max number of items	Max byte count	Min message length	Max message length
1	DO	2008 (251 * 8)	N/A	8	8
2	DI	2008 (251 * 8)	N/A	8	8
3	AI	125	N/A	8	8
4	AO	125	N/A	8	8
5	DO	N/A (1 fixed)	N/A	8	8
6	AO	N/A (1 fixed)	N/A	8	8
15	DO	1976 (247 * 8)	247	10	256
16	AO	123	246	11	256

The device performs the following checks on the above-mentioned fields:

- Max number of items, conforming to the Function Code
- Byte Count congruency with the Number of Items
- Data value field length congruency with the Byte Count

Moreover, also the following checks are performed:

- (Starting Address + Number Of Items) belongs to the section pointed by the Function Code
- (Starting Address + Number Of Items) belongs to a valid part of the pointed section

2.1.7.2 Response

1. Read function codes

Byte Count (only for writing functions 15 and 16) [1 byte]
How many data bytes follow

Figure 5. Read function response data field structure

Function Code	Data Type	Max number of items	Max byte count	Min message length
1	DO	2008 (251 * 8)	251	6
2	DI	2008 (251 * 8)	251	6
3	AI	125	250	7
4	AO	125	250	7

2. Single item Write function codes (5, 6)
   It' simply an echo of the query message.

3. Multiple items Write function codes (15, 16)

Starting Address [2 bytes]	Number of items [2 bytes]
Starting item	How many items to read/write

Figure 6. Multiple items Write function response data field structure

So the message length is fixed and equal to 8.

2.1.8 Exception Responses

In this case, the MSb of the function code in the response message is set to one and an error code is added.

Error Code	Error Name	Meaning
01	ILLEGAL FUNCTION	The function code received in the query is not an allowable action for the slave. If a 'Poll Program Complete' command is issued, this code indicates that no program function preceded it.
02	ILLEGAL DATA ADDRESS	The data address received in the query is not an allowable address for the slave.
03	ILLEGAL DATA VALUE	A value contained in the query data field in not an allowable value for the slave.
06	SLAVE DEVICE BUSY	The slave is processing a long-duration program command. The master should retransmit the message later when the slave is free.

Table 6. Exception response error codes

No response is sent by the slave device if there is a communication error (i.e. a parity o a CRC error).

Error Code	Error Name	When
01	ILLEGAL FUNCTION	1. The message is too short (i.e. there is NO Function Code field!), with right CRC. 2. Device does NOT support the received Function Code. Please note that this means that the Function Code 2 (Read Input Status, DI) will NOT lead to this Exception.
02	ILLEGAL DATA ADDRESS	1. The message is too short (i.e. there is NO Starting Address field!), with right CRC. 2. Starting Address is > 10000 (Standard Addressing Type). 3. Starting Address is outside a map section (ABB SACE Addressing Type). 4. Starting Address doesn't belong to any buffer.
03	ILLEGAL DATA VALUE	1. The message is too short, with right CRC. 2. The message is too long, with right CRC. 3. Diagnostic function: sub-function is not supported (≠ 0) 4. The Number of Items is NOT in range (= 0 or > Max number of items, see 2.1.7). 5. Byte Count is different from the number of bytes calculated using the number of items and the relevant data type. 6. The whole query requested buffer (Starting Address + Number of Items) doesn't belong to a device map buffer. 7. Force Single Coil function: the value is different from 0x0000 or 0xFF00. 8. Command value: it is different from '1'. 9. DCP Installation Date value: not valid
06	SLAVE DEVICE BUSY	1. Start-up (before complete polling of PU information) 2. Commands inhibition (see par. 6.2.3)

2.2 Installation and Configuration

At the first start-up, the device is configured for communication to the Remote System, i.e. Operating Mode = REMOTE.
The communication parameters to be defined are:

Communication Parameters	Allowed Values	Start Up Values
Slave Address	{1 … 247} | 255 (UNCONFIGURED)	255 (UNCONFIGURED)
Baud Rate	9600 | 19200 bit/s	19200 bit/s
Parity	Even | Odd	Even
Addressing Type	Standard | ABB SACE	Standard

These parameters can be changed locally only using device dip switches.

If the device is NOT configured (i.e. Slave Address = 255), no query is processed.

3. Start-up behaviour

At start up, the Communication Unit switches on all the LEDs, and needs about 5 seconds to update the information coming from the Protection Unit. During this time, the data are not available to the Remote System: the Communication Unit returns a "SLAVE DEVICE BUSY" exception response to any query coming from it.

If an "Internal Bus Fault" condition occurs during the Start-up, preventing from information update, the CU sets all the information to default values, letting the Remote System to read the data:

Data Type	Default Values	Description
States/Events/Alarms/Trips (but IB Status)	0	No alarm pending: the only one set is "IB Fault"
IB Status	1	This value are readable only when a "IB fault" condition occurs at start up
CB States	Value read from I/O	They don't depend on Internal Bus communication
Parameters	0xFF	Values out of allowed ranges
Measurements	0xFF	Values out of allowed ranges → Not reliable data
Communication Statistics	0	They are updated run-time
PU Process Statistics	0xFF	Data not available
CU Process Statistics	Value read from EEPROM	They don't depend on Internal Bus communication

4. Operating Mode

The device can operate in two different modes, Local and Remote. The mode can be selected by pressing the 'REMOTE DISABLED' push button and the 'REM. DIS. / I.B. FAULT' LED displays the actual state.
At start-up, the default state is "Remote", i.e. 'REM. DIS. / I.B. FAULT' LED switched off.
See the following finite state machine:

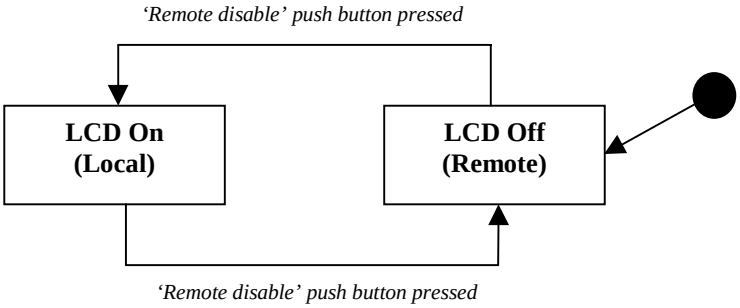


Figure 7. 'REMOTE DISABLED' push button and 'REM. DIS. / I.B. FAULT' LED behaviour

Please note that if there is an Internal Bus Fault, the 'REM. DIS. / I.B. FAULT' LED flashes until the I.B. connection returns OK. After that, the 'REM. DIS. / I.B. FAULT' LED displays the actual operating mode again.

4.1 Local Operating Mode

From the remote point of view, the device has the following behaviour:

Actions forbidden	Actions allowed
No remote parameterisation allowed	Consultation of measurements
No remote command allowed	Consultation of configuration parameters of the device
	Consultation of protection unit information

4.2 Remote Operating Mode

From the remote point of view, the device has the following behaviour:

Actions forbidden	Actions allowed
None	Remote parameterisation allowed
	Remote command allowed
	Consultation of measurements
	Consultation of configuration parameters of the device
	Circuit Breaker commands (open / close)
	Trip Reset / CB Reset

5. Configuration parameters programming model

The Protection Unit connected to the Communication Unit can use two different parameter sets:

1. Manual parameter set
2. Electronic parameter set, also called Protection Configuration Parameters (PCPs)

The frontal PU dip-switch 'MAN / ELT' selects which set is used and is reported to the Remote System via the 'Electronic/Manual Parameters Settings' state.

Moreover, there are also two different parameter sets for the CU:

3. Manual parameter set
4. Electronic parameter set, also called Dialogue Configuration Parameters (DCPs)

The programming model described further applies to the electronic parameter set only.

5.1 PU Manual parameters

Manual parameter values can be changed **locally only** using frontal PU dip-switches, so these values are READ ONLY from the System.
This set is used by the PU when either the 'MAN / ELT' dip-switch is set to 'MAN' or the Electronic parameters are corrupted.

The Communication unit reads the manual parameter set from the Protection Unit:

- at start-up
- when the 'MAN / ELT' dip switch is set to 'MAN', every 2 seconds
- when the 'MAN / ELT' dip switch is changed from 'MAN' to 'ELT'
- after an I.B. fault

Every time the manual parameter set is read, if it's changed, the 'Manual parameter changed' event rise up.
Moreover, if some parameters are not consistent with each other (e.g. Protection L and Protection S thresholds), also the 'Manual parameter error' event rise up and the register 'Programming Fail Code' contains the code associated to the description of the error (see par. 8.1.4).

NOTE
The manual 'Neutral Selection' parameter is always periodically read because this parameter is necessary to calculate the right neutral current value.

5.2 CU Manual parameters

Also CU Manual parameter values can be changed **locally only** using upper CU dip-switches, so these values are READ ONLY from the System.
This set is concerning the communication parameters only:

Communication Parameters
Slave Address
Baud Rate
Parity
Addressing Type

These parameters are read at start-up ONLY (e.g. after a reset pressing the RESET push button).
So the following actions are needed to change the CU manual parameters:

1. Set the relevant CU dip-switches
2. Press the RESET push button

5.3 Local programming state

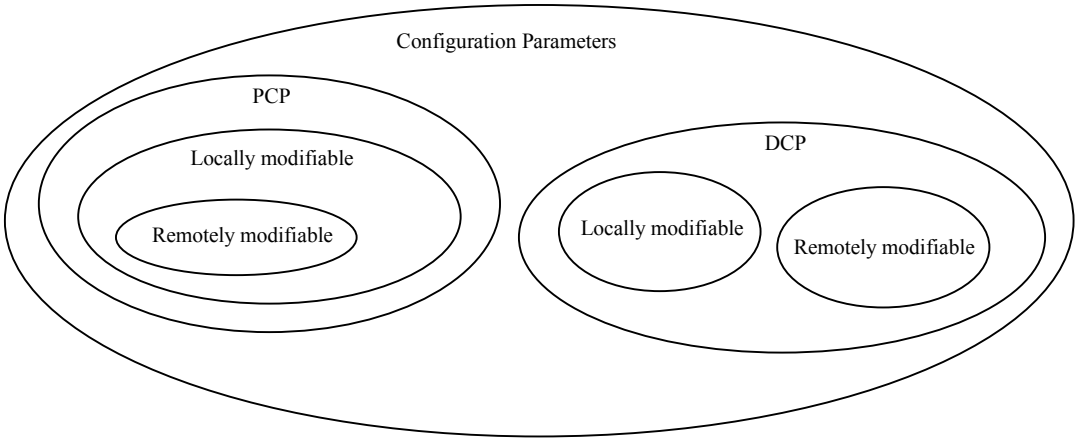


Figure 8. Configuration parameters categories

PR212/P is considered to be in "Local Programming" state when at least one of the following situations is verified:

1. Test Unit Connected
   When the Test Unit disconnection occurs, the CU always reads the electronic parameter set to eventually update it towards the Remote System.

5.4 Remote programming model

It is possible to configure two different kinds of configuration parameters:

a) Protection Configuration Parameters (PCP) relevant to the PU
b) Dialogue Configuration Parameters (DCP) relevant to the CU

All these configuration parameters are readable, while only some of them are remotely modifiable.

All configuration parameters are Items. They can be:

- READ ONLY (the system can't modify them)
  The configuration parameter is associated only to an Input Item (DI / AI)
- READ/WRITE (the system can modify them)
  The configuration parameter is associated both to an Input (DI / AI) **and** to an Output (DO / AO) Item

Obviously, "READ/WRITE" configuration parameters are a subset of those "READ ONLY".

5.4.1 Programming Model

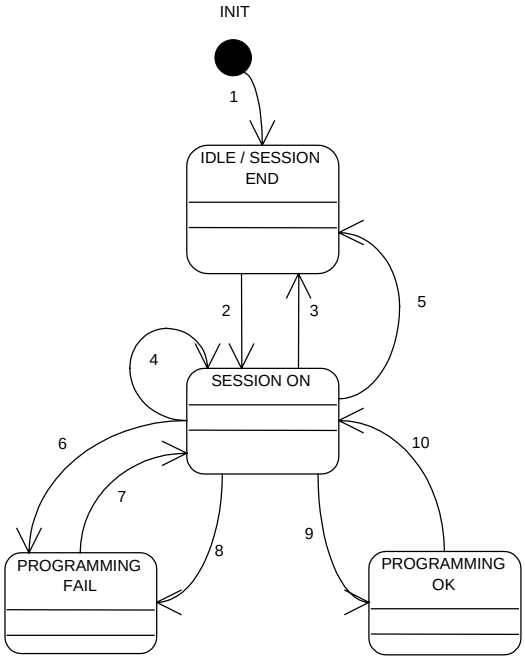


Figure 9. Remote Programming Model state chart

STATE NAME	STATE DESCRIPTION	PROGRAMMING OK Item	PROGRAMMING FAIL Item
INIT	Initial state	0	0
IDLE / SESSION END	Session is ended	0	0
SESSION ON	Session is active	1	1
PROGRAMMING OK	Session ended without errors	1	0
PROGRAMMING FAIL	Session ended with errors	0	1

TRANSITION	INITIAL STATE	FINAL STATE	TRANSITION CONDITION
1	INIT	IDLE / SESSION END	Start-up
2	IDLE / SESSION END	SESSION ON	'Start programming' command received from system.
3	SESSION ON	IDLE / SESSION END	'Abort programming' command received from system.
4	SESSION ON	SESSION ON	'Start programming' command received from system.
5	SESSION ON	IDLE / SESSION END	Session timeout (1 hour)
6	SESSION ON	PROGRAMMING FAIL	'Stop programming' command received from system **and** errors detected (see also 'Programming Fail Code').
7	PROGRAMMING FAIL	SESSION ON	'Start programming' command received from system.
8	SESSION ON	PROGRAMMING FAIL	A 'local' aborting event has occurred: 1. Internal Bus Fault 2. Operating Mode from REMOTE to LOCAL
9	SESSION ON	PROGRAMMING OK	'Stop programming' command received from system **and** NO errors detected.
10	PROGRAMMING OK	SESSION ON	'Start programming' command received from system.

The actions associated to each transition are:

TRANSITION	ACTION
1	N/A
2	1. Set the programming items. 2. Copy the 'Present parameters' buffer into 'New Parameters'.
3	Reset the programming items.
4	Copy the 'Present parameters' buffer into 'New Parameters'.
5	Reset the programming items.
6	1. If needed, PU programming. 2. If there is NO error and it's needed, CU programming. 3. If there is an error, reset the 'Programming OK' item **and** write the 'Programming Fail Code' item.
7	1. Set the 'Programming OK' item. 2. Copy the 'Present parameters' buffer into 'New Parameters'.
8	Reset the 'Programming OK' item.
9	1. If needed, PU programming. 2. If there is NO error and it's needed, CU programming. 3. If there is NO error, reset the 'Programming Fail' item **and** set the 'Parameter Changed' item
10	1. Set the 'Programming Fail' item. 2. Copy the 'Present parameters' buffer into 'New Parameters'.

NOTE: When the CU is in SESSION ON state, the Internal Bus is NOT shared with the Test Unit, i.e. the Master Token is not released from the CU to the Test Unit.

6. Commands

The CU manages two different command 'sources':

1. Remote Operator Station, i.e. a remote command from the system (remote command)
2. Local Operator, i.e. an action performed locally on the circuit breaker (local command)

From now on, the word 'command' means 'remote command'.

CONSTRAINT: no remote CB command can be completed (i.e. the CB mechanical status changes) if the frontal AUTO / MANUAL selector is set to MANUAL.
In this case, the relevant Modbus™ Map item is **NOT** reset, so no other CB command can be processed.
The only way to reset it is a LOCAL CB command (i.e. Open, Close or Reset).

6.1 Command Categories

Remote commands handled by CU can be organised in three different categories:

a) Protection Unit Slow Commands: they are the commands requiring a significant amount of time for being executed due to an 'heavy' interaction with the PU
   - Start Programming
   - Stop Programming

b) Protection Unit Fast Commands: they are the commands requiring a negligible amount of time for being executed, even if there is an interaction with the PU
   - Abort Programming
   - Wink
   - Trip Reset

c) Circuit Breaker Commands: they are commands concerning only the Circuit Breaker
   - CB Open
   - CB Close
   - CB Reset

Only the value '1' is allowed for a command.
If a different value is sent, an exception response 'ILLEGAL_DATA_VALUE' will be returned.

The commands concerning only the PU (e.g. Trip Reset) and not the Circuit Breaker are independent from CB states.
'CB Reset' command implies the 'Trip Reset' command too, so this command concerns both the PU and the CB.

6.1.1 Wink Command

The "wink" command is used for recognising a device by making its POWER LED flashing.
The command is sent from the Remote System and has a toggle behaviour, i.e., to stop the POWER LED display flashing another "wink" command has to be sent.
See the following finite state machine:

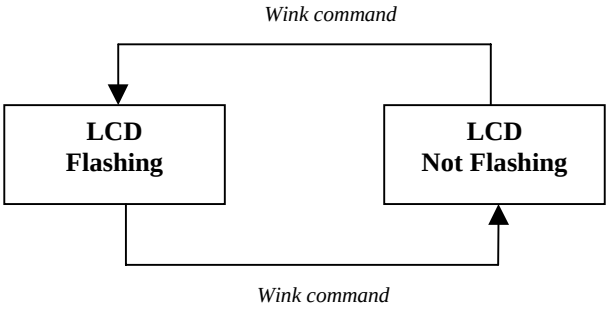


Figure 10. Wink Command behaviour

6.1.2 Trip Reset
This command resets:

1. the internal CU states
2. the external signalling unit (e.g. PR010/K)

6.1.3 CB Reset
This command resets:

1. the internal CU states
2. the external signalling unit (e.g. PR010/K)

and changes the mechanical CB status from TRIPPED to OPEN. After a Trip Command Fail and CB in OPEN state, this command doesn't change the mechanical CB status.

This is also the behaviour of the CU when a LOCAL CB Reset command is issued by opening the CB (i.e. changing its mechanical status from TRIPPED to OPEN).

6.1.4 Remote 'CB Close' command after Trip Command Fail
When a "Trip Command Fail" condition occurs (see its definition in par. 1.3.2), the CB reaches the "Open" position: in this situation the only allowed remote command is "Trip Reset". Only after it, the "Close" command is accepted.

6.2 Commands management

6.2.1 Commands completion

After receiving a command, the CU verifies the inhibition conditions and sends the response.
If there is an error, an exception response is sent and the requested command is NOT processed.

Even if there is an error or not, during this time, the relevant command item is NOT reset, signalling that the command is pending, and command completion will be signalled by the relevant item reset.

If there is NO error, the command result is signalled in the following way:

	Command result
Start Programming	Programming OK = Programming Fail = 1 (i.e. Remote programming session ON)
Abort Programming	Programming OK = Programming Fail = 0 (i.e. Remote programming session OFF)
Stop Programming	1. Programming result = OK • Programming OK = 1, Programming Fail = 0 • Parameter changed = 1 2. Programming result = FAIL • Programming OK = 0, Programming Fail = 1 3. Nothing changed • Programming OK = Programming Fail = 0
Wink	1. LCD Display flashing ON / OFF 2. Warning message on the first line of the LCD Display
Trip Reset	1. Trip Command Fail reset, if previously set (mutually exclusive with CB Tripped Item) 2. Other Trip reset, if previously set (mutually exclusive with Protection Trip Item) 3. Relevant Trip Item reset ➔ Any Trip reset 4. Signalling Unit reset, if present
CB Open	CB Open / Closed = 0
CB Close	CB Open / Closed = 1
CB Reset	1. Open command to the 2. CB Tripped = 0, if previously set (mutually exclusive with Trip Command Fail Item) 3. Trip Command Fail reset, if previously set (mutually exclusive with CB Tripped Item) 4. Other Trip reset, if previously set (mutually exclusive with Protection Trip Item) 5. Relevant Trip Item reset ➔ Any Trip reset 6. Signalling Unit reset, if present

LEGENDA		Slow Command Type
		Circuit Breaker Command Type
		Fast Command Type

Table 7. Command results

6.2.2 CB commands execution

In case of CB command (i.e. 'CB Open', 'CB Close' and 'Cb Reset'), the command implies an external actor (i.e. a power actuator) for its completion.
Because of this, a particular event is defined, 'CB Command Executed', that signals the end of the CU command processing.

This event is reset before the CU starts driving the external actor and it's set after the CU has completed driving the external actor:

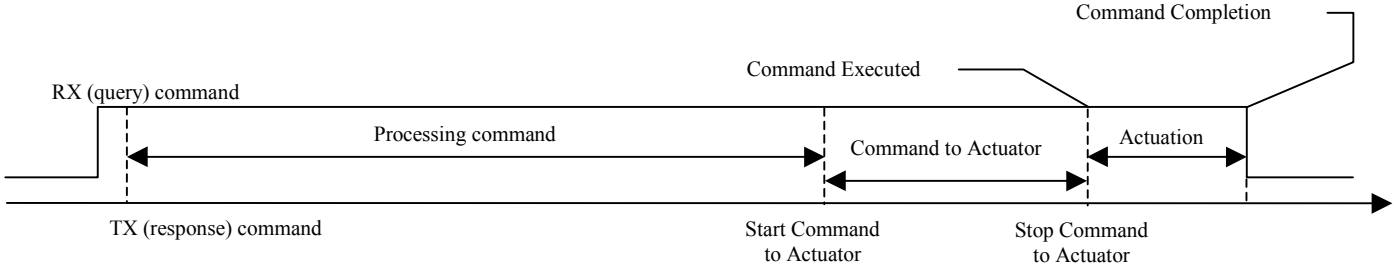


Figure 11. 'Command Executed' event (Executed before completion)

Please note that also the following situation is allowed:

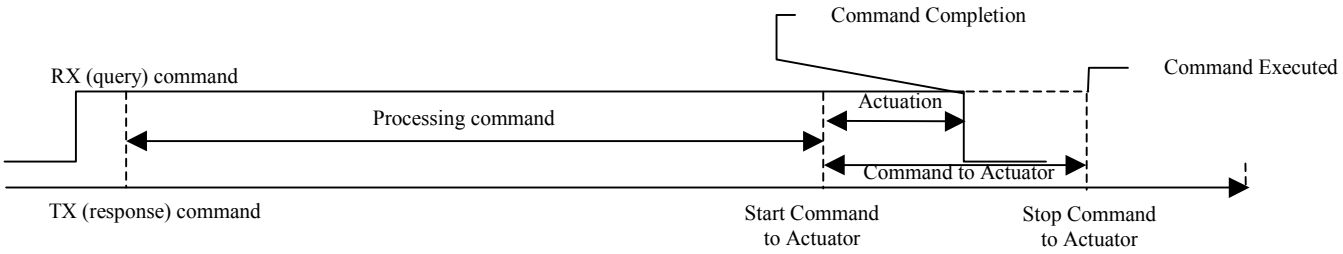


Figure 12. 'Command Executed' event (Completed before execution)

This situation represents an electromechanical dynamics faster than the electronic command or an electronic command longer than what the actuator needs.

In this case, both 'CB Command Executed' and CB status (related to the command) events are set for a little period of time.

In both situations, this event tells the system that:

1. the command is correctly received (normal response);
2. the SW has correctly processed it ('Command Executed' reset);
3. the SW has correctly driven the actuator ('Command Executed' set).

So this event could be helpful to analyse CB command failures.

6.2.3 Commands inhibition

There are three different levels of command inhibition conditions:

1. functional conditions (highest)
   Ex.: Abort / Stop Programming command outside a remote programming session.
2. feasibility conditions
   Ex.: programming commands with the Test Unit connected
3. security conditions (lowest)
   Ex.: remote command in Operating Mode = LOCAL

Moreover, inside a command category only one command at a time can be processed, i.e. if there is another pending command belonging to the same category of the issued command, the latter will be refused.

	Operating Mode LOCAL	IB Fault	Test Unit Connected	CB Isolated	CB Tripped	Pending Command	Functional conditions
Start Programming	**X**	**X**	**X**			**X**	
Abort Programming	**X**	**X**	**X**			**X**	**Programming Session ON**
Stop Programming	**X**	**X**	**X**			**X**	**Programming Session ON**
Wink	**X**	**X**	**X**			**X**	
Trip Reset	**X**	**X**	**X**			**X**	**Any Trip ON**
CB Open	**X**			**X**		**X**	**CB CLOSED**
CB Close	**X**	**X**	**X**	**X**	**X**	**X**	**CB OPEN & Any Trip OFF & Trip Command Fail OFF**
CB Reset	**X**		**X**	**X**		**X**	**CB TRIPPED | (CB OPEN & Trip Command Fail ON)**

LEGENDA		Slow Command Type
		Circuit Breaker Command Type
		Fast Command Type

Table 8. Conditions for commands' inhibition

The refused command is signalled via an exception response 'SLAVE_DEVICE_BUSY', that means 'the device is not ready to perform the requested command'.

NOTE: there is a little probability that a command is NOT be executed and no exception response sent when an inhibition condition rises up after the normal response has been sent.
This behaviour is due to different period of time (milliseconds) between query message processing (leading to the normal or exception response) and the requested command management.

6.3 Local Commands management

The CU manages three local commands:

1. CB Open
2. CB Close
3. CB Reset

6.3.1 CB Open

A local user performs this command when he switches manually the circuit breaker from CLOSED to OPEN.

The CU manages this command in the following way:

- CB status change
- Number of CB operation update
- Number of CB manual operation update

6.3.2 CB Close

A local user performs this command when he switches manually the circuit breaker from OPEN to CLOSED.

The CU manages this command in the following way:

- CB status change

6.3.3 CB Reset

A local user performs this command when he switches manually the circuit breaker either from TRIPPED to OPEN (after a protection trip, a simulated trip with the PR010/K or another kind of trip) or from CLOSED to OPEN (after a Trip Command Fail).

The CU manages this command in the following way:

- CB status change
- Number of CB operation update
- If the CB was in TRIPPED state, reset the relevant event and perform a Trip Reset.
- If the CB was in OPEN state, reset the relevant event and perform a Trip Reset.
- Reset of relevant event (any trip, simulated trip with the PR010/K or another kind of trip)

7. Human-Machine Interface / Local User Interface

The HMI is based on:

1. RESET push button
2. REMOTE DISABLED push button
3. Power LED
4. REM. DIS. / I.B. FAULT LED
5. Network LED, also called TX LED
6. Watchdog LED (controlled by hardware)

7.1 RESET push button Management

When the RESET push button is pressed, an HW reset is performed.

7.2 REMOTE DISABLED push button & REM. DIS. / I.B. FAULT LED Management

See par. 4.

7.3 Power LED Management

The Power LED is always ON except when it flashes at 1 Hz due to a remote 'Wink' command.

7.4 Network LED Management

The Network LED is switched ON when a message is sent on the external bus to the system.

7.5 Watchdog LED Management

The internal hardware switches ON the µp Fault LED when it recognises a microcontroller fault.

8. Modbus™ Map description

All the information is divided among the different application objects. The criteria for the subdivision are:

1. The handling of all protection configuration parameters is entrusted to the AppObj "Node Object", which reads and writes them. In this document, however, the configuration parameters are allotted to the pertaining Application Objects. For example, the configuration parameter "Protection L Threshold" can be found into the description of the AppObj "Protection L" even if its handling is completely delegated to the AppObj "Node Object".
2. AppObj "Node Object", Circuit Breaker and Load Controller handles the command input slave variables.
3. The output slave variables are organised in buffers: for every AppObj are showed the buffers and those variables inside them that the AppObj handles. The Remote System can choose how to read the variables, on the assumption that it is always possible to read either all the information or single information contained in a buffer, but can not query outside of it.

The Modbus™ map is contained in par. 9.

8.1 Buffers

These are the buffers defined for this device:

Buffer Name	Buffer Type	Items Number	Description
One buffer for each command	Analog Output	1 Register	
Reports	Digital Input	29 Coils	States, Events, Alarms and Trips reports
Trip Reports	Digital Input	29 Coils	States, Events, Alarms and Trips reports after trip
Statistics	Analog Input	14 Registers	Communication and Process Statistics
Programming Fail Code	Analog Input	1 Registers	Code of the wrong configuration parameters
Run-time RMS Measurements	Analog Input	10 Registers	Run time measurements
Trip currents	Analog Input	10 Registers	Measurements after trip
Present Parameters (in use)	Analog Input	52 Registers	Reading Parameters
New Parameters	Analog Output	15 Registers	Writing Parameters

8.1.1 Reports

STATES / EVENTS	ALARMS	TRIPS
Any Alarm	L Pre-alarm	L tripped
Any Trip	L Alarm (timing / tripping)	S tripped
CB tripped	S Alarm (timing / tripping)	I tripped
CB open/closed	G Alarm (timing / tripping)	G tripped
CB connected/withdrawn		
Trip command fail		
Other Trip		
Simulated Trip from Test Unit		
I.B. Fault		
Local/Remote Operating Mode		
Test Unit connected		
Programming OK		
Programming Fail		
Electronic Parameter changed		
CB command executed		
Trip data available		
Electronic/Manual Parameters Settings		
Manual Parameter error		
Manual Parameter changed		
Nominal current unknown		
CB Type unknown		

Table 9. Reports Buffer

(1) 'Any Trip' is set if any of trip item is set. It is reset after either a remote 'Trip Reset' or a local / remote 'CB Reset'.
(2) 'Any Alarm' is set if any of alarm item is set. It is reset when all the alarm items are equal to 0.
(3) If the CB is in TRIPPED **mechanical** state, also 'CB tripped' is set.
(4) CB contacts mapping:

CB open/closed	0 = Open, 1 = Closed
CB connected/withdrawn	0 = Isolated, 1 = Withdrawn

(5) 'Other Trip' is set if and only if the CB tripped state is due to a electronic / mechanical trip test, a UVR trip or a SOR trip.
(6) Operating Mode mapping:

Local/Remote Operating Mode 0 = Remote, 1 = Local

(7) Remote Programming Status:

Programming OK	Programming Fail	Description
0	0	Idle / Remote programming session OFF
0	1	Programming Fail
1	0	Programming OK
1	1	Remote programming session ON

(8) 'Trip Data available' is always ON, but when the PU is storing trip currents after a trip. The data are considered to be available after a period of about 350 ms.
(9) If 'L Alarm (timing / tripping)' is set, 'L Pre-alarm' is reset.
(10) If 'X tripped' is set, the relevant 'X Alarm (timing / tripping)' is reset.

8.1.2 Trip Reports
Their structure is the same as “Reports”, described in par. 8.1.1.

8.1.3 Statistics

Communication Statistics
Number of received messages (Bus Message Count)
Number of received messages with char/frame error (Bus Communication Error Count)
Number of responses (Slave Message Count)
Number of Slave Busy responses (Slave Busy Count)
Number of exception responses (Bus Exception Error Count)

Process Statistics
CB number of operations
CB number of manual opens
CB number of protection trips
CB number of protection trips fail
CB number of other trips
Protection L number of trips
Protection S number of trips
Protection I number of trips
Protection G number of trips

Table 10. Statistics Buffer

8.1.4 Programming Fail Code
During a programming session, both the Communication Unit and the Protection Unit make some checks on the configuration parameters to find possible errors. The relevant codes are subdivided into three categories:

System Error Codes	Error Type
0	NO ERROR
1 – 1000	Parameter errors detected by PU
1001 – 2000	Parameter errors detected by CU
2001 – 3000	Other errors detected by CU

Inside every block, the error codes are not consecutive to let spaces for further upgrades. Homogeneous blocks are indicated with the colour of the cells.

The not used error code are intentionally NOT described because they are used into the other devices (e.g. PR113/PD-M), so that two different devices have the same code for the same error.

System Error Code	Description
0	NO ERROR
31	S Threshold ≤ L Threshold
32	I Threshold ≤ S Threshold
1006	CB Type Out Of Range
1007	Nominal Current Out Of Range
1031	L Threshold Out Of Range
1033	L Time Delay Out Of Range
1036	L Pre-Alarm Disable Out Of Range
1040	S Disable Out Of Range
1041	S Curve Type Out Of Range
1042	S Threshold Out Of Range
1043	S Time Delay Out Of Range
1050	I Disable Out Of Range
1051	I Threshold Out Of Range
1060	G Disable Out Of Range
1062	G Threshold Out Of Range
1063	G Time Delay Out Of Range
2001	Abort Program – IB Error
2002	Abort Program – Local
2003	Abort Program – Query Error
2004	Abort Program – CU Flash Error

Table 11. Programming Fail Error Code

8.1.5 Run-time RMS Measurements

RMS current phase L1
RMS current phase L2
RMS current phase L3
RMS current neutral
RMS current ground

Table 12. Run-time RMS Measurements Buffer

At start-up, all values are set to the full range scale value (0xFFFFFFFF = VALUE NOT AVAILABLE).
If any current is < 2% of In (0.02*In), the value is considered to be not reliable and the value provided to the Remote System is 0.
If phase / neutral current is ≥ 12*In, 12*In is returned.
If the Ground current is ≥ 4*In, the full range scale value (0xFFFFFFFF = VALUE NOT AVAILABLE) is returned.

8.1.6 Trip currents

Trip current phase L1
Trip current phase L2
Trip current phase L3
Trip current neutral
Trip current ground

Table 13. Trip currents Buffer

See 8.1.5.

8.1.7 Present Parameters (in use)

Slave ID (DCP)
Product execution (PCP)
Relay Serial Number (PCP)
Protection Unit SW version (PCP)
Communication Unit SW version (DCP)
Slave Address (DCP)
Addressing Type (DCP)
Baudrate (DCP)
Even / Odd parity (DCP)
Manual Neutral selection (PCP)
Protection L manual trip level (PCP)
Protection L manual trip delay (PCP)
Protection S manual disable (PCP)
Protection S manual curve type (PCP)
Protection S manual trip level (PCP)
Protection S manual trip delay (PCP)
Protection I manual disable (PCP)
Protection I manual trip level (PCP)
Protection G manual disable (PCP)
Protection G manual trip level (PCP)
Protection G manual trip delay (PCP)
CU Serial Number (DCP)
Int. toroid value / Protection Unit nominal current In (PCP)
CB type (PCP)
CB Serial Number (DCP)
Date of installation (DCP)
Protection L trip level (PCP)
Protection L trip delay (PCP)
Protection L pre-alarm disable (PCP)
Protection S disable (PCP)
Protection S curve type PCP)
Protection S trip level (PCP)
Protection S trip delay time (PCP)
Protection I disable (PCP)
Protection I trip level (PCP)
Protection G disable (PCP)
Protection G trip level (PCP)
Protection G trip delay time (PCP)

Table 14. Present Parameters Buffer

8.1.8 New Parameters

Date of installation (DCP)
Protection L trip level (PCP)
Protection L trip delay (PCP)
Protection L pre-alarm disable (PCP)
Protection S disable (PCP)
Protection S curve type (PCP)
Protection S trip level (PCP)
Protection S trip delay time (PCP)
Protection I disable (PCP)
Protection I trip level (PCP)
Protection G disable (PCP)
Protection G trip level (PCP)
Protection G trip delay time (PCP)

Table 15. New Parameters Buffer

9. Modbus™ Logical Map

In this section are contained all the Modbus™ variables, both in Input and in Output, handled by CU and accessible from the Remote System. They are divided according to their Modbus™ data type: Analog/Digital, Input/Output.

9.1 Digital Output

Not applicable.

9.2 Digital Input

9.2.1 Buffer "Reports"

This buffer contains all States / Events / Alarms / Trips reports during run-time:

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
Reports	**10001**	**0001**	**0000**	**0000**	**29**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address – 1 (HEX)	Number of items	Description	Comments
States/Events	**10001**	**0001**	**0000**	**0000**	**21**		
	10001	0001	0000	0000	1	Any Alarm	
	10002	0002	0001	0001	1	Any Trip	
	10003	0003	0002	0002	1	CB tripped	
	10004	0004	0003	0003	1	CB open/closed	
	10005	0005	0004	0004	1	CB connected/withdrawn	
	10006	0006	0005	0005	1	Trip command fail	
	10007	0007	0006	0006	1	Other Trip	
	10008	0008	0007	0007	1	Simulated Trip from Test Unit	
	10009	0009	0008	0008	1	I.B. Fault	
	10010	0010	0009	0009	1	Local/Remote Operating Mode	
	10011	0011	0010	000A	1	Test Unit connected	
	10012	0012	0011	000B	1	Programming OK	
	10013	0013	0012	000C	1	Programming Fail	
	10014	0014	0013	000D	1	Electronic Parameter changed	Event
	10015	0015	0014	000E	1	CB command executed	Event
	10016	0016	0015	000F	1	Trip data available	
	10017	0017	0016	0010	1	Electronic/Manual Parameters Settings	
	10018	0018	0017	0011	1	Manual Parameter error	
	10019	0019	0018	0012	1	Manual Parameter changed	Event
	10020	0020	0019	0013	1	Nominal current unknown	
	10021	0021	0020	0014	1	CB Type unknown	
Alarms	**10022**	**0022**	**0021**	**0015**	**4**		
	10022	0022	0021	0015	1	L Pre-alarm	
	10023	0023	0022	0016	1	L Alarm (timing / tripping)	
	10024	0024	0023	0017	1	S Alarm (timing / tripping)	
	10025	0025	0024	0018	1	G Alarm (timing / tripping)	
Trips	**10026**	**0026**	**0025**	**0019**	**4**		
	10026	0026	0025	0019	1	L tripped	
	10027	0027	0026	001A	1	S tripped	
	10028	0028	0027	001B	1	I tripped	
	10029	0029	0028	001C	1	G tripped	

Table 16. DI – Buffer 'Reports'

9.2.2 Buffer "Trip Reports"

This buffer is the copy, at trip time, of the above reports.

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
Trip Reports	**10201**	**0201**	**0200**	**00C8**	**29**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address – 1 (HEX)	Number of items	Description	Comments
Trip States/Events	**10201**	**0201**	**0200**	**00C8**	**21**		
	10201	0201	0200	00C8	1	Any Alarm	
	10202	0202	0201	00C9	1	Any Trip	
	10203	0203	0202	00CA	1	CB tripped	
	10204	0204	0203	00CB	1	CB open/closed	
	10205	0205	0204	00CC	1	CB connected/withdrawn	
	10206	0206	0205	00CD	1	Trip command fail	
	10207	0207	0206	00CE	1	Other Trip	
	10208	0208	0207	00CF	1	Simulated Trip from Test Unit	
	10209	0209	0208	00D0	1	I.B. Fault	
	10210	0210	0209	00D1	1	Local/Remote Operating Mode	
	10211	0211	0210	00D2	1	Test Unit connected	
	10212	0212	0211	00D3	1	Programming OK	
	10213	0213	0212	00D4	1	Programming Fail	
	10214	0214	0213	00D5	1	Electronic Parameter changed	
	10215	0215	0214	00D6	1	CB command executed	
	10216	0216	0215	00D7	1	Trip data available	
	10217	0217	0216	00D8	1	Electronic/Manual Parameters Settings	
	10218	0218	0217	00D9	1	Manual Parameter error	
	10219	0219	0218	00DA	1	Manual Parameter changed	
	10220	0220	0219	00DB	1	Nominal current unknown	
	10221	0221	0220	00DC	1	CB Type unknown	
Trip Alarm	**10222**	**0222**	**0221**	**00DD**	**4**		
	10222	0222	0221	00DD	1	L Pre-alarm	
	10223	0223	0222	00DE	1	L Alarm (timing / tripping)	
	10224	0224	0223	00DF	1	S Alarm (timing / tripping)	
	10225	0225	0224	00E0	1	G Alarm (timing / tripping)	
Trip Trips	**10226**	**0226**	**0225**	**00E1**	**4**		
	10226	0226	0225	00E1	1	L tripped	
	10227	0227	0226	00E2	1	S tripped	
	10228	0228	0227	00E3	1	I tripped	
	10229	0229	0228	00E4	1	G tripped	

Table 17. DI – Buffer 'Trip Reports'

The **Persistence** of these trip reports is **Permanent (CU)**.

9.3 Analog Input

9.3.1 Buffer "Statistics"

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
Statistics	**30001**	**0001**	**0000**	**0000**	**14**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address – 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments	Range	Unit of Meas.	Persistence
Communication Statistics	**30001**	**0001**	**0000**	**0000**	**5**							
	30001	0001	0000	0000	1			Number of received messages	Bus Message Count	0 - 65535		
	30002	0002	0001	0001	1			Number of received messages with char/frame error	Bus Communication Error Count	0 - 65535		
	30003	0003	0002	0002	1			Number of responses	Slave Message Count	0 - 65535		
	30004	0004	0003	0003	1			Number of Slave Busy responses	Slave Busy Count	0 - 65535		
	30005	0005	0004	0004	1			Number of exception responses	Bus Exception Error Count	0 - 65535		
Process Statistics	**30006**	**0006**	**0005**	**0005**	**9**							
	30006	0006	0005	0005	1			CB number of operations		0 - 65535		Permanent (PU)
	30007	0007	0006	0006	1			CB number of manual opens		0 - 65535		Permanent (CU)
	30008	0008	0007	0007	1			CB number of protection trips		0 - 65535		Permanent (CU)
	30009	0009	0008	0008	1			CB number of protection trips fail		0 - 65535		Permanent (CU)
	30010	0010	0009	0009	1			CB number of other trips		0 - 65535		Permanent (CU)
	30011	0011	0010	000A	1			Protection L number of trips		0 - 65535		Permanent (CU)
	30012	0012	0011	000B	1			Protection S number of trips		0 - 65535		Permanent (CU)
	30013	0013	0012	000C	1			Protection I number of trips		0 - 65535		Permanent (CU)
	30014	0014	0013	000D	1			Protection G number of trips		0 - 65535		Permanent (CU)

Table 18. AI – Buffer 'Statistics'

'Persistence = PERMANENT' means that value is saved into non-volatile memory (into PU or CU).

9.3.2 Buffer "Programming Fail Code"

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
Programming Fail Code	**30051**	**0051**	**0050**	**0032**	**1**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address – 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments	Range	Unit of Meas.	Persistence
Programming Fail Code	**30051**	**0051**	**0050**	**0032**	**1**			Programming Fail Error Code		see Table 20		

Table 19. AI – Buffer 'Programming Fail Code'

System Error Code	Description	System Error Code	Description	System Error Code	Description
0	NO ERROR	1006	CB Type Out Of Range	2001	Abort Program – IB Error
31	S Threshold ≤ L Threshold	1007	Nominal Current Out Of Range	2002	Abort Program – Local
32	I Threshold ≤ S Threshold	1031	L Threshold Out Of Range	2003	Abort Program – Query Error
		1033	L Time Delay Out Of Range	2004	Abort Program – CU Flash Error
		1036	L Pre-Alarm Disable Out Of Range		
		1040	S Disable Out Of Range		
		1041	S Curve Type Out Of Range		
		1042	S Threshold Out Of Range		
		1043	S Time Delay Out Of Range		
		1050	I Disable Out Of Range		
		1051	I Threshold Out Of Range		
		1060	G Disable Out Of Range		
		1062	G Threshold Out Of Range		
		1063	G Time Delay Out Of Range		

Table 20. 'Programming Fail Code' range

9.3.3 Buffer "Run-time RMS Measurements"

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
Run-time RMS Measurements	**30101**	**0101**	**0100**	**0064**	**10**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address - 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments	Range	Unit of Meas.	Persistence
Run-time RMS Measurements	**30101**	**0101**	**0100**	**0064**	**10**							
	30101	0101	0100	0064	2			RMS current phase L1			A	
	30103	0103	0102	0066	2			RMS current phase L2			A	
	30105	0105	0104	0068	2			RMS current phase L3			A	
	30107	0107	0106	006A	2			RMS current neutral			A	
	30109	0109	0108	006C	2			RMS current ground			A	

Table 21. AI – Buffer 'Run-time RMS Measurements'

9.3.4 Buffer "Trip currents"

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
Trip currents	**30201**	**0201**	**0200**	**00C8**	**10**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address - 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments	Range	Unit of Meas.	Persistence
Trip currents	**30201**	**0201**	**0200**	**00C8**	**10**							
	30201	0201	0200	00C8	2			Trip current phase L1			A	Permanent (PU)
	30203	0203	0202	00CA	2			Trip current phase L2			A	Permanent (PU)
	30205	0205	0204	00CC	2			Trip current phase L3			A	Permanent (PU)
	30207	0207	0206	00CE	2			Trip current neutral			A	Permanent (PU)
	30209	0209	0208	00D0	2			Trip current ground			A	Permanent (PU)

Table 22. AI – Buffer 'Trip currents'

9.3.5 Buffer "Present Parameters"

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
Present parameters	**30301**	**0301**	**0300**	**012C**	**52**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address - 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments	Range	Default	Mapped in
Present parameters	**30301**	**0301**	**0300**	**012C**	**52**							
	30301	0301	0300	012C	1	N/A		Slave ID (DCP)			22	
	30302	0302	0301	012D	1	N/A		Product execution (PCP)		[LSI | LSIG]		[0 | 1]
	30303	0303	0302	012E	5			Relay Serial Number (PCP)	One byte for each character			
	30308	0308	0307	0133	1			Protection Unit SW version (PCP)	'major'.'minor'			
	30309	0309	0308	0134	1			Communication Unit SW version (DCP)	'major'.'minor'			
	30310	0310	0309	0135	1	N/A		Slave Address (DCP)		[255 (UNCONFIGURED) | {1 … 247}]	255	
	30311	0311	0310	0136	1	N/A		Addressing Type (DCP)		[Standard | ABB SACE]	Standard	[0 | 1]
	30312	0312	0311	0137	1			Baudrate (DCP)		[9600 | 19200]	19200	
	30313	0313	0312	0138	1	N/A		Even / Odd parity (DCP)		[Even | Odd]	Even	[0 | 1]
	30314	0314	0313	0139	1	N/A		Manual Neutral selection (PCP)		[50 | 100] %	50%	
	30315	0315	0314	013A	1			Protection L manual trip level (PCP)		[0.4 | 0.5 | 0.55 | 0.6 | 0.65 | 0.7 | 0.75 | 0.8 | 0.85 | 0.875 | 0.9 | 0.925 | 0.95 | 0.975 | 1] In	1	scaled *1000
	30316	0316	0315	013B	1	N/A		Protection L manual trip delay (PCP)		[3 | 6 | 12 | 18] s	18	
	30317	0317	0316	013C	1	N/A		Protection S manual disable (PCP)		[Disabled | Enabled]	ON	[1 | 0]
	30318	0318	0317	013D	1	N/A		Protection S manual curve type (PCP)		[Definite Time | Inverse Time]	Inverse Time	[0 | 1]
	30319	0319	0318	013E	1	N/A		Protection S manual trip level (PCP)		1 | 2 | 3 | 4 | 6 | 8 | 10 In		
	30320	0320	0319	013F	1	N/A		Protection S manual trip delay (PCP)		0.5 | 0.1 | 0.25 | 0.5 s with Definite Time Curve (@8In with Inverse Time Curve)	0.5	scaled *100
	30321	0321	0320	0140	1	N/A		Protection I manual disable (PCP)		[Disabled | Enabled]	OFF	[1 | 0]
	30322	0322	0321	0141	1	N/A		Protection I manual trip level (PCP)		1.5 | 2 | 4 | 6 | 8 | 10 | 12 In	4	scaled *10
	30323	0323	0322	0142	1	N/A		Protection G manual disable (PCP)		[Disabled | Enabled]	ON	[1 | 0]
	30324	0324	0323	0143	1	N/A		Protection G manual trip level (PCP)		0.2 | 0.3 | 0.4 | 0.6 | 0.8 | 0.9 | 1 In		scaled *10
	30325	0325	0324	0144	1	N/A		Protection G manual trip delay (PCP)		0.1 | 0.2 | 0.4 | 0.8 s	0.8	scaled *10

Table 23. AI – Buffer 'Present parameters', Part 1

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address - 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments	Range	Default	Mapped in
	30326	0326	0325	0145	5			CU Serial Number (DCP)	One byte for each character			
	30331	0331	0330	014A	1	N/A		Int. toroid value / Protection Unit nominal current In (PCP)		**IEC**: [100 | 160 | 250 | 320 | 400 | 630 | 800 | 1000 | 1250 | 1600] A **UL**: [100 | 150 | 250 | 300 | 400 | 600 | 800 | 1000 | 1200] A	100	
	30332	0332	0331	014B	1	N/A		CB type (PCP)	One byte for each character	see Table 25	S4N160	
	30333	0333	0332	014C	5			CB Serial Number (DCP)	One byte for each character			
	30338	0338	0337	0151	3			Date of installation (DCP)	DD, MM, YYYY		0000/00/00	
	30341	0341	0340	0154	1	N/A		Protection L trip level (PCP)		{0.40 … 1.00}In, step 0.01	1.00	scaled *100
	30342	0342	0341	0155	1	N/A		Protection L trip delay (PCP)		{3 .. .18}s, step 0.5	18	scaled *10
	30343	0343	0342	0156	1	N/A		Protection L pre-alarm disable (PCP)		[Disabled | Enabled]	OFF	[1 | 0]
	30344	0344	0343	0157	1	N/A		Protection S disable (PCP)		[Disabled | Enabled]	ON	[1 | 0]
	30345	0345	0344	0158	1	N/A		Protection S curve type PCP)		[Definite Time | Inverse Time]	Inverse Time	[0 | 1]
	30346	0346	0345	0159	1	N/A		Protection S trip level (PCP)		{1 … 10}In, step 0.1	????????	scaled *10
	30347	0347	0346	015A	1	N/A		Protection S trip delay time (PCP)		{0.05 … 0.5}s, step 0.01 with both curve types	0,5	scaled *100
	30348	0348	0347	015B	1	N/A		Protection I disable (PCP)		[Disabled | Enabled]	OFF	[1 | 0]
	30349	0349	0348	015C	1	N/A		Protection I trip level (PCP)		{1.5 … 12}In, step 0.1	4	scaled *10
	30350	0350	0349	015D	1	N/A		Protection G disable (PCP)		[Disabled | Enabled]	ON	[1 | 0]
	30351	0351	0350	015E	1	N/A		Protection G trip level (PCP)		{0.2 … 1.00}In, step 0.02	????????	scaled *100
	30352	0352	0351	015F	1	N/A		Protection G trip delay time (PCP)		{0.10 … 0.80}s, step 0.01	0,8	scaled *100

Table 24. AI – Buffer 'Present parameters', Part 2

Parameter Value	IEC
0	S4N160
1	S4H160
2	S4L160
3	S4N250
4	S4H250
5	S4L250
6	S4X250
7	S5N400
8	S5H400
9	S5L400
10	S5N630
11	S5H630
12	S5L630
13	S6X400
14	S6N630
15	S6S630
16	S6H630
17	S6L630
18	S6X630
19	S6N800
20	S6S800
21	S6H800
22	S6L800
23	S7S1250
24	S7H1250
25	S7L1250
26	S7S1600
27	S7H1600
28	S7L1600

Parameter Value	ANSI
29	S4N-A250
30	S4H-A250
31	S4L-A250
32	S5N-A400
33	S5H-A400
34	S5L-A400"
35	S6N-A800
36	S6H-A800
37	S6L-A800
38	S7S-A1200
39	S7H-A1200
40	S7L-A1200

Table 25. ‘CB Type’ range

9.4 Analog Output

9.4.1 Buffer "CB Open" command

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
CB Open	**40001**	**0001**	**0000**	**0000**	**1**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address - 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments
CB Open	**40001**	**0000**	**0000**	**0000**	**1**				
	40001	0001	0000	0000	1	N/A		CB Open	Mutually exclusive to other CB commands

Table 26. AO – Buffer 'CB Open' Command

9.4.2 Buffer "CB Close" command

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
CB Close	**40003**	**0003**	**0002**	**0002**	**1**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address - 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments
CB Open	**40003**	**0003**	**0002**	**0002**	**1**				
	40003	0003	0002	0002	1	N/A		CB Close	Mutually exclusive to other CB commands

Table 27. AO – Buffer 'CB Close' Command

9.4.3 Buffer "CB Reset" command

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
CB Reset	**40005**	**0005**	**0004**	**0004**	**1**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address - 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments
CB Reset	**40005**	**0005**	**0004**	**0004**	**1**				
	40005	0005	0004	0004	1	N/A		CB Reset	Mutually exclusive to other CB commands

Table 28. AO – Buffer 'CB Reset' Command

9.4.4 Buffer "Start programming session" command

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
Start Programming session	**40007**	**0007**	**0006**	**0006**	**1**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address - 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments
Start Programming session	**40007**	**0007**	**0006**	**0006**	**1**				
	40007	0007	0006	0006	1	N/A		Start Programming session	Mutually exclusive to other 'Slow' commands. They require an EEPROM operation to the PU.

Table 29. AO – Buffer 'Start programming session' Command

9.4.5 Buffer "Abort programming session" command

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
Abort Programming session	**40009**	**0009**	**0008**	**0008**	**1**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address - 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments
Abort Programming session	**40007**	**0007**	**0006**	**0006**	**1**				
	40009	0009	0008	0008	1	N/A		Abort Programming session	Mutually exclusive to other 'Fast' commands.

Table 30. AO – Buffer 'Abort programming session' Command

9.4.6 Buffer "Stop programming session" command

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
Stop Programming session	**40011**	**0011**	**0010**	**000A**	**1**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address - 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments
Stop Programming session	**40011**	**0011**	**0010**	**000A**	**1**				
	40011	0011	0010	000A	1	N/A		Stop Programming session	Mutually exclusive to other 'Slow' commands. They require an EEPROM operation to the PU.

Table 31. AO – Buffer 'Stop programming session' Command

9.4.7 Buffer "Trip Reset" command

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
Trip Reset	**40013**	**0013**	**0012**	**000C**	**1**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address - 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments
Trip Reset	**40013**	**0013**	**0012**	**000C**	**1**				
	40013	0013	0012	000C	1	N/A		Trip Reset	Mutually exclusive to other 'Fast' commands.

Table 32. AO – Buffer 'Trip Reset' Command

9.4.8 Buffer "New Parameters"

Section	Absolute Address	Relative Address	Relative Address – 1	Relative Address – 1 (HEX)	Number of items
New parameters	**40338**	**0338**	**0337**	**0151**	**15**

and these are the relevant items:

Section	Absolute Address	Relative Address	Relative Address - 1	Relative Address - 1 (HEX)	Number of items	HIGH byte	LOW byte	Description	Comments	Range	Default	Mapped in
	40338	0338	0337	0151	3			Date of installation (DCP)	DD, MM, YYYY		0000/00/00	
	40341	0341	0340	0154	1	N/A		Protection L trip level (PCP)		{0.40 … 1.00}In, step 0.01	1.00	scaled *100
	40342	0342	0341	0155	1	N/A		Protection L trip delay (PCP)		{3 .. .18}s, step 0.5	18	scaled *10
	40343	0343	0342	0156	1	N/A		Protection L pre-alarm disable (PCP)		[Disabled | Enabled]	OFF	[1 | 0]
	40344	0344	0343	0157	1	N/A		Protection S disable (PCP)		[Disabled | Enabled]	ON	[1 | 0]
	40345	0345	0344	0158	1	N/A		Protection S curve type PCP)		[Definite Time | Inverse Time]	Inverse Time	[0 | 1]
	40346	0346	0345	0159	1	N/A		Protection S trip level (PCP)		{1 … 10}In, step 0.1	????????	scaled *10
	40347	0347	0346	015A	1	N/A		Protection S trip delay time (PCP)		{0.05 … 0.5}s, step 0.01 with both curve types	0,5	scaled *100
	40348	0348	0347	015B	1	N/A		Protection I disable (PCP)		[Disabled | Enabled]	OFF	[1 | 0]
	40349	0349	0348	015C	1	N/A		Protection I trip level (PCP)		{1.5 … 12}In, step 0.1	4	scaled *10
	40350	0350	0349	015D	1	N/A		Protection G disable (PCP)		[Disabled | Enabled]	ON	[1 | 0]
	40351	0351	0350	015E	1	N/A		Protection G trip level (PCP)		{0.2 … 1.00}In, step 0.02	????????	scaled *100
	40352	0352	0351	015F	1	N/A		Protection G trip delay time (PCP)		{0.10 … 0.80}s, step 0.01	0,8	scaled *100

Table 33. AO – Buffer 'New parameter'