User Manual
Hadron RTU – HD3002

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Summary

1. Introduction

The Remote Terminal Unit (RTU) Hadron HD3002 is an evolution of Hadron HD3001 RTU and was designed for automation of power substations and electrical centrals, allowing the execution of supervision, telecommand and interlocking functions.

The HD3002 RTUs are modular, offering a wide range of points and types of inputs and outputs, according to the requirements of each application. The types available are digital input modules with event log, digital output modules with CBO (check before operate) and analog input modules.

In addition, the RTU can communicate with operation centers or local HMIs (Human Machine Interfaces) through various slave protocols, and with IEDs (Intelligent Electronic Devices) through various master protocols.

The RTUs can be easily configured through the MasterTool Hadron XE HD8000 tool. Beside the basic supervision and telecommand operation, it is possible to implement additional interlock functions, for automatic execution of commands from the specific conditions found in local entries or entries from IEDs.

Hadron HD3002 RTU Features

Expansibility and Modularity

The hardware of a HD3002 RTU is composed of modules installed on racks. A HD3002 RTU has a main rack. In addition, up to four additional racks can be used for expansion. The expansion is implemented using a simple or redundant PROFIBUS DP network, ensuring the update of the expansion input and output points in one scanning cycle of the main CPU.

I/O Modules

Several digital and analog I/O modules can be installed in the RTU, such as:

- AL-3130, AL-3132, AL-3138: SOE (sequence of events) digital input
- AL-3150, AL-3150/8, AL-3151, AL-3151/8: analog inputs
- AL-3202: CBO (check before operate) digital outputs

Communication Interfaces

Several interface modules are available for communication with control centers, local HMIs and IEDs, such as:

- AL-3412: client/server ALNET II TCP communication interface
- AL-3414: communication interface for:
    - ALNET II TCP client/server
    - MODBUS TCP client/server or
    - MODBUS RTU client/server over TCP/IP
- AL-3415: IEC 60870-5-104 sever communication interface
- AL-3417: DNP3 server communication interface
- AL-3406: PROFIBUS DP-V0 master interface
- AL-2005: generic coprocessor that allows the installation of various serial communication protocols, based on RS-232 or RS-485:
    - MODBUS RTU master/slave
    - DNP3 master
    - ALNET I master/slave
    - Others (consult for availability)

Easy Configuration

Configuration is done through MasterTool Hadron XE, which helps the following tasks:

- Architecture configuration (configuration of I/O modules and expansion racks)
- Configuration of communication interfaces with control centers through the following protocols:
    - Server IEC 60870-5-104 (AL-3415)
    - Server DNP3 (AL-3417)
- Configuration of communication interfaces with IEDs through the following protocols:
    - Master DNP3 serial (AL-2005 with driver AL-2743)
    - Master MODBUS RTU serial (AL-2005 with driver AL-2734)
    - Client MODBUS TCP (AL-3414)
    - Client MODBUS RTU over TCP/IP (AL-3414)

ATTENTION: In the case of MODBUS protocols, the automatic configuration performed by MasterTool Hadron XE is made only for periodical (cyclic) read and writes. To use acyclic read or write operations, the User must configure the interface manually.

User Logics

Through the MasterTool Hadron XE configurator, it´s also possible to create user logics in situations where this is necessary, for example:

- Logical interlocks (for example, security logics, start and stop of generators, etc.)
- Internal calculation
- Communication interfaces with control centers or IEDs through proprietary protocols and/or standardization for data objects, events and commands

PROFIBUS DP-V0

In HD3002 RTU, the master PROFIBUS DP-V0 AL-3406 can be used in two different ways:

- To connect up to four expansion racks to the main rack. In this case, the application is automatically generated by MasterTool Hadron XE
- To connect PROFIBUS DP-V0 IEDs, for example, remote I/O modules of ALTUS Ponto Series, or third party equipment. In this case, the application must be generated manually by the user

ATTENTION: Each AL-3406 module can only be used in one of these two modes. If it is needed to use both modes simultaneously, at least two AL-3406 modules must be used.

Documents Related to this Manual

For additional information about other equipment used together with the HD3002 RTU, other documents can be found (manuals and technical characteristics) other than this one. These documents are available in its latest version in www.altus.com.br.

Each product has a document called Technical Characteristics (CE), with the characteristics of the product in question. Additionally, the product may have instruction guide (in this case, the manual codes are listed on CE).

It is advisable to read the manuals listed in the table below, as well as reading the technical characteristics of the products used.

Document Code	Description
MU208802	MasterTool Hadron XE HD8000 User Manual (Portuguese)
MU208852	MasterTool Hadron XE HD8000 User Manual (English)
MU207011	AL-2002/AL-2003/AL-2004 User Manual
MU203013	AL-3150 / AL-3151 User Manual
MU203014	AL-3202 Module User Manual
MU207006	AL-2005 / RTMP User Manual
MU202610	AL-3406 User Manual
MU202001	AL-3416 User Manual
MU299026	PROFIBUS Network User Manual
MU299032	PROFITOOL User Manual
MU202002	AL-3414 User Manual
MU207103	AL-2734 User Manual
MU207114	AL-2743 User Manual

Table 1-1. Related documents

Technical Support

To contact Altus Technical Support in Sao Leopoldo, RS, call +55 51 3589-9500. To find the centers of Altus Technical Support in other existing locations, see our website (www.altus.com.br) or send an email to altus@altus.com.br.

If the equipment is already installed, please have the following information when requesting assistance:

- The models of the equipment used and the configuration of the system installed
- CPU serial number
- The revision of the equipment and the executive version of the software listed on the label affixed in the side of the product
- Information on the operating mode of the CPU, obtained from the MasterTool Hadron XE programmer
- The content of the application program (modules), obtained from the MasterTool Hadron XE programmer
- The version of the programmer used

Warning Messages Used in this Manual

In this manual, the warning messages will present the following formats and meanings:

DANGER:
Report potential causes, which if not observed, *may lead* to damage to physical integrity and health, property, environment and loss of production.

CAUTION:
Report details of the configuration, implementation and installation that *must be* followed to avoid conditions that can lead to system failure and its related consequences.

ATTENTION:
Indicate important details of configuration, application or installation to obtain maximum performance of the system.

2. Technical Description

This chapter presents the technical characteristics of the Hadron HD3002 RTU, addressing the all parts of the system, its architecture, limits, general and electrical characteristics.

RTU Architecture

A HD3002 RTU has at least one main rack. In addition, up to four additional racks can be used for expansion. If there is expansion, the same is done through a single or redundant PROFIBUS DP

The figure bellow illustrates the expansibility of the HD3002 RTU

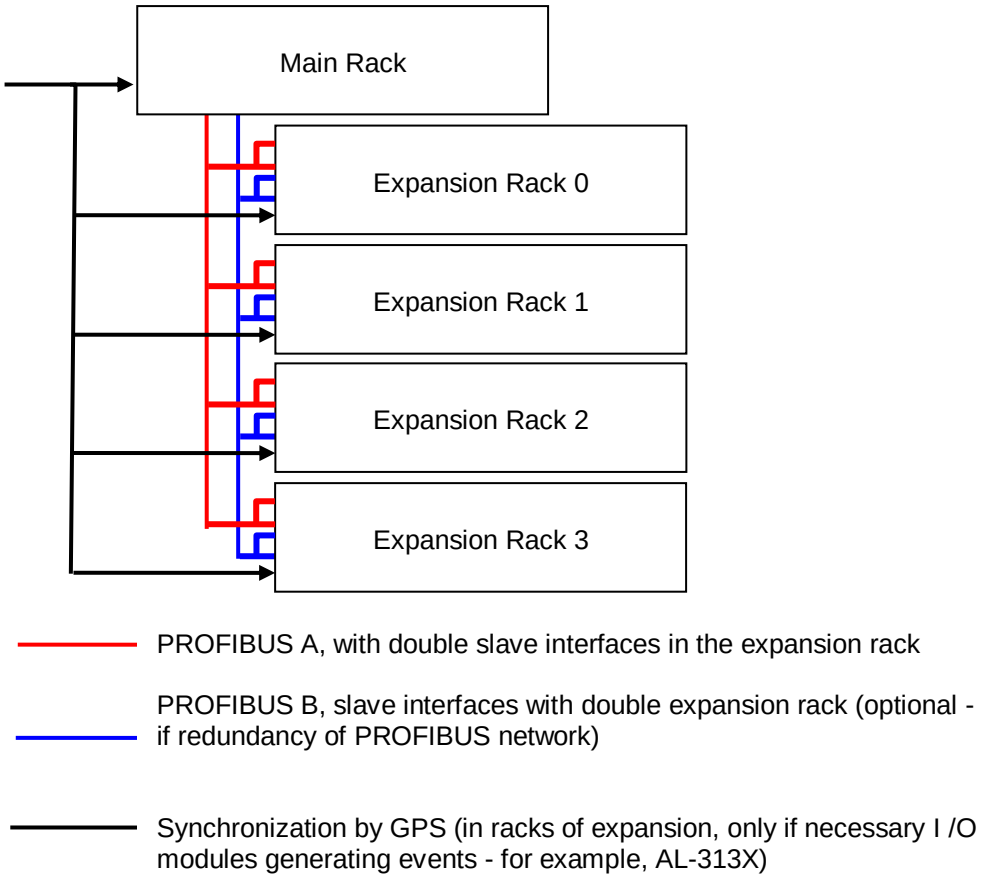
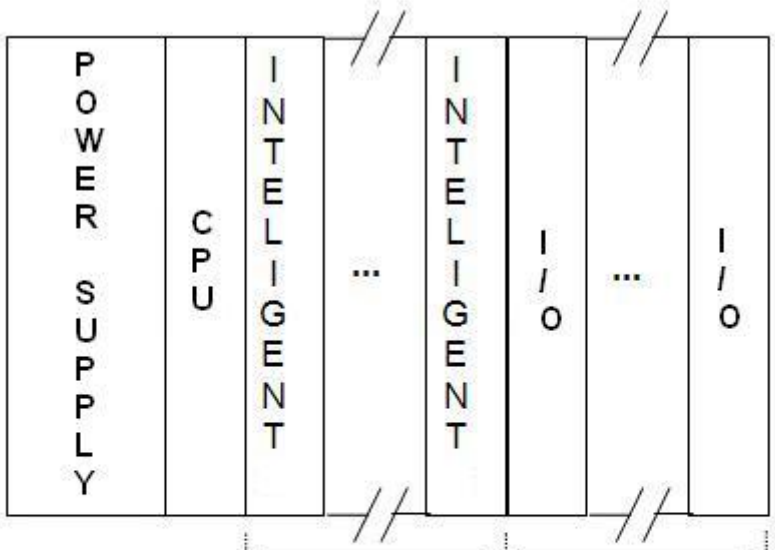


Figure 2-1. RTU expansibility

Racks

The following racks can be used:

- AL-3631: power supply, and four intelligent modules
- AL-3635: power supply, CPU and eight intelligent modules
- AL-3634: power supply, CPU, five intelligent modules and 11 I/O modules
- AL-3642: power supply, CPU, eight intelligent modules and 8 I/O modules



AL-3631	4 slots	0 slots
AL-3635	8 slots	0 slots
AL-3634	5 slots	11 slots
AL-3642	8 slots	8 slots

Figure 2-2. Racks structure

Looking the rack from the front view, and starting by left:

- The first position is double-wide, and destined to the power supply
- The second position is destined to the CPU
- The next positions are for intelligent modules or I/ O modules. It is possible to install I/O modules in positions destined to intelligent modules
- Finally, there are the positions for the installation of I/O modules only

The distinction between modules and intelligent I/O modules is necessary because the positions for intelligent modules have an extended bus, which allows the module to have direct access to the CPU memory. You can install an I/O module in a position for an intelligent module, but you cannot install an intelligent module in a position destined for an I/O module.

The number of modules that can be installed on the rack can also be limited by the maximum electrical current that the power supplies AL-3511 or AL-3512 can provide. Both models can provide up to 10A on +5Vdc rail, 1A for the +15Vdc rail and 1A for the -15Vdc rail of the rack power supply bus. The following table shows the current consumption of each module.

Module	+5 Vdc	+15 Vdc	-15 Vdc
AL-2004	530 mA	50 mA	30 mA
AL-2005	850 mA	0 mA	0 mA
AL-3406	800 mA	50 mA	0 mA
AL-3412	600 mA	0 mA	0 mA
AL-3414	600 mA	0 mA	0 mA
AL-3415	600 mA	0 mA	0 mA
AL-3416	800 mA	50 mA	0 mA

Module	+5 Vdc	+15 Vdc	-15 Vdc
AL-3417	600 mA	0 mA	0 mA
AL-3130	100 mA	0 mA	0 mA
AL-3132	100 mA	0 mA	0 mA
AL-3138	100 mA	0 mA	0 mA
AL-3150	850 mA	0 mA	0 mA
AL-3150/8	550 mA	0 mA	0 mA
AL-3151	850 mA	0 mA	0 mA
AL-3151/8	550 mA	0 mA	0 mA
AL-3202	80 mA	0 mA	0 mA
AL-2405/232	300 mA	0 mA	0 mA
AL-2405/485	300 mA	0 mA	0 mA

Table 2-1. Current consumption of Hadron RTU modules

The modules AL-2405/232 and AL-2405/485 are serial interfaces. They are used on AL-2004 CPU when an additional serial channel is need on COM2, or when the rack is configured to use NMEA synchronism. They are also used on the AL-2005 co-processor for each configured serial channel.

If the rack is used as an expansion rack, the limit of installed modules is also limited by the data transfer limit of PROFIBUS network that is used for communication between the main and expansion racks. Each expansion rack can have up to 236 bytes for reading from the main rack, and can receive up to 96 bytes of write data. The following table shows in details the amount of read and write bytes of the I/O modules:

Module	Read bytes	Write bytes
AL-3130	6 bytes	4 bytes
AL-3132	6 bytes	4 bytes
AL-3138	6 bytes	4 bytes
AL-3150	48 bytes	0 bytes
AL-3150/8	24 bytes	0 bytes
AL-3151	48 bytes	0 bytes
AL-3151/8	12 bytes	0 bytes
AL-3202	4 bytes	4 bytes

Table 2-2. Byte allocation on PROFIBUS messages for an expansion rack

The modules AL-3130, AL-3132 and AL-3138 uses 4 write bytes for transferring the value of the event disabling DOs for the expansion rack. Even if this option is not configured for the modules, these 4 bytes are reserved.

The module AL-3202 uses 4 read bytes for transferring the module diagnostics.

Power Supply

There are two possible models for use in main rack and in expansion racks:

- AL-3511: DC input , between 19,2 and 57,6 Vdc
- AL-3512:
    - AC input between 93 and 253 Vac, from 47 to 63 Hz
    - DC input between 100 and 300 Vdc

ATTENTION: The AL-3511 and AL-3512 can be referred in this manual in a generic form as AL-351X

CPU – Central Processing Unit

The CPU used is the AL-2004 model, both in the main rack as expansion racks.

Intelligent Modules

The following subsections describe the intelligent modules that can be used as well as the functions performed, and eventual restrictions.

AL-3406

This is a master PROFIBUS DP-V0, which can be installed only in the main rack.

If the PROFIBUS network is redundant, the AL-3406 modules must be used in pairs, and installed in adjacent positions.

A certain AL-3406 module (or certain redundant pair of modules AL-3406) can perform one of two different functions:

1. Connection of up to four expansion racks. To perform this function, insert the module on the MasterTool Hadron XE architecture window, then select the "Expansion Rack". MasterTool Hadron XE automatically generates all the logic necessary for the rack expansions.
2. Connection of PROFIBUS DP-V0 IEDs. To perform this function, insert the module on the MasterTool Hadron XE architecture window, and then select "Manual Configuration". User must create manually the logic necessary to communicate with the PROFIBUS DP-V0 IEDs.

ATTENTION: These two functions are conflicting with each other in the same AL-3406 module. If the two functions are necessary in the same RTU HD3002, you should use different AL-3406 modules to perform this.

AL-3416

It is a slave PROFIBUS DP-V0, which can only be installed in expansion racks. Its only function is to allow the connection of the expansion rack to the main rack.

If an expansion rack contains AL-313X modules, it can generate events. The transfer of events to the main rack demands an additional AL-3416 expansion rack. If there are no modules in AL-313X expansion rack, a single AL-3416 module is used to transfer the points of communication associated with the I /O modules installed in the slot for expansion.

If the PROFIBUS network is redundant, the AL-3416 modules must be used in pairs, and installed in adjacent positions.

The AL-3416 must always be installed at the first positions. Its position indicates its function in the network, or whether it is used to transfer data or events.

Therefore, considering the presence of AL-313X modules and redundancy of PROFIBUS network, the number of AL-3416 modules in a rack expansion and function of each one can be:

PROFIBUS Network	There is AL-313x on rack	Number of AL-3416	AL-3416 Position 0	AL-3416 Position 1	AL-3416 Position 2	AL-3416 Position 3
Simple	**No**	1	Data	Not used	Not used	Not used
Simple	**Yes**	2	Data	Events	Not used	Not used
Redundant	**No**	2	Data Network A	Data Network B	Not used	Not used
Redundant	**Yes**	4	Data Network A	Data Network B	Event Network A	Event Network B

Table 2-3. Functions and amount of AL-3416 Modules

AL-3412

This module is a client / server ALNET II TCP interface with 100BASE-TX Ethernet (10/100 Mbps twisted pair). It can be installed only in the main rack.

Next are listed the functions executed by the module:

Function of AL-3414	Description
1. Server ALNET II TCP.	This function is useful, for example, to enable remote configuration via MasterTool Hadron XE. It can also be used to receive read / write executed from another HD3002 RTU in client mode ALNET II TCP (ECR instructions and LTR).
2. Client ALNET II TCP.	This function is useful for executing writes / reads to another RTU HD3002 ALNET II TCP server mode (ECR instructions and LTR).

Table 2-4. Functions performed by AL-3412

ATTENTION:
Only one Ethernet interface (AL-3414 or AL-3412) can be enabled for the functions of client / server ALNET II TCP. The use of a AL-3412 interface blocks the use of a AL 3414 module to be as a client / server.

AL-3414

This module is a client / server ALNET II TCP, MODBUS TCP and MODBUS RTU over TCP, with 100BASE-TX Ethernet interface (10/100 Mbps twisted pair). It can be installed only in the main rack.

The AL-3414 can be used in redundant mode, and in this case it should be used in pairs, and placed in adjacent positions. In redundant mode, both AL-3414 modules allocate the same IP address, and only one is active at any given time.

ATTENTION:
The configuration of the MODBUS protocol between TCP and RTU over TCP are conflicting with each other. The choice of one blocks the use of the other for both server and client modes. On the other parts of this manual, the protocol will be referred only as MODBUS TCP.

ATTENTION:
A maximum of one AL-3414 module (or a redundant pair of them) can be used with the ALNET II TCP protocol enabled, since there is no AL-3412 modules in the rack. In other hand, the MODBUS protocol is enabled on all AL-3414 modules

One AL-3414 module can perform several different functions. In some cases, different functions may be conflicting in the same AL-3414 module. When this occurs, it is necessary to add additional AL-3414 modules to do the different functions that conflict with each other. Below are listed the functions performed by the module, showing possible conflicts between functions that cannot be performed on the same AL-3414 (or redundant pair of modules AL-3414):

AL-3414 Function	Description
1. Server ALNET II TCP.	This function is useful, for example, to enable remote configuration via MasterTool Hadron XE. It can also be used to receive read / write executed from another HD3002 RTU in client mode ALNET II TCP (ECR instructions and LTR).
2. Client ALNET II TCP.	This function is useful for executing writes / reads to another RTU HD3002 ALNET II TCP server mode (ECR instructions and LTR).
3. Server MODBUS.	This function is useful for responding to communications requested by other MODBUS clients. One of these clients may be even another RTU HD3002 in MODBUS client mode.
4. MODBUS client Automatic configuration.	This function is useful for communication with MODBUS IEDs, and supports only cyclical (periodic) communication. MasterTool Hadron XE automatically generates all the logics and relations of read / write, mapping these relations to communication points. For the AL-3414 to perform this function, when configuring the AL-3414 module on the architecture window, select the option “Automatic” on Configuration Type of MODBUS Client Relationships in the configuration window of AL 3414. The automatic mode also has an execution control of the relationship of reading / writing disabling for a minute the relations with timeout error.
5. Client MODBUS Manual Configuration.	This function is useful when acyclic communications are necessary, and when you do not want to associate these read/write relations to communication points. For the AL-3414 to perform this function, when configuring the AL-3414 module on the architecture window, select the option “Manual” on Configuration Type of MODBUS Client Relationships in the configuration window of AL 3414.

Table 2-5. Functions performed by AL-3414

ATTENTION:
The functions four and five are conflicting with each other, and cannot be performed by the same AL-3414 module (or redundant pair of modules AL-3414).

ATTENTION:
For the functions 1 and 2 to work is necessary to check the option *ALNET II Protocol* in the configuration window of AL-3414. Only one Ethernet interface (AL-3414 or AL-3412) can be enabled for the functions of TCP ALNET II client /server.

AL-3415

This is an IEC 60870-5-104 server Ethernet interface module, with 100BASE-TX Ethernet interface (10/100 Mbps twisted pair).

Up to four AL-3415 or AL-3417 modules can be installed on the main rack. The AL-3415 module can not be installed on expansion racks.

Each module allows the logical connection of up to four IEC 60870-5-104 clients.

ATTENTION:
Throughout this manual the IEC 60870-5-104 protocol may also be referred to as IEC104.

AL-3417

This is a DNP3 server Ethernet interface module, with 100BASE-TX Ethernet interface (10/100 Mbps twisted pair).

Up to four AL-3417 or AL-3415 modules can be installed on the main rack. The AL-3417 module can not be installed on expansion racks.

Each module allows the logical connection up to four DNP3 clients.

AL-2005

This is a generic interface that allows the installation of various serial communication protocols, based on RS-232 or RS-485, with baud rate up to 38400 bps.

You can install one or two serial ports in AL-2005, and is possible to select, for each port, the RS-232 or RS-485 physical media and the implemented protocol.

Thus, up to two communication applications can be installed in a AL-2005 module (one application for each serial port).

ATTENTION:
For some complex protocols such as DNP3 master, a maximum of one communication application can be installed, which will use one of the serial ports. The other port, in this case, can not be used for any other application.

ATTENTION:
Typically, the maximum baud rate is 38400 bps in a communication application. However, if there are two communication applications installed on the same AL-2005 (two serial ports in use), the baud rate cannot be greater than 19.200 bps in both applications.

When setting up an AL-2005 on the MasterTool Hadron XE architecture window, it is need to declare both installed applications, known as application 0 and application 1.

The options for application 0 and 1 are:

Option	Description	Application
Master serial DNP3	MasterTool Hadron XE automatically generates the logics and communication points with the DNP3 IEDs	Only 0.
Master MODBUS RTU	MasterTool Hadron XE automatically generates the logics and communication points with the MODBUS RTU IEDs. All the read/write communications must be cyclical (periodic).	0 and 1
Other Driver	This option should be selected to indicate that a communication application different from previous ones is being used. In this case, the MasterTool Hadron XE does not generate any logic to configure this driver, being the responsibility of user to do it.	0 and 1

Option	Description	Application
No Driver	This option indicates that there is no communication application 0. In this case, also it is not possible to exist any communication application 1. This case is reserved for situations in which the AL-2005 is used to perform arithmetic coprocessor applications (ex: 100 PID loops, etc..), without using any serial port	0 and 1

Table 2-6. Configuration options of Applications 0 and 1 in AL-2005

ATTENTION:
The "Other Driver" option can be used in place of the option "MODBUS RTU Master" the MODBUS RTU Master driver is installed and you want to configure it manually. This is useful when acyclic read/write relationships are need, or when user do not want to associate these relations with communication points.

I/O Modules

The following I/O modules can be used both in the main or expansion racks:

I/O Module	Description
AL-3130	32 digital inputs 125 Vdc
AL-3132	32 digital inputs 48 Vdc.
AL-3138	32 digital inputs 24 Vdc
AL-3150	16 isolated analog inputs V-I
AL-3150/8	8 16 isolated analog inputs V-I
AL-3151	16 isolated analog inputs RTD-Term
AL-3151/8	8 isolated analog inputs RTD-Term
AL-3202	32 digital outputs with NA relays, type BOD (check-before-operate).

Table 2-7. Available I/O modules

The AL-3130, AL-3132 and AL-3138 modules are used as digital input, having also the function of event log or SOE (sequence of events) with an accuracy of 1 ms. These modules can be referred on this manual, on a general way, as AL-313x.

Modules AL-3150 and AL-3151 are used for analog data acquisition. Both modules have individual isolated input channels, and each channel can be individually configurated. The AL-3150 is designed for voltage and current type input while the AL-3151 is designed for RTD and thermocouple input type. These modules can be referenced in this manual, in a general way, as AL-315x.

Modules AL-3150/8 and AL-3151/8 are used for analog data acquisition. Both modules have individual isolated input channels, and each channel can be individually configurated. The AL-3150/8 is designed for voltage and current type input while the AL-3151/8 is designed for RTD and thermocouple input type. These modules can be referenced in this manual, in a general way, as AL-315x/8.

The AL-3202 modules are used to control equipments and can be used as a single output or as a double output when configured on trip/close mode. These modules also features the CBO function (check-before-operate).

RTU Synchronism

The synchronism of HD3002 RTU is required to assign timestamps to events, and can be obtained through various methods.

The following racks must be synchronized:

- Main rack
- Expansion racks which contain AL-313X modules (the other do not generate events)

Currently RTU HD3002 has two synchronism methods, by GPS and protocol. Each rack has an individual synchronism configuration with two options for each one: the main rack can be synchronized by GPS or by protocol (enabled individually in the configuration of each client by the " accepts command of time" setting), while the expansion rack can be synchronized by GPS or by a PROFIBUS (enabled individually in the settings of each expansion rack by the "PROFIBUS network" setting).

The HD3002 allows to enable the two methods of synchronism simultaneously for each rack, and in this case the GPS method will be always priority. This way, it is possible to use the GPS as primary synchronism mechanism, and in case of failure, use the protocol synchronism as a secondary mechanism. While the GPS is working properly, all the racks are being synchronized by GPS. If a protocol synchronism command is received in this situation, the server interface will accept the command but it will have no effect. When there is some failure in the GPS, the main rack will start to execute the protocol synchronism commands and the expansion racks will synchronize their time with the time of the main rack through the PROFIBUS network.

Although you can select the GPS method for the main rack and the PROFIBUS method for expansion racks, this configuration is not recommended since there will be always a loss of accuracy while transferring the time information over the PROFIBUS network. If there is a GPS available, you should use it as a source of synchronism for all racks.

GPS Synchronism

The most accurate and recommended method and is to connect the AL-1480 GPS receiver, or other GPS receiver (NMEA0183/PPS protocol), on the AL-2004 CPU of the main rack, and on the AL-2004 CPUs of expansion racks which have AL-313X modules.

AL-2004 CPUs of expansion racks that do not contain AL-313X modules do not need to be synchronized, since they do not generate events.

This method ensures timing accuracy of 1 ms for events generated by AL-313X modules.

ATTENTION: The GPS must be connected to the AL-2004 CPU by AL-1422 Sync Generator. For more information on how to install GPS in the AL-2004, see the Technical Characteristics of AL 1422.

Protocol Synchronism

Another synchronization method supported by the RTU is the protocol synchronization, which is much less accurate than the GPS method. Should be used only in applications where the time synchronism is not critical or in case of failure of GPS. In this method, the server interface receives the synchronization command from the client containing the new date and time, and then makes the time setting in the main rack. This command may take up to 3 cycles of RTU program to be executed, so the user must consider this time on the accuracy of this synchronization method. Also, the time resolution of this method is "seconds", because the "mili-seconds" information is cleared before setting the time setting is performed on the RTU. The expansion racks are synchronized with the main rack via the PROFIBUS network. For making this, the "PROFIBUS" option must be

checked in the synchronization options of expansion rack. In this case, there will always be a slight lag between the time of the main rack and the expansion rack due to the update cycle of the PROFIBUS network.

ATTENTION: In the current version of the HD3002, the protocol synchronism command is supported only by the DNP3 protocol (AL-3417 interface).

RTU Time Update

After the start of a time update process (start of GPS communication or changing the time zone/day light setting), the RTU needs some time until all the modules have their time updated, because the AL-2004 CPU have a periodic process for updating the other modules of the RTU. The "mili-seconds" information is updated every 1 second, while the complete time is updated periodically every 1 minute. This way, when the RTU receives a time update where the time difference is less than 1 second, after 1 second the "mili-second" information will be updated in all RTU modules. On the other hand, when the RTU receives a time update where the time difference is greater than 1 second, the other modules of the RTU will only be updated with this new time after 1 minute.

When receiving a time update through protocol synchronism command, it is performed an absolute setting of date and time on the RTU, i.e., all date and time information is updated immediately on the CPU and after 4 seconds on the other modules.

Configuration with MasterTool Hadron XE

The MasterTool Hadron XE is used to configure the HD3002 RTU. Its main features are:

- Friendly user interface for:
    - Defining the architecture of the RTU, composed by the main rack and expansion racks
    - Configurations (general and specific for each client) of slaves communication interfaces:
        - AL-3415 (IEC 60870-5-104)
        - AL-3417 (DNP3)
    - Configuration of master communication interfaces of IEDs:
        - AL-2743 (DNP3 Serial Master in AL-2005)
        - AL-2734 (MODBUS RTU Serial Master in AL-2005)
        - AL-3414 (MODBUS Client)
    - Definition of internal communication points, associated with:
        - Internal Calculation (alarms, mathematic calculation, etc.)
        - Alarm limits, dead bands, enabling events, set points, etc
        - Master or slaves communication interfaces for special or proprietary protocols (slave MODBUS RTU, master/slave ALNET I, etc.)
        - Configuration error detection in edition time
    - Allocation of addresses, operands and tags for the communication points:
        - Related to I/O modules
        - Related to IEDs
        - Internal
- Verification of system general architecture:
    - If the right modules are in right positions in the racks
    - Violations related to the current consumption of voltage rails of AL-3511 and AL-3512 power supplies(+(+5 Vdc, +15 Vdc, -15 Vdc)
    - Violations related to the maximum number of PROFUBUS DP bytes in the expansion racks
- Automatic generation of application code, for functions like:
    - General RTU Diagnostics
    - Basic treatment of I /O modules (configuration, update the value and quality of points, execution commands, etc.)
    - Configuration of AL-3415 and AL-3417 communication interfaces
    - Configuration of master communication interfaces of IEDs in the following protocols:
        - DNP3 Serial Master – driver AL-2743 for AL-2005
        - MODBUS RTU Serial Master – driver AL-2734 for AL-2005
        - MODBUS TCP Client – AL-3414

ATTENTION:
In the case of MODBUS RTU (AL-2005 with driver AL-2734) and MODBUS TCP (AL-3414), automatic configuration by MasterTool Hadron XE is made only when using periodic (cyclical) read/ write. Acyclic read/write operations can be done only with manual configuration.

Limits

- Supports up to 5000 communication points, distributed in up to 256 groups of communication points
- The number of clients (control centers) connected to an AL-3415 communication interface cannot be greater than four.
- The maximum number of mapped points is 20,000
- The number of analog points with event detection can not be greater than 2,000
- The RTU have a maximum number of events that are processed per execution cycle, however this is not a fixed value and it is defined according to chapter 7 - RTU Performance
- The maximum number of master communication interfaces of IEDs (AL-2005 or AL-3414) cannot exceed eight. Should be noted other physical limits that can reduce this number, such as number of free positions for intelligent modules in the main rack.
- AL-2005 modules can support one or two communication drivers, through two different serial channels (COM A and COM B). If a single communication driver is used, the baud rate used can be up to 38400 bps. However, with two communication drivers installed on the same AL-2005, the baud rate of each driver cannot exceed 19.200 bps.
- Limits for AL-3415 configuration:
    - Maximum of four AL-3415 interfaces installed in the main rack, noting other physical limits such as free positions for intelligent modules and current consumption of the entire rack
    - Maximum of four clients for each AL-3415 interface
    - Maximum of 512 mapping groups for each client of the AL-3415 interface
    - Maximum of 7680 point groups for AL-3415 for RTU
    - Maximum of 500 analog points (AI) with event detected by integral dead band
    - Maximum of 500 analog points (AI) of engineering conversion
    - Maximum of 256 %M operands to allocate groups of digital points (DI) of alarms (each %M can contain up to 16 alarms)
    - Maximum of 4000 events stored for each client, respecting the limit of a total of 8000 events.
- Limits for AL-3417 configuration:
    - Maximum of four AL-3417 interfaces installed in the main rack, noting other physical limits such as free positions for intelligent modules and current consumption of the entire rack
    - Maximum of four clients for each AL-3417 interface
    - Maximum of 512 mapping groups for each client of the AL-3417 interface
    - Maximum of 7680 point groups for AL-3417 for RTU
    - Maximum of 500 analog points (AI) with event detected by integral dead band
    - Maximum of 500 analog points (AI) of engineering conversion
    - Maximum of 256 %M operands to allocate groups of digital points (DI) of alarms (each %M can contain up to 16 alarms)
    - Maximum of 256 Counters and 256 Frozen Counters
    - Maximum of 3000 events stored for each client, respecting the limit of a total of 6000 events
- Limits for DNP3 master (AL-2743) driver configuration:
    - Maximum of 31 slave devices
    - Maximum of 200 groups (or relations)
    - Maximum of 1024 bytes for mapping the groups to operands of the AL-2004 CPU
    - It must be the only driver installed on AL-2005 module

- Limits of the configuration of MODBUS master (AL-2734) driver:
    - Maximum of 128 groups (or relations)
    - Maximum number of points in the group is limited by the capacity of a MODBUS communication request
- Limits for interfaces with ALNET II protocol:
    - Only one module, or a redundant pair, of AL-3414 can be configured to use ALNET II over TCP/IP. If used together with the AL-3412 interface, the use of ALNET II protocol on AL-3414 interfaces is blocked.
- Limits of AL-3414 interface:
    - Maximum of 128 connections, including client and server ALNET II connections, client and server MODBUS connections and opened listen ports
- Limits for MODBUS master driver (AL-3414):
    - Maximum of 20 relations on server mode
    - Maximum of 63 relations on client mode (MODBUS TCP communication groups)

Compatibilities

Some hardware and software modules are compatible with the Hadron HD3002 RTU only starting from a specific version, detailed in the following tables.

Hardware Modules		
Code	**Description**	**Version**
AL-2004	CPU for RTU HD3002	3.04
AL-2005	Real Time Multitasking Processor	3.00
AL-3406	PROFIBUS DP Master Network interface.	1.21
AL-3412	10-100 Mbit Ethernet Interface	1.04
AL-3414	MODBUS TCP Ethernet Interface	2.04
AL-3415	IEC 60870-5-104 Ethernet Interface	1.10
AL-3417	DNP3 Ethernet Interface	1.00
AL-3416	Slave PROFIBUS DP network interface	1.06
AL-3150	16 EA (version /current) 16 bits isolated module	2.10
AL-3150/8	Isolated 8 EA (version /current) 16 bits module	1.10
AL-3151	Isolated 16 EA (RTD/ 16 bits Thermo pair) module	2.10
AL-3151/8	Isolated 8 EA 16 bits (RTD/Thermo pair)	1.10
AL-3130	32 ED (125 Vdc) – register of events, 1 ms resolution module	1.58
AL-3132	32 ED (48 Vdc) – register of events, 1 ms resolution module	1.58
AL-3138	32 ED (24 Vdc) – register of events, 1 ms resolution module	1.58
AL-3202	32 SD CBO(Check Before Operate) relay module	1.15

Table 2-8. Hardware modules versions

Software Modules		
Code	**Description**	**Version**
HD8000	MasterTool Hadron XE	1.10
AL-2734	MODBUS Master/Slave Driver	3.01
AL-2743	DNP3 Master Driver	1.22

Table 2-9. Software modules versions

3. Basic Concepts

This chapter introduces several basic concepts necessary to understand the following chapters.

Communication Point

This is the basic unit of information for the purpose of communication with control centers and IEDs.

It is a data structure resident in memory of AL-2004 CPU, which can be accessed by the communication interfaces (AL-3415, AL-3417, AL-2005, AL-3414, AL-3406, etc..) that implement specific protocols.

The data structure of a point of communication, in the memory of the AL-2004 CPU, has two fields:

- **Value (V)**: represents the current status of the communication point, for example:
    - 0 or 1, for single digital inputs
    - -32.768 to +32.767, for analog16 bits inputs with signal

- **Quality (Q)**: this is an optional field (sometimes not available), which contains relevant diagnostic information of the communication point, such as:
    - The information of the value was updated recently and it is reliable
    - The digital inputs module from where the point is read is in failure
    - The IED where the point is read have a communication failure and therefore the value information is obsolete or has never been updated
    - The analog input is saturated in upper or lower limit

From the point of view of storage in the AL-2004 CPU, a communication point has the following main properties, which are described in the following sections:

- Type
- Address
- Variation

Besides these main properties, there are additional properties, which are described below.

Communication Point Groups

It is a set of communication points, which *necessarily* have consecutive addresses and share the same type and variation.

The objectives for the creation of such groups are the following:

- Decreases the effort and memory of configuration. In other words, it allows the descriptions of common properties of multiple similar points, instead of individual descriptions for each point. Next, its shown the group descriptors of communication points and the properties described by them.
- Memory saving in AL-2004 CPU for storing information of quality. There are groups of communication points where all the point have common information of quality.

In addition to the characteristics needed to define a point group (same type and variation, consecutive addresses), other characteristics must be present in order to the group has a practical sense. One of these additional features is the origin of the points that must be the same (e.g. all points of the group belong to the same I/O module).

See section *Origin of the Communication Points.*

A practical example of group of communication points are 32 points of a AL-3130 digital input module. All these 32 points have the same type, same variation and consecutive addresses. Also, they have the same origin (the same module inputs). The AL-3130 module has unique diagnostic information of failure, so the 32 points share common quality information based on this diagnostic, saving memory.

Point Groups Storage Locations

The communication point groups can be stored in two different places:

- In AL-2004 CPU memory. These points can be accessed by the user application and by the clients of all interfaces AL-3415 or AL-3417 of the RTU
- In memory of a specific AL-3415 or AL-3417 interface. They are accessible only by clients (0 to 3) of this particular interface, and are destined only for diagnostics of this interface that are of interest of these clients

Points stored in the AL 2004 CPU are responsible for almost all points of the RTU. On the other hand, a very small amount of diagnostic points is stored in each AL-3415 and AL-3417 interfaces.

Origin of the Communication Points

The origin of the communication points defines the device where the points come from.

Knowing the origin of the communication points is important for several reasons, such as:

- Decide whether you can define a group of communication points with common quality. Therefore, it is necessary that everyone has the same origin
- Change the value of quality due to communication problems or failure in origin

In the section *Point Groups Storage* , it was observed that the points can be stored in the AL -2004 CPU, or in each of the AL-3415 and AL-3417 interfaces. The origin of the points initially takes into account these two places. Further, it is defined the classifications for subsequent origins.

Origin of the Stored Points in AL-2004 CPU

Points stored in the AL-2004 CPU can have various origins, initially divided into three categories, defined in the following three subsections.

Internal Points

These points are typically associated with functions such as:

- Results of internal calculations (e.g. alarms, calculated values in AL-2004 CPU, etc.)
- Set points assigned by slaves and/or server communication interfaces (examples: AL 3415/17, slave ALNET I or MODBUS RTU in an AL-2005, a MODBUS server in an AL 3414). Among those set points include, for example, auxiliary points of communication for control of events (dead bands, disabling of events)
- IEDs PROFIBUS DP-V0 connected to a AL-3406 in *Manual Configuration* mode
- IEDs or other MODBUS devices connected to a AL-3414 in manual mode
- IEDs or other devices connected to an AL2005, manually configured (*other driver* mode).

Internal points are classified in two categories:

- Points of diagnostic and configuration: these groups are automatically generated by MasterTool Hadron XE depending on the architecture of the RTU, and are used to indicate internal failure of RTU (e.g. failure of the GPS synchronization, failure of memory retain, etc.)..
- User-defined points: these groups are created by the user and are related to a specific application (e.g., alarm and signals calculated, set points, dead bands, etc.).

I/O Module Points

These points are related to allowed I/O modules (AL-313X, AL-315x, AL-315x/8 and AL-3202). Groups of these points are automatically generated by MasterTool Hadron XE as they are included in the architecture of the RTU.

They can be installed in both main and expansion racks.

Such group of points with common quality is limited to a single I / O module.

IEDs Points

These points are related to the IEDs and are automatically configured by MasterTool Hadron XE.

They are classified in three categories.

- IEDs connected to an AL-2005 interface with DNP3 Master Serial Driver (AL-2743)
- IEDs connected to an AL-2005 interface with MODBUS RTU Master Serial driver (AL-2734)
- IEDs connected to an AL-3414 interface with MODBUS TCP Client driver in automatic mode

Such group of points with common quality is limited to a single IED, noting that a single AL-2005 or AL-3414 master interface can be connected to several IEDs. In addition, the group must be restricted to a single data type (example: analog inputs associated with a group of points of type AI in memory of AL-2004 CPU).

Origin of the Points Stored on AL-3415/17 Interfaces

Communication points stored in an AL-3415/17 interface have all a single source, which is the interface itself.

Groups of these points are predefined and automatically generated by MasterTool Hadron XE. User does not need to worry about defining them.

Types of Communication Points

The types of communication points are the following:

- DI: digital input
- AI: analog input
- DO: digital output
- AO: analog output
- CN: counter
- FC: frozen counter

Addresses of Communication Points

Addresses allows to differentiate the various communication points of the same type. The address ranges are different for points stored in the AL -2004 CPU and for points stored in AL-3415/17 clients (see section *Point Groups Storage*).

Addresses of points stored in AL-2004 CPU

For these points, the addresses may vary between 0000 and 9999. This methodology allows the creation of up to 10,000 points in each of the types mentioned above (DI, AI, DO, AO, CN, FC).

ATTENTION: This does not mean that you can create 60,000 communication points (6 types * 10000 points) in the HD3002 RTU. The limits reported earlier in this manual must be observed.

The name of a specific communication point is done by combining the type and address, for example, DI0200 is a point of type DI with address 0200. Another point with address 0200 can exist, but in this case it must be of another type (e.g. AI0200).

Addresses of Points Stored In AL-3415/17 Interfaces

For these points, the addresses may vary between 10,000 and 10,099, within each AL 3415/17 interface.

The name of a specific communication point is done by combining the type and address, for example, DI10003 is a point of type DI with address 10003. Another point with address 10003 can exist, but in this case it must be of another type (e.g. AI10003).

Addresses can be repeated in different AL-3415/17 interfaces. For example, there may be a point DI10003 in AL-3415/17 interface position 2 of the main rack, and other point DI10003 in AL-3415/17 interface position 3 of the main rack. The first point DI10003 can be accessed only by clients of AL-3415/17 position 2, and the second point DI10003 can be accessed only by clients of AL-3415/17 position 3.

Formats of the Communication Points

For each group of communication points, user must define a data format, which tells how the value and quality of the points are stored in the AL -2004 CPU.

The storage formats for the value of each point can be the following:

- D1: discrete variable of 1 bit (applicable only for DI and DO types)
- D2: discrete variable of 2 bits (applicable only for DI and DO types)
- D8: discrete variable of 8 bits (applicable only for DI and DO types)
- I16: integer variable of 16 bits with signal (applicable only for AI, AO, CN, FC types)
- UI16: integer variable of 16 bits without signal (applicable only for AI, AO, CN, FC types)
- I32: integer variable of 32 bits with signal (applicable only for AI, AO, CN, FC types)
- UI132: integer variable of 32 bit without signal (applicable only for AI, AO, CN, FC types)
- F32: floating point variable of 32 bit with signal (applicable only for AI, AO, CN, FC types)
- N: null (does not allocate memory for value). Useful, for example, for pulsed digital outputs (DO type), which are usually in a non-energized state (applicable only for AO and DO types). This format is used for "buffered commands" further described.

ATTENTION:
The output points with the value storage format of N, when read through DNP3 protocol, always returns the value 0.

ATTENTION:
Points with storage format UI16 and UI32, when read through DNP3 protocol in floating-point format, will return an invalid value since DNP3 protocol does not have support for unsigned integer data type.

The format for storage of quality value of each point can be the following:

- Without quality (QA)
- Common quality, shared by all point of the group (QC)
- Specific quality for each point of the group (QE)

ATTENTION:
Information of quality is always stored in 8 bits, although the syntax of these 8 bits may vary according to the source of the information. The several syntaxes of quality are defined later.

The variation is defined by combining these two formats. Returning to the example of the AL-3130, it has 32 points of DI type, with D1QC variation (value storage format D1 and quality storage format QC). So, for example, a group associated with an AL-3130 communication module could be defined as:

- Points: DI0065 ... DI0096
- Variation: D1QC

Groups of Points Stored in AL-3415/17 Interfaces

Each AL-3415/17 module has a group of points stored internally, which have no image at AL-2004 CPU, as already mentioned in Section *Point Groups Storage* . These points can be accessed only by four clients that are connected to the AL-3415/17 module. This group can serve, for example, to inform diagnostics to clients.

This group is predefined in MasterTool Hadron XE, being formed by eight DI points with variation D1QA. The points that make up the group are detailed in the section Internal Diagnostics of AL-3415/17 Modules.

Automatically Created Communication Points Groups

There are groups that are automatically created in a Hadron RTU project, allowing the user to define some properties of it.

Groups automatically created in the memory of AL-2004 CPU:

- Groups associated to diagnostics and configurations (Internal Points):
    - For the main rack:
        - Group of 64 DI points with D1QC variation
        - Group of 16 DO points with D1AQ variation
    - For each expansion rack:
        - Group of 16 DI points with D1QC variation
        - Group of 16 DO points with D1QC variation
- Groups associated to I/O modules (I/O modules points)
    - For each AL-313X module, group of 32 DI point with D1QC variation
    - For each AL-315X module, group of 16 AI points with I16QE variation.
    - For each AL-315X/8 module, group of eight AI points with I16QE variation.
    - In the specific case of AL-3202, the same is divided in four groups, one for each byte (32 relay NA outputs type). Each byte can be configured in “latched” or “trip/close” modes.
        - For each byte of the AL-3202, in latched mode, group of eight points DO with D1QC variation
        - For each byte of AL-3202 in trip/close mode, group of four DO points with NQC variation. The common quality reports diagnostics of the byte points, and the values do not exist because they do not make sense (buffered command, described below).

- Groups automatically created in the memory of the AL-3415/17 interface:
    - Group of eight DI points with D1QA variation for each AL-3415/17 interface.

ATTENTION: For more details see the section *Origin of the Communication Points*.

Group of Communication Points Created by the User

As described previously, several groups of communication points are automatically created by MasterTool Hadron XE, according to the defined architecture.

User can create groups of communication points that are stored only in the AL -2004 CPU, according to the following categories:

- Internal points defined by the user
- IEDs points:
    - DNP3 Serial
    - MODBUS RTU
    - MODBUS TCP

ATTENTION: For more details see the section *Origin of the Communication Points*.

Storage of the Point Group in AL-2004 CPU

The type of operand of the AL-2004 CPU used to store the value and quality of a communication point group of is defined by the format of the value:

- D1, D2, D8, I16, UI16, N: %M operands
- I32, UI32: %I operands
- F32: %F operands

ATTENTION: Although the N value format does not allocate any memory for storing the value, it can allocate operands %M for storing the quality (variations NQC NQE). In the case of AA variation, no memory is allocated at all.

The storage area is subdivided in two continuous areas, in the following order:

- Area for storing the value
- Area for storing the quality

Next are showed some examples of storage of communication point groups, in order to clarify the way storage is made in the memory of the AL-2004 CPU.

Example 1:

- Type: DI
- Number of Points: 32
- Initial Address: 200 (group DI0200...DI0231)
- Variation: D1QC
- Initial %M operand for storage: %M3000
- Storage:
    - %M3000.0: value of DI0200
    - ...
    - %M3000.F: value of DI0215
    - %M3001.0: value of DI0216
    - ...
    - %M3001.F: value of DI0231
    - %M3002b0: common quality for all the 32 points
    - %M3002b1: not used

Example 2:

- Type: DI
- Number of Points: 16
- Initial Address: 500 (group DI0500...DI0515)
- Variation: D2QE
- Initial %M operand for storage: %M3500
- Storage
    - %M3500.0 e %M3500.1: value of DI0500
    - ...
    - %M3500.E e %M3500.F: value of DI0507
    - %M3501.0 e %M3501.1: value of DI0508
    - ...
    - %M3501.E e %M3501.F: value of DI0515
    - %M3502b0: quality of DI0500
    - %M3502b1: quality of DI0501
    - ...
    - %M3509b0: quality of DI0514
    - %M3509b1: quality of DI0515

Example 3:

- Type: AI
- Number of Points: 9
- Initial Address: 100 (group AI0100...AI0108)
- Variation: I16QE
- Initial %M operand for storage: %M3000
- Storage:
    - %M3000: value of AI0100
    - ...
    - %M3008: value of AI0108
    - %M3009b0: quality of AI0100
    - %M3009b1: quality of AI0101
    - ...
    - %M3013b0: quality of AI0108
    - %M3013b1: not used

Example 4:

- Type: AI
- Number of Points: 9
- Initial Address: 200 (group AI0200...AI0208)
- Variation: F32QC
- Initial %F operand for storage: %F1000
- Storage:
    - %F1000: value of AI0200
    - ...
    - %F1008: value of AI0208
    - %F1009b0: common quality to all the 9 points
    - %F1009b1, %F1009b2, %F1009b3: not used

Example 5:

- Type: AI
- Number of Points: 9
- Initial Address: 500 (group AI0500...AI0508)
- variation: I32QE
- Initial %I operand for storage: %I1000
- Storage:
    - %I1000: value of AI0500
    - ...
    - %I1008: value of AI0508
    - %I1009b0: quality of AI0500
    - %I1009b1: quality of AI0501
    - ...
    - %I1011b0: quality of AI0508
    - %I1011b1, %I1011b2, %I1011b3: not used

Example 6:

- Type: AO
- Number of Points: 9
- Initial Address: 500 (group AO0500...AO0508)
- Variation: F32QA
- Initial %F operand for storage: %F1200
- Storage:
    - %F1200: value of AO0500
    - ...
    - %F1208: value of AO0508
    - No storage for quality (QA)

Example 7:

- Type: DO
- Number of Points: 8
- Initial address: 700 (group DO0700...DO0707)
- Variation: NQE
- Initial %M operand for storage: %M1500
- Storage:
    - No storage for values (N)
    - %M1500b0: quality of DO0700.
    - %M1500b1: quality of DO0701.
    - ...
    - %M1503b0: quality of DO0706.
    - %M1503b1: quality of DO0707.

Quality Formats

The HD3002 RTU provides several quality formats. When setting a group of communication points, in some cases it must be informed the format of the quality used. In other cases, the format is set automatically by MasterTool Hadron XE. Regardless of the format selected, the quality is always stored in eight bits, so all the previous considerations about quality storage are valid.

Each communication protocol defines one or more formats of quality, and in some cases gives another name to the quality (e.g., DNP3 calls *status*).

The objective of supporting multiple formats of quality in HD3002 RTU is to avoid loss of information when quality format conversions are performed (protocols conversions).

Consider an example where the HD3002 RTU read points from a DNP3 IED by an AL-2005, and reports to an IEC104 server through a AL-3415.

If the HD3002 RTU stores the qualities in a single internal format (e.g., OPC), it would require two conversions (DNP3 to OPC followed by OPC to IEC104).

However, the RTU HD3002 stores the quality of read points from IEDs DNP3 in DNP3 quality format. Therefore, only a single conversion is necessary, directly from DNP3 to IEC104. Obviously, this strategy is better because the chance of errors in conversion of quality is lower.

ATTENTION: Points configured in QA quality format are reported as code 0 for IEC104 clients and as code 1 for DNP3 clients.

For more information, see *Annex A* where are described in details the different quality formats supported in the RTU HD3002, as the conversions that occur between them when necessary.

Engineering Conversion

Field values, which comes from a analog-to-digital conversion process, are typically represented in a scale that is difficult for the user to understand, since he does not know the characteristics of the field sensor or of the analog input module. For solving this issue, these field values are converter for engineering units, which represents the sensor values in a better way for understanding.

A current transductor can represent its measurement scale by a range of integer numbers, from 0 to 30,000 for example, which cam represent a real field value of -100 to 200A.

The engineering conversion process is performed by the following expression:

AI(Eng. Conv.) = AI(Field Unit) x MF + AF,

where:

MF : Multiplicative Factor

AF : Additive Factor

Basically the engineering conversion represents a change in scale (range), where the multiplicative and additive factors are responsible for this conversion. On the previous example, the factors should be 0.01 for the multiplicative and -100 for the additive.

The AL-3415 and AL-3417 modules can perform the engineering conversion of analog inputs by configuring the specific AI groups for this purpose. On the conversion are used two blocks of %F operands to store the multiplicative and additive factor related to this operation.

The reading of the %F operands with the additive and multiplicative factors by the modules is not performed in all execution cycles, because such factors are rarely changed. Usually it is done only at startup (power-on) of the RTU, or it can be done later if the user wants to through the DO command **Read engineering conversion factors in this cycle**. The recommended procedure is as follows:

- Change the %F operands with multiplicative and additive factors
- Set the bit that corresponds to the command of configuration **Read engineering conversion factors in this cycle**
- The AL-3415/17 modules, by realizing this bit is set, read the %F operands with the multiplicative and additive factors

Besides the engineering conversion, the modules are also responsible for copying the information of quality of the group with field units to the group with engineering units.

The calculation of engineering conversion is performed at each cycle of the RTU. During the execution of this operation, the application program on AL-2004 CPU keeps stopped waiting until it finishes, however it is possible to allow this operation to be executed in parallel with the application program of AL-2004. In this case, the values will be updated only in the next AL-2004 CPU execution cycle.

ATTENTION: If the conversion results in an overflow, the value is limited to the maximum value of a %F operand.

ATTENTION:
The engineering conversion will be performed only by the first AL-3415/17 interface that is declared on the rack. In the case of the AL-3417 module, if the first AL-3417 module on the rack fails, the second module will perform the conversion, and in a similar case for the other modules. In the case of a mixed rack with AL-3415 and AL-3417 modules, the conversion will be performed by the first AL-3415 and by the first AL-3417 modules. This must be considered while defining the Hadron RTU cycle time.

For further information about the engineering conversion groups, please consult the section *Exclusive Properties for the Groups of Engineering Conversion.*

Alarms Calculation

The AL-3415 and AL-3417 modules can also perform calculations of high and low alarm from analog inputs. The calculation results are stored in groups of internal points of type DI with format D1QA.

The alarms calculation is performed at each cycle of the RTU. During the execution of this operation, the application program on AL-2004 CPU keeps stopped waiting until it finishes, however it is possible to allow this operation to be executed in parallel with the application program of AL-2004. In this case, the values will be updated only in the next AL-2004 CPU execution cycle.

For further information about the configuration of alarm calculation groups, please consult the section *Exclusive Properties for the Alarm Digital Input Groups.*

Events

An event contains historic information of value (V) and quality (Q) of a point, which occurred at some time in the past (T), where T is known for timestamp.

An event is typically generated when there are changes in value (V) and / or quality (Q) of a communication point.

In the case of analog variables and counters, the changes in value should normally be relevant, i.e., greater than a minimum magnitude called dead band. If any small variation in inputs would produce events, there would be too much events because usually there is a background noise that causes constant fluctuations in analog inputs.

Events should normally be transmitted to one or more control centers for storage on a historical database with high capacity and are used for failure analysis, among other objectives.

An event is described through the following fields:

- Unique identification of the communication point. In case of a point of the AL-2004 CPU, this is done using the **type** and **address** of the point, previously defined. The variation is not necessary, since this information can be restored from descriptors stored in the configuration area.
- The triple VQT (**value, quality, time stamping**) associated to the event for this point.

Events Queue

A single communication point can have multiple events, if it suffers a number of changes in value and / or quality throughout the history of the equipment that generates the event.

You cannot store all events generated in the history of equipment, as this would require an infinite memory, even for a finite number of points. Thus, events must be stored in circular queues of events, with finite size. The events must be transmitted from the RTU to the control centers, where they can be stored in mass storage unities with high capacity, which still must have periodic cleaning operations, as even the mass storage of high capacity is not infinite.

In the HD3002, there are several queues of events, many of them interconnected (events transferred from a queue to another subsequent queue). The following figure shows the various queue of events in HD3002, their capacities, and interconnections between them. This figure is based on an example where there are:

- Three expansion racks (0, 1 and 2), besides the main rack. It is considered that there are AL-313X modules (event producers) only in the expansion racks 0 and 2. For this reason, the rack 1 has no line of events, and was not represented in the figure.
- One AL-2005 module with AL-2743 (DNP3 Serial) driver, connected to IEDs
- Two AL-3415 modules (IEC 60870-5-104 Ethernet interfaces). On this case is used the interface AL-3415, however it could be also considered the use of two AL-3417 (Ethernet interface DNP3) interfaces.

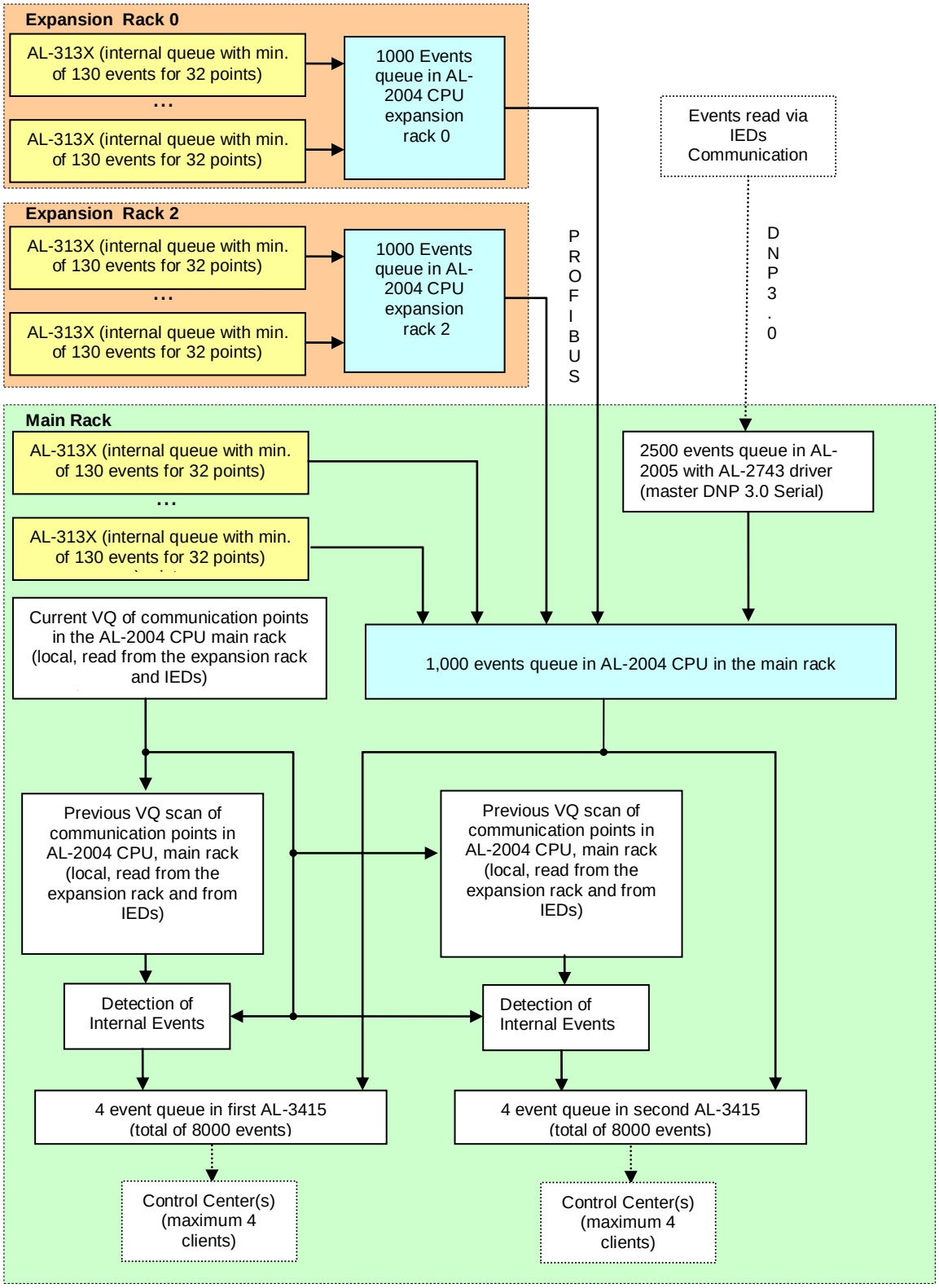


Figure 3-1. Example of events queue and events flow

Based on a practical example of architecture, the previous figure allows us to understand various mechanisms related to the event queues and event detection, which are explained below.

Events Generated by AL-313X Modules

Among the I/O modules that can be installed in racks of HD3002 (main or expansion), only the modules AL-313X generate events directly, and with a resolution of 1 ms. The accuracy can also be 1 ms, since the rack where the AL-313X is installed is being synchronized by a GPS.

Each AL-313X module has 32 points and a circular queue of internal events of variable size, which can store at least 130 events.

Events Generated by IEDs

Events also can be generated by IEDs, and read through the master communication interfaces, such as the AL-2005 with AL-2743 (master serial DNP3) driver.

Events in AL-2004 CPU Queues in Expansion Racks

Each AL-2004 CPU of an expansion rack has a circular queue with configurable capacity.

The events stored on a queue of this type can come only from AL-313X modules that are installed in the rack.

If an expansion rack does not have AL-313X modules, the event queue of its AL-2004 CPU remains empty, and the rack does not need to be synchronized.

Events in the Queue of AL-2004 CPU of the Main Rack

Events stored in this queue can have three different origins:

- AL-313X modules that are eventually installed in this rack
- Event queues transferred from the expansion racks through the PROFIBUS DP network
- Events read from IEDs through master communication interfaces, as, for example, AL-2005 with master DNP3 serial driver as shown in previous figure
- Events inserted by the user application.

The storage capacity of the event queue of the main rack AL-2004 CPU is configurable, and the default value is 1000. The configuration of this parameter is described in chapter

Size of the Event Queue of AL-2004 CPU.

Events in the Queues of AL-3415/17 Interfaces

Each AL-3415/17 interface has four internal event queues, since there is one queue for each possible client.

The events stored in these four queues can come from two different origins:

- Events queue from the main rack AL-2004 CPU
- Internal Events, detected by the AL-3415/17 interface itself. For more information, see the section *Detection Methods of Internal Events in a AL-3415/17 Module*.

The storage area for these four queues is organized into two segments (segment A and segment B), and each segment has a capacity of 4000 events for the AL-3415 interface and 3000 events for the AL-3417 interface. Therefore, the AL-3415 as a whole can store 8000 events internally, while each AL-3417 interface supports up to 6000 events.

User must configure the segment (A or B) and the size of each of the four queues, or disable the event queue for one client. Some restrictions should be considered:

- A client queue must not have over 4000 events in the case of the AL-3415 interface or 3000 events in AL-3417 interface
- The sum of the queue size in each segment must not be over 4000 events in the case of the AL-3415 interface or 3000 events in AL-3417 interface

Example of a valid configuration for an AL-3415 interface:

- Client 0: 4000 events on segment A
- Client 1: 3000 events on segment B
- Client 2: 1000 events on segment B
- Client 3: 0 events

ATTENTION:
The queue clear command, when executed by the AL-3415/17 interfaces, need at least one CPU execution cycle to be executed. Thus, even after sending the command, a DNP3 client can receive messages indicating the existence of events for some class while the command was not effectively executed.

Retentive Memory for Events Queue

The retentive memory for the events stored in the queues mentioned earlier is used to retrieve old events even after a power loss in the HD3002 RTU.

ATTENTION:
The event queue of each AL-313X module is not stored in retentive memory. In case of power loss, events stored in these modules will be lost.

ATTENTION:
Although the AL-3415 have retentive memory to store events, the IEC 60870-5-104 protocol does not have any message to confirm the events received by the master IEC. As soon as the events are inserted into the frame they are also removed from the event queue. Therefore, if the frame does not reach its destination (the IEC104 master) for some reason, the events will be lost.

Events Overflow Alarms

The Hadron MasterTool XE automatically allocates some DI type communication points to indicate events overflow alarms in event queues of the AL -2004 CPUs or of AL-313X modules, both on the main rack and expansion racks.

In addition, each AL-3415/17 Ethernet interface allocates four DI points for internal diagnostic (DI10000 ... DI10003) to indicate the occurrence of events overflow in the queue of its four clients.

These diagnostics are described in the chapter *Internal Diagnostics of AL-3415/17 Modules.*

It must be noted that the indication of event overflow is an extremely fast pulse in DI point, lasting a single scan of the AL-2004 CPU main rack.

On the AL-3415 interface, when a situation of overflow for each client (DI10000. .. DI10003) occurs, the event queue is cleared and the events contained in this queue are lost. Events after the overflow, including the event that caused the overflow, are normally inserted in the queue that has just been cleared. On the AL-3417 interface, it is possible to configure the two modes of operation for this

overflow condition. The behavior of the first mode is identical to the AL-3415 interface, where the events that are on the queue are cleared. On the second mode, the oldest events are kept on the queue until at least one position of the queue gets free. None event is inserted on the queue, and the client overflow diagnostic is kept set until there is at least one free position on the queue.

If there is an event overflow in a AL-2004 queue of the main rack (occurrence of a greater number of events than the maximum configured, in the same cycle) it is generated a diagnostic through DI10007. In this situation, the events that are in the queues are normally transferred to the internal queues of the AL-3415/17 modules.

If there is an event overflow in a AL-2004 queue of an expansion rack, it is generated a diagnostic through a specific DI corresponding to that rack. For the corresponding diagnostic DI, please see the section *Equivalence of Diagnostic Addresses of the Expansion Racks*. When the overflow occurs, the module F-EVTREM.117 discards all the events that are on the expansion rack queues.

Specific Parameters for Events from AL-313X Modules

Al-313X has three specific parameters, which are also used for the control of events.

Types of Lost Events in Case of Overflow in a AL-313X

If there is an overflow in the internal event queue of AL-313X (which supports a minimum of 130 events) it is possible to choose which events are going to be maintained:

- The older ones
- The most recent ones (the default option)

This parameter is fixed and must be edited in the moment of the configuration via MasterTool Hadron XE. It is common for all the 32 points in an AL-313X.

Filters of an AL-313X

The filter parameter prevents that fast pulses in the inputs of an AL-313X, typically caused by noise, to be detected and then generate events. It can be configured with the following values: 0, 10, 12, 14... 254 ms.

This parameter is fixed and must be edited in the moment of the configuration via MasterTool Hadron XE. It is common for all the 32 points in an AL-313X.

Debounce of an AL-313X

The debounce parameter prevents additional bounces in an input of an AL-313X, after a commutation, to be considered as events. It can be configured between 0 and 255 ms.

This parameter is fixed and must be edited in the moment of the configuration via MasterTool Hadron XE. It is common for all the 32 points in an AL-313X.

Events Generation

MasterTool Hadron XE allows to configure four types of events generation for a group constituted of N communication points:

- **Enabled:** event of all points of the group are always enabled
- **Disabled:** event of all points of the group are always disabled.
- **Disabled by a Common DO:** a group of a single point of type DO, with variation D1QA, is allocated to disable events of all the N points of the group (DO = 1 to disable).
- **Disabled by an Individual DO:** a group of N points of the type DO with variation D1QA, is allocated to disable events, individually, of each of the N points of the group (DO = 1 to disable).

ATTENTION: Events generated in IEDs are not affected by this option.

DO and AO Types without Events

There are no events for DO and AO types.

Types of Dead Band

MasterTool Hadron XE allows to configure five types of dead band for the control of events at points of type AI, CN and FC.

Considering a group of N points of any of these types, you can select one of the following types of dead band:

- **Null**: any modification in the value of a point of the group, the least it is, generates an event for such point
  Absolute Common AO: a group with a single point of AO type contains an absolute dead band. If the module of the value variation of a point of the group (AI, CN, and FC) is greater than this AO, an event to this point is generated.
- **Individual Absolute AO**. A group of N points of AO type contains dead band for each individual point of the group of points (AI, CN, and FC). The operation of an absolute dead band was explained previously.
- **Common Integrated AO**. A group with a single point of AO type contains a integrated dead band. If the module of the integral of the value variation of a point of the group (AI, CN, and FC) is greater than this AO, an event to this point is generated. Negative changes are considered in integration with negative sign. The integration interval is one second.
- **Individual Integrated AO**. A group with N of AO type contains dead band integrated for each point of the group of points (AI, CN, and FC). The working of an integrated dead band was explained before.

ATTENTION: The User must not use negative values for dead band AO points, since in this case there will happen a continuous generation of events.

The data format of the dead band AO type point group depends on the data format of the group of points where events are detected (AI, CN, CF), according to the following table. The quality of the dead band AO point group is absent (QA).

Format of the Group (AI/CN/FC)	Format of the dead band (AO) group
I16, UI16	I16, UI16
I32, UI32	I16, UI16, I32, UI32
F32	F32

Table 3-1. Data format for a group of dead bands

Detection Methods of Internal Events in a AL-3415/17 Module

Events of a communication points group can reach an AL-3415/17 module through the event queue from the AL-2004 CPU, but can also be detected inside the module, which can analyze changes in value and/or quality of the communication points.

In order to the detection of internal events to be properly performed in AL-3415/17 module, it is necessary to select one of the methods of detection of internal events.

Next, are described the available methods.

- **Disabled:** the AL-3415/17 will never generate events for this group of points. This configuration is recommended for:
    - Groups of points for which there is no need for events.
    - Groups of communication points where all the events come from the events queue of the AL-2004 CPU in the main rack, so it is unnecessary that AL-3415/17 generates additional events
- **Q**: any variation of quality generates events. This configuration is recommended for:
    - Points of AL-313X. AL-313X modules generates internal events with precision and resolution of 1 ms for value changes, but never generates events based on changes in quality. Thus, when a AL-313X module fails, or when the PROFIBUS DP communication with expansion rack that contains AL-313X fails, the AL-3415/17 generates events for the points of the AL-313X.
    - Points read from IEDs that are able to generate events for value changes, but not capable of generating events for quality changes.
- **QC**: change in quality related to communication (failure or recover of communication) generates events. This configuration is recommended for:
    - Points read from IEDs that are able to generate events, both by changes of value and quality. When the communication with the IED is lost, the AL-3415/17 should generate events for communication quality change. Note that in this case, the events will be dated with the time of the Hadron RTU and not with the time of the IED.
- **QNC**: any variation in quality not related to communication (failure or recover of communication) generates events. Thus, a failure or recover of communication leads to changes in quality of various points, but does not generate events in these points. This configuration can be used to avoid cascades of events due to communication failures and is recommended for:
    - Points of AL-313X. AL-313X modules generates internal events with precision and resolution of 1 ms for value changes, but never generates events based on changes in quality. With this configuration, hardware failures in an AL-313X module generate events for its 32 points. However, if the communication with an expansion rack containing five AL-313X modules fails, it will not be generated 160 events of communication quality variation for these points.
    - Points read from IEDs that are able of generating events for changes in value, but not capable of generating events for quality changes. Avoid of generating quality events in the case of failure of communication with these points. Note that in this case, the events will be dated with the time of the Hadron RTU and not with the time of the IED.

- **V_Q**: any change in value or quality generates an event. This configurations recommended for:
    - Internal points of AL-2004 CPU, since it does not generate event for this type of points.
    - Points of AL-351X e AL-351X/8 module, since AL-2004 CPU does not generate events for this type of points.
    - Points of IEDs with no capacity to generate events.
- **V**: any change in value generates an event, and changes in quality do not produce events. This configuration is recommended when events generated due to changes in quality are not wanted or when there is not quality available (variations with absent quality. or QA), or even when it is undesirable or irrelevant. In some cases, changes in quality can happen simultaneously in dozens or hundreds of points, which can generate cascades of events (e.g. failure to communicate with an IED, fail in an I/O module). This configuration is recommended for:
    - Internal points of AL-2004 CPU with no quality (QA variation).
    - IEDs points with no capacity to generate events.
- **V_QC**: any variation in value, or any variation of quality related only with the communication (failure or recover of communication) generate events.
- **V_QNC**: any change in value, or any variation in quality not related to communication, generates events. Thus, a failure or recover of communication leads to changes in quality at various points, but does not cause events at these points. This configuration can be used to avoid cascades of events due to communication failures and is recommended for:
    - Points of modules AL-315x or AL-315x / 8 located in expansion racks. In case of failure of communication with the expansion rack via PROFIBUS DP, this setting will prevent the generation of events by quality change.
    - Points read from IEDs that are not capable of generating events. In case of failure of communication with the IED, this setting will prevent the generation of events by quality changes.

ATTENTION: This method applies only to the generation of internal events in AL-3415 and AL-3417 modules. It does not allow blocking incoming events from the event queue of the AL -2004 CPU in main rack. For example, if the option "Disable" is selected for this method, this does not prevent events to reach the group through the event queue of the AL -2004 CPU in main rack.

ATTENTION: This method is applied together with other controls of event generation previously showed, described in the sections *Events Generation* and *DO and AO Types without Events*.

The events of expansion racks can have different times depending of the event type. The events of value change of digital inputs of a AL-313x module use the local time of the expansion rack. On the other hand, the events of the following points use the time of the main rack because they are generated on the modules AL-3415/17:

- Value and quality events of the expansion racks diagnostics
- Value and quality events of the AL-315x modules
- Quality events of the AL-313x modules

Commands

Commands are transmitted from a source to a destination device, where it should cause an effect. The destination device should normally return a status for the source equipment, reporting the result (success or failure) of the command.

Command Source Devices

In the HD3002 RTU context, a command can have two sources:

- A client of a AL-3415/17 module, for example, an IEC 60870-5-104 client connected to a AL-3415. Up to four AL-3415/17 modules may be present in the RTU, and each one can have up to four clients connected. Thus, the maximum number of clients is 16.
- User application, executed by the main rack AL-2004 CPU. This way, it is an internally generated command to the RTU HD3002 through user-created logic.

Command Destination Devices

In the HD3002 RTU context, a command can have three destinations:

- Internal points of the RTU, resident in the operand memory of the AL-2004 CPU
- Points of AL-3202 modules, located in the main or expansion racks
- Points of IEDs, connected through AL-2005 or AL-3414 modules

Concepts of Immediate and Buffered Commands

Commands can be classified as immediate or buffered.

Immediate commands are executed in a single execution cycle of the AL-2004 CPU, and for this reason do not require buffers for being stored on the RTU. These commands are executed directly by an AL-3415/17 module when received from an IEC104 or DNP3 client, because the AL-3415/17 module can perform write and read operations in memory of the AL -2004 CPU. In other cases, the source equipment is just the user application running in AL-2004 CPU, which is responsible for writing and reading in the appropriate operands.

Buffered commands often require several execution cycles of the AL-2004 CPU to be completed, so buffers are used to store the command until they are completed. These buffers can come from a AL-3415 module (transferred from an IEC104 client), from a AL-3417 (transferred from a DNP3 client) or from the user application on AL-2004 CPU.

ATTENTION: Commands received through AL-3415/17 interface need at least one CPU execution cycle to be executed.

Immediate Commands Provided in HD3002 RTU

In HD3002 RTU, there are three cases in which the immediate commands are used:

- Commands over internal points, resident in the operand memory of main rack AL -2004 CPU. These commands are executed by writing over one or more operands of AL-2004 CPU (%M, %I or %F), associated with points of types DO, AO, CN or CF that are configured as internal points. The status returned to the command source equipment is always "ok".
- Commands over bytes of AL-3202 modules configured in the "latched" mode. These commands are executed by writing over an operand %M of AL-2004 CPU, associated with the group of eight points of the type DO, variation D1QC of the latched byte of the AL-3202. The status returned to the source equipment depends on the quality (diagnostics) of the respective byte of the AL-3202 module (there may be failures in the module, or failure to communicate with expansion racks).
- Commands for MODBUS RTU and MODBUS TCP IEDs. These commands are executed by writing over one or more operands of AL-2004 CPU (%M, %I or %F), associated with points of types DO or AO that are configured as MODBUS RTU or MODBUS TCP. The status returned to the command source equipment depends on quality of the MODBUS point (there may be failure to communicate with the MODBUS IED).

Buffered Commands Provided in HD3002 RTU

In HD3002 RTU, there are three types of buffered commands, for which there must be always a status return:

- Commands for bytes of AL-3202 modules configured in trip/close mode
- Commands for serial DNP3 IEDs
- User commands over internal points, which must be decoded by the user

ATTENTION: The buffered commands are of N type, therefore it is not possible to read the status of these points.

Data Structures and Command Management Process

The following figure shows the data structures involved with the commands in the scope of the main rack, the processes involved, the operation and their restrictions. It must be remembered the following limits established previously, to understand this picture:

- The maximum number of AL-3415/17 modules is four, however the number of data structures was defined as eight, indexed by the position where AL-3415/17 was installed (0 to 7)
- The maximum number of clients for an AL-3415/17 module is four
- The maximum number of AL-2005 or AL-3414 modules is eight, containing masters drivers of standard IEDs (Serial DNP3, MODBUS RTU and MODBUS TCP)
- The maximum number of racks with AL-3202 modules is 5 (the main rack and four expansion racks)

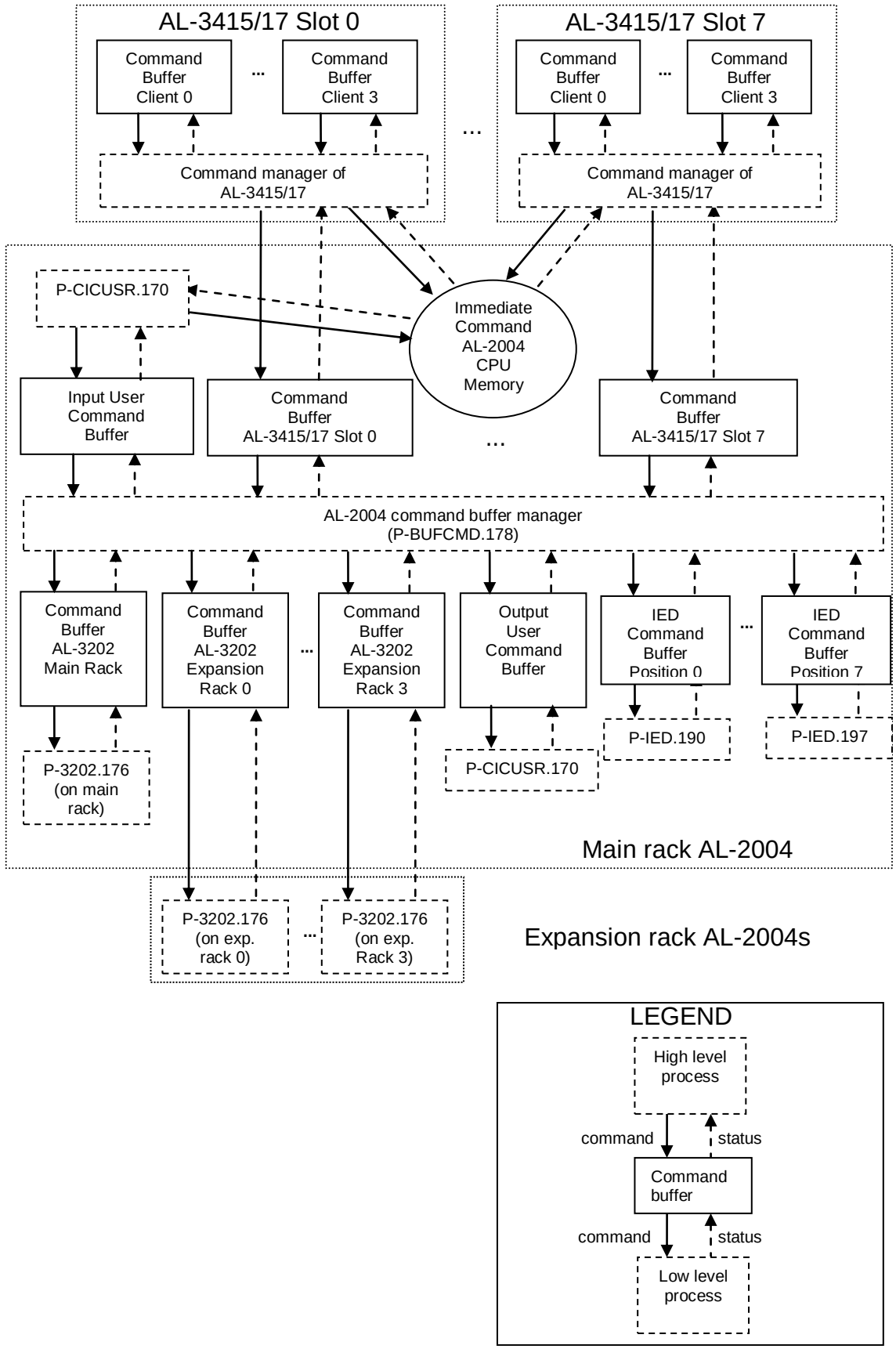


Figure 3-2.Commands buffer in main rack

The figure shows that the AL-3415/17 modules, as well as the user application of AL-2004 CPU, can perform immediate commands in a simple way, and for this it is only needed to read/write in operands of AL-2004 CPU memory, what can be done in a single execution cycle.

In the other hand, the buffered commands have a more complex operation. The following sections describe the operation of the buffered commands.

Hierarchy of the Command Buffers Manager Process

There is a hierarchy of processes that manage the command buffers in the HD3002 RTU, as the previous figure shows.

On top of this hierarchy, there are:

- The AL-3415/17 modules. For example, if there is a AL-3415/17 module in slot 3, the command buffers that it receives from its 4 possible IEC104 or DNP3 clients (0 to 3) are assigned to the **Command Buffer AL-3415/17 Slot 3**. This buffer is the output buffer of the AL-3415/17 in slot 3. In the other hand, each AL-3415/17 has 4 input buffers, from the 4 IEC104 or DNP3 clients (0 to 3). Note that there are 8 command buffers for AL-3415/17, one for each rack slot between 0 and 7, where this type of module can be installed.
- The user application on AL-2004 CPU, which output buffer is the **Input User Command Buffer.**

In the intermediary level of the hierarchy, there is the P-BUFCMD.178, executed in AL-2004 CPU and automatically generated by MasterTool Hadron XE.

The output buffers of the AL-3415/17 modules and the Input User Command Buffer, previously described, are the 9 input buffers of P-BUFCMD.178 showed on the previous figure.

In addition, P-BUFCMD.178 has 14 output buffers that are also described on the previous figure:

- 5 **AL-3202 Command Buffers**, used for sending commands to AL-3202 modules (bytes on trip/close mode), where there is one buffer for each rack (one for the main rack, and up to four for the expansion racks)
- 1 **Output User Command Buffer,** for sending commands over internal points to the user (executed by the user application on P-CICUSR.170 module)
- 8 **IED Command Buffers**, for commands to serial DNP3 IEDs, which AL-2005 masters can be installed in slots between 0 and 7 of the main rack (AL-2005 modules with AL-2743 driver). It should be remembered that the MODBUS RTU (AL-2005 with AL-2734 driver) and MODBUS TCP (AL-3414) protocols executes only immediate commands and, therefore, do not use these buffers.

In the lower level of the hierarchy are:

- The five P-3202.176 modules (one in the main rack, the others in expansion racks) responsible, between other things, for processing buffered commands to trip/close bytes of the AL-3202 modules, on the five racks (main and up to four expansion). The five **AL-3202 Command Buffers** are considered its input buffers.
- The module P-CICUSR.170, or user application, responsible for processing the commands received on the output user command buffer. Such commands perform operations over the internal points. The **Output User Command Buffer** is considered it input buffer.
- The eight P-IED.190 … P-IED.197 modules (one for each position between 0 and 7) responsible, between other things, for the treatment of serial DNP3IEDs. These modules receives the 8 **IED Command Buffers** as input buffers.

ATTENTION:
The current revision of AL-3415 module does not generates commands destined to the **Output User Command Buffer**, which must be executed by the user application. At the moment, only the AL-3417 module have this functionality.

Multiplexing and Release of Command Buffers

The processes described before in the three hierarchy levels, have input and output buffers.

In some cases, a process receives two or more input buffers simultaneously, which are targeted to the same output buffer. In this case, the last input buffer has to wait for the release of the output buffer to which it is intended.

A command buffer is released by the process that considers it as an input buffer, after completing the command.

Normal and Timeout Releases of Command Buffers

A process can release an input buffer in three different ways:

- Timeout for allocating the output buffer. The timeout was expired before it was able to allocate the output buffer for which the input buffer must be passed. This occurs because the output buffer can be busy with a previously running command (multiplexing buffers). This timeout is not checked in the low-level processes (P-3202.176 and P -IED.19x) because they do not have output buffers.
- Status return timeout. The timeout was expired before receiving the status of the process output buffer. The corresponding input buffer is released, indicating timeout. This timeout is checked only by low-level processes (P-3202.176 and P -IED.19x).
- In normal way. In this case, the process receives the status information on its output buffer before the respective timeout is expired, and must pass this status to the corresponding input buffer.

For the first two options described above, the timeout parameters used are chosen by the type of the output buffer to which the command is destined. There are three types of output buffers, and each one uses its own timeout:

- Timeout for DNP3IEDs
- Timeout for AL-3202 modules, both in main rack and expansion racks
- Timeout for user commands

User Interface with P-BUFCMD.178

In several cases, it is not need to understand the functioning of P-BUFCMD.178 and format of its input and output command buffers. These cases are the ones where the buffered commands come from the AL-3415/17 modules and are destined to AL-3202 modules or to serial DNP3 IEDs.

On the other hand, there are some cases where the user application (P-CICUSR.170) wants to:

- Generate buffered commands for a AL-3202 module or for a serial DNP3 IED
- Execute buffered commands over internal points, received from a AL-3415/17 module

For these last cases, the user must understand the functioning of the P-BUFCMD.178 module and the format of the following buffers:

- **Input User Command Buffer**, generated by the user application on the AL-2004 CPU (P-CICUSR.170). being one of the input buffers of P-BUFCMD.178. It allows to generate buffered commands for a AL-3202 module or for a serial DNP3 IED.
- **Output User Command Buffer**, generated by P-BUFCMD.178, and used by the user application (P-CICUSR.170) for executing commands over internal points, received from a AL-3415/17 module.

On the next sections, it is described the functioning of P-BUFCMD.178 and the format of these two buffers.

ATTENTION: The current revision of AL-3415 module does not generates commands destined to the **Output User Command Buffer**, which must be executed by the user application. At the moment, only the AL-3417 module have this functionality.

Operation of the P-BUFCMD.178

The P-BUFCMD.178 module can handle simultaneously several commands, as it has several input and output buffers. The maximum limit is nine simultaneous commands, since there are nine input buffers and 14 output buffers. This limit, however, is only achieved if the controls of nine input buffers are in use and if they are destined to nine different output buffers.

From the perspective of a specific command, the P-BUFCMD.178 module works as follows:

- Checks for the arrival of the command in an input buffer. As the previous figure shows, there are nine input buffers on P-BUFCMD.178:
    - Input User Command Buffer
    - AL-3415/17 Command Buffer in slot 0
    - …
    - AL-3415/17 Command Buffer in slot 7
- Passes the command of the input buffer to the proper output buffer, since it is free. If it cannot allocate the output buffer within the timeout, the processing of the command ends, and the input buffer is released indicating that the cause was timeout. The transfer to the output buffer also does not occur if there is a communication failure between the AL-2004 of the main rack and the destination command process (an expansion rack with AL-3202 modules, or a AL-2005 DNP3 master). As shown in the previous figure, there are 14 output buffers on P-BUFCMD.178:
    - AL-3202 Command Buffer in the Main Rack
    - AL-3202 Command Buffer in the Expansion Rack 0
    - …
    - AL-3202 Command Buffer in the Expansion Rack 3
    - Output User Command Buffer
    - IED Command Buffer in slot 0
    - …
    - IED Command Buffer in slot 7
- Waits for the release of the output buffer, indicated by the return of command status. The status is inserted into the output buffer by the low-level process (P-3202.176, P-IED.19x or P-CICUSR.170). The status received from the output buffer is passed to the input buffer, which this way is released. If a communication failure occurs between the AL-2004 of the main rack and the destination command process an expansion rack with AL-3202 modules, or a AL-2005 DNP3 master) during the processing of the command, P-BUFCMD.178 releases the input buffer , indicating that the status has not been received.

The P-BUFCMD.178 process does not perform any format conversion between input and output buffers, neither for the command that is transferred from the high-level process to the low-level process, nor for the status that is returned from the low-level process to the high-level process. Therefore, P-BUFCMD.178 assumes that the format that comes from the high-level process is already ready to be transferred to the low-level process, and that the status that returns from low-level process is already ready to be passed on to the high-level process.

Format of Input User Command Buffer

This buffer has 20 %M operands and is divided in two consecutive areas of %M operands:

- Command write area (15 %M operands): this area is written by the source of the command (an AL-3415/17 or the user application on P-CICUSR.170), and read by the P-BUFCMD.178 process
- Command read area (5 %M operands): this area is written by the P BUFCMD.178 process, and read by the source of the command (a AL-3415/17 or the user application on P-CICUSR.170)

ATTENTION: The format of Input User Command Buffer, described below, is identical to the format of all other input buffers of P-BUFCMD.178, i.e., the command buffers that come from AL-3415/17. This way, the following description allows to understand and decode the AL-3415/17 commands.

Command Write Area (15 %M Operands)

- BUSY (1 %M operand):
    - 0: There is no command in the buffer. For this buffer to be allocated, it is necessary that BUSY is zero, and also that FINAL is zero (see description of FINAL below, in reading area)
    - 1: There is a command in the buffer
- SOURCE (1 %M operand): Identify the process that requested the command. This information is used by P-BUFCMD.178 to return the reading area of the command for the correct process (may be the user application on P-CICUSR.170, or can be a AL-3415/17 in a slot between 0 and 7). The values of SOURCE must be the following:
    - 32, if the source process is the user application on P-CICUSR.170, using the Input User Command Buffer.
    - P * 4 + C, if the source process is the client C of the AL-3415/17 on the position P of the rack. Remember that P can be between 0 and 7, and that C can be between 0 and 3. For example, for the client 2 of AL-3415/17 on slot 5, the value SOURCE will be 22 (5 * 4 + 2)
- DESTINATION (1 %M operand): Process identifier for which the command should be passed. This information is used by P-BUFCMD.178 to pass the command description area to the correct output buffer. The possible values are:
    - 0 : slaves DNP3 IEDs of the AL-2005 with AL-2743 driver in slot 0
    - ...
    - 7 : slaves DNP3 IEDs of the AL-2005 with AL-2743 driver in slot 7
    - 8: AL-3202 modules of the main rack
    - 9: AL-3202 modules of the expansion rack 0
    - ...
    - 12: AL-3202 modules of the expansion rack 3
    - 13: Output user command (Output User Command Buffer), which must be decoded and executed by the P-CICUSR.170 module.

- COMMAND DESCRIPTION (12 %M operands): This area describes the command that the end device must execute. The several formats of the description area of the command are described in the section *Buffers and Command Status Formats*. The user must know these formats when he wants to generate user commands (SOURCE=32) through P-CICUSR.170. Considering that P-BUFCMD.178 does not execute any format conversion between the input and output buffers, the user must insert the buffer in the proper format for the output buffer.

ATTENTION: Even it is theoretically possible, the combination SORUCE=32 and DESTINATION=13 does not make sense, since it would be a command sent from the user to itself. When DESTINATION=13, the expected SOURCE is between 0 and 31, i.e., that the command comes through a AL-3415/17.

Reading Area of the Command (5 %M Operands)

- FINAL (1 %M operand):
  0: if BUSY (writing area) is also 0, the buffer is empty and can be allocated to the insertion of a new command. If BUSY is 1, P-BUFCMD.178 must pass this input buffer to the output buffer corresponding to the DESTINATION field (writing area).
  - 1: The command of the buffer is being processed
  - 2: The buffer processing was finished and no status information is available on the 4 %M operands following the reading area of command
  - 3: The buffer processing was terminated abnormally (timeout), and there is no status information available in the 4 %M operands following the reading area of the command.
- STATUS (4 %M operands): This area contains the status returned by the device or process which executed the command. The several formats of the status area are described in the section *Buffers and Command Status Formats*.

Methodology for the Generation of Buffered Commands in the User Application

In this section, it is recommended a methodology for the user application (P-CICUSR.170) to send buffered commands using the Input User Command Buffer. Such commands must be destined to a AL-3202 module or a serial DNP3 IED.

In first place, the application should only write in the buffer when it is free. The condition to be free is verified when BUSY is 0 and FINAL is also 0.

In second place, the application must write in the write area of the buffer:

- Put the command description in the 12 related %M operands (positions 13 to 14)
- Write the proper value in DESTINATION
- Write 32 in ORIGIN
- Write 1 in BUSY

In third place, it must wait for the value of FINAL to become 2 or 3, indicating that the command is finished.

- If it finishes with FINAL = 3, the application knows that the command has failed due to some timeout or not identified failure
- If it finishes whit FINAL = 2, the application can get the status information on the four STATUS %M operands

In fourth place, the application must clear BUSY. When seeing this, the P-BUFCMD.178 process clears FINAL, completing the process of releasing the Input User Command Buffer for a next command.

Format of Output User Command Buffer

This buffer has 20 %M operands and is divided in two consecutive areas of %M operands:

- Command write area (15 %M operands): this area is written by the process P-BUFCMD.178 and must be read by the user application (P-CICUSR.170)
- Command read area (5 %M operands): this area is written by the user application (P-CICUSR.170), and read by the process P-BUFCMD.178

Command Write Area (15 %M Operands)

- BUSY (1 %M operand):
    - 0: There is no command in the buffer. For this buffer to be allocated, it is necessary that BUSY is zero, and also that FINAL is zero (see description of FINAL below, in reading area)
    - 1: There is a command in the buffer
- SOURCE (1 %M operand): Identify the process that requested the command. Eventually, P-CICUSR.170 can analyze who requested the command, and then block some process that should not have authorization for sending commands to it. The values of SOURCE are the following:
    - 32, if the source process is the user application on P-CICUSR.170, using the Input User Command Buffer. Actually, this situation is not expected, because it would be useless the P-CICUSR.170 sending commands for itself.
    - P * 4 + C, if the source process is the client C of the AL-3415/17 on the position P of the rack. Remember that P can be between 0 and 7, and that C can be between 0 and 3. For example, for the client 2 of AL-3415/17 on slot 5, the value SOURCE will be 22 (5 * 4 + 2)
- DESTINATION (1 %M operand): considering that the command has reached the Output User Command Buffer, the DESTINATION value must be 13. Any other different value should not be accepted.
- COMMAND DESCRIPTION (12 %M operands): This area describes the command that the P-CICUSR.170 must execute, and its format is described in the section *Buffers and Command StatusFormats*. The user must know these formats for correct executing the commands.

ATTENTION:
The current revision of AL-3415 module does not generates commands destined to the **Output User Command Buffer**, which must be executed by the user application. At the moment, only the AL-3417 module have this functionality.

ATTENTION:
Even it is theoretically possible, the combination SORUCE=32 and DESTINATION=13 does not make sense, since it would be a command sent from the user to itself. When DESTINATION=13, the expected SOURCE is between 0 and 31, i.e., that the command comes through a AL-3415/17.

Reading Area of the Command (5 %M Operands)

- FINAL (1 %M operand):
    - 0: if BUSY (writing area) is also 0, the buffer is empty and can be allocated to the insertion of a new command by P-BUFCMD.178. If BUSY is 1, P-CICUSR.170 knows that there is a new command to be executed.
    - 1: P-CICUSR.170 indicates that the buffer is being processed
    - 2: P-CICUSR.170 indicates that the buffer processing was finished, and there is a status information available on the 4 %M operands following the command read area.
- STATUS (4 %M operands): On this area the P-CICUSR.170 writes the command status after finishing its execution. The format of the status area is described in the section *Buffers and Command Status Formats*.

Methodology for the Execution of Buffered Commands by the User Application

In this section, it is recommended a methodology for the user application (P-CICUSR.170) to decode and execute the buffered commands that come from AL-3415/17 modules. Such commands are received by the P-CICUSR.170 on the Output User Command Buffer, being associated to internal points.

In first place, the application detects the presence of a new command when BUSY = 1 and FINAL = 0.

In second place, the application must change FINAL to 1, indicating to the P-BUFCMD.178 that it is executing a command.

In third place, on the command decoding stage, the P-CICUSR.170 can analyze SOURCE, and eventually can block commands that does not come from valid or authorized sources. Also, it must analyze the DESTINATION, which should be 13. And finally, it must analyze the next 12 %M operands (COMMAND DESCRIPTION), which should describe the command itself. The format of this area is described in the section *Buffers and Command Status Formats*.

In fourth place, after decoding the command, if it is valid, it must be executed.

In fifth place, after executing the command, it must write the result on the 4 %M operands of the STATUS area, and after this write FINAL = 2. In some cases where the command execution is too slow, this can be executed even before finishing the command execution.

ATTENTION: The current revision of AL-3415 module does not generates commands destined to the **Output User Command Buffer**, which must be executed by the user application. At the moment, only the AL-3417 module have this functionality.

Cold Restart Command

This is the command to reset the RTU via DNP3 protocol. By receiving the command from the Master DNP3, the DO0004 point is set. This DO point is part of the main rack command group, created automatically by the MasterTool Hadron XE and covers the range of DO0000 to DO0015 points. This configuration, besides being automatically generated, is fixed, i.e., the user does not have the option to change the DO point associated with this command. DO0004 point is associated to the bit 4 of a particular %M operand (%M3005 by default), depending on the allocation of the %M operands in Hadron configuration. To check which %M operand is associated with the cold restart command, just look at the configuration of "Main Rack Commands" group.

To use this command to reset the HD3002, it is necessary that the user associate, by ladder (P-CICUSR.170 module), the DO0004 point (bit 4 of the allocated %M operand) to an output point of some digital output module of the RTU.

In order to the power of the HD3002 to be interrupted, it is necessary that the digital output point drives an external circuit, for example a relay or a contactor. Using a relay with 1 NC contact connected in series with the power of the main rack (and expansion rack, if there is any one), the output point would trigger the coil of the relay, making its NC contact to open and interrupt the RTU power.

The shutdown of the RTU power makes the output point to be disabled and, in consequence, the coil of the relay to be de-energize, closing the contact and restoring the power to the RTU.

ATTENTION:
The output point associated to the Cold Restart command must be configured for *latched* operation mode. The *latched* operation mode is already the default mode for the output modules, but for more details about the configuration of the operation modes of I/O modules, the user should consult the section *Common Properties of the I/O Groups*.

ATTENTION:
If the output module that have the point associated to the Cold Restart command is located on some of the expansion racks, the bit %M operand bit associated to this output point must receive the Cold Restart command by ladder. In this case, it should not be used directly the %S operand. The %M and %S operands associated to the output points can be consulted and/or changed on the group edition window, which is created automatically by MasterTool Hadron XE for each byte of each output module.

4. Configuration

The configuration of a HD3002 RTU is made using the MasterTool Hadron XE programmer.

Some RTUs may have a very simple configuration, which does not require the development of custom logics by the user. As an example, an RTU which the objective is to make remote measuring and remote command of points located in I/O modules (AL-313X, AL-315X, AL-315X/8, AL-3202) and IEDs (DNP3 or MODBUS RTU with AL-2005, or MODBUS TCP with AL-3414).

Other RTUs may require the user to develop additional logics (functions), such as insertion of interlocking logics, or communications with IEDs through a proprietary or not standardized protocol.

When the user logics are required, the user must know the allocation of communication points, operands and program modules that are made automatically by MasterTool Hadron XE. Operands and program modules automatically allocated by MasterTool Hadron XE require user discipline, for example:

- Program modules allocated by MasterTool Hadron XE cannot be allocated again by the user, and usually cannot even be referenced by the user
- Operands allocated by MasterTool Hadron XE cannot be allocated again by the user, although in some cases they can and should be referenced in program modules developed by the user

In this chapter, it is described the use of the MasterTool Hadron XE programmer, having or not the user logics. It is also discussed the allocation of communication points, operands and program modules.

ATTENTION: The configuration of the AL-3415/17 interface can be a long process, depending on the number of groups and communication points configured in the architecture.

ATTENTION: The allocations made by MasterTool Hadron XE can be modified, changing the settings of this programmer. In this manual, it is referred to the default settings MasterTool Hadron XE.

Operands Declaration in C000 Configuration Modules

In MasterTool Hadron XE the declaration of simple operands %M, %I, % D, %F, % A, % E and % S are made in the *Operands Allocation* tab of the item *Hadron configuration* of C module. In this item, it is declared the ranges of use of such operands. The function of each band is described in the section *Use Functions for Operands*.

For the table operands, only the %TM operand type is declared in *Operands Allocation* item. Other types of operands, %TD, %TI and %TF, are declared in *Operands* item. The user must be careful when declaring the number of positions of each %TM operand in order to not overwrite the draft %TM operands area, because when the project is recompiled this setting is overridden by the configuration used in the generated ladder. The draft operands will be discussed later in this chapter.

Operands Retain

All operands (single and tables) are retain. Thus, considering the user-allocated operands, this has the responsibility to initialize them with some constant value when it is not wanted to be retain. This issue is talked later.

Allocation of Program Modules

In the design of a Hadron RTU, the main rack may contain user logics. User can then allocate operands and program modules. For this to be done with no problems, the User must pay attention to MasterTool Hadron XE allocations, to avoid conflicts and making correct references.

The program modules are divided into configuration (C), execution (E), procedure (P) and function (F). The following table shows the modules that can be used in a project, describing its function and which modules can be accessed by the user and may be created, changed or removed.

Module Type	File	Access	Language	Description
Starting module	E-INIT.000	Blocked	Ladder	Only executed in the first cycle of the CPU.
Main Module	E-MAIN.001	Blocked	Ladder	Executed in every cycle of the CPU.
Time interruption module	E-xxxxxx.018	Free	Ladder	Executed in the time period configured in the C 000 module.
Procedure module	P-xxxxxx.000 to P-xxxxxx.149	Free	Ladder or ST	Procedure modules used by the application program.
	P-xxxxxx.151 to P-xxxxxx.169 and P-xxxxxx.171 to P-xxxxxx.199	Blocked	Ladder	Procedure modules managed by MasterTool Hadron XE.
	P-INIUSR.150	Free	Ladder	Procedure module executed only in the first cycle of the CPU. It is created automatically by MasterTool Hadron XE and should be used by user to initialize its variables.
	P-CICUSR.170	Free	Ladder	Procedure module executed every CPU cycle. It is created automatically by MasterTool Hadron XE and should be used by user to build its application program.
Function module	F-xxxxxx.000 to F-xxxxxx.228	Free Blocked	Assembly, Ladder or ST	Function modules used to organize the application program. They have the advantage over the procedures modules, of working with input and output parameters allowing the use of the same routine in several situations.

Module Type	File	Access	Language	Description
				The function modules in assembly language are distributed by Altus and have blocked access to the user. However, modules in Ladder or ST languages are created by the own users.
Configuration module	C-CONFIG.000	Free	Binary	Configuration of AL-2004 CPU
Extended configuration module	C-PROFI.003	Blocked	Binary	Configuration of the AL-3406 used for communication with the expansion racks.
	C-xxxxxx.004 and C-xxxxxx.005	Free	Binary	Used for the configuration of the AL-3406 modules manually configured by the user.
	C-xxxxxx.006 to C-xxxxxx.009	Blocked	Binary	Used for the configuration of the AL-3415/17 communication interface.

Table 4-1 Restrictions of names and use of the modules of the project

On the previous table, all modules marked as *blocked* are for exclusive use by MasterTool Hadron XE and should not be created or changed by the user. These modules are created and inserted automatically into the project according to the architecture.

Some modules marked as *free* are automatically created by MasterTool Hadron XE, but can be freely edited by the user. These modules are:

- **C-CONFIG.000**: Configuration module of the AL-2004 CPU. Must always exist
- **P-INIUSR.150**: Module for initialization of the user variables. When it does not exist, it is created an empty module
- **P-CICUSR.170**: User execution module. It is used by the user when it wants to include control logics. When it does not exist, it is created an empty module

Some modules can be referred by its abbreviated name in this document, composed by the initial letter and its number. For example:

- C-CONFIG.000 is referred by C000
- E-INIT.000 is referred by E000

E-INIT.000 Module

This is the module executed just after the start of the RTU, and it is responsible for operands initialization procedures.

It should be modified by the user.

P Modules called inside the E-INIT.000

ATTENTION: The suffixes of P modules mentioned below corresponds to the default allocation settings of MasterTool Hadron XE. They can change if these settings are changed.

The E-INIT.000 module calls several modules P, which therefore are previously allocated by MasterTool Hadron XE:

- P-INIUSR.150: Initialization of operands allocated by user
- P-INIC_M.151: Initialization of operands %M allocated by MasterTool Hadron XE
- P-INIC_I.152: Initialization of operands %I allocated by MasterTool Hadron XE
- P-INIC_D.153: Initialization of operands %D allocated by MasterTool Hadron XE
- P-INIC_F.154 Initialization of operands %F allocated by MasterTool Hadron XE

- P-INIC_A.155 Initialization of operands %A allocated by MasterTool Hadron XE
- P-INIC_S.156: Initialization of operands %S allocated by MasterTool Hadron XE
- P-INI_TM.157 Initialization of operands %TM allocated by MasterTool Hadron XE
- P158 to P169: reserved for future use by MasterTool Hadron XE , for calling on E000

Initialization of Operands Allocated by MasterTool Hadron XE

The modules P151 to P159 initialize operands allocated by MasterTool Hadron XE. User may not change these modules.

Initialization of Operands Allocated by User

The module P-INIUSR.150 will initialize operands allocated by user, so user can make changes to this module.

If the P-INIUSR.150 module still do not exists, it is automatically created by MasterTool Hadron XE with the logic 000 including a NEG instruction, which can be later erased by user.

ATTENTION: It is important to remember that all operands declared in C-CONFIG.000 are retain (simple operands and tables of operands). If the user does not want that some of the allocated operands to be retain, he should initialize them with constant values (usually, but not necessarily, zero). It is recommended to use CAB instructions for such initializations, called within the module P-INIUSR.150.

E-MAIN.001 Module

This is the module that is cyclically executed. His first run is done after the execution of the E-INIT.000 module. Then, its execution is repeated indefinitely, i.e., a new execution of E-MAIN.001 occurs soon after ending the previous execution of E-MAIN.001.

E-MAIN.001 module must not be modified by the user.

P Modules Called inside E-MAIN.001

ATTENTION The suffixes of P modules mentioned below corresponds to the default allocation settings of MasterTool Hadron XE. They can change if these settings are changed.

E-MAIN.001 module calls several P modules. Such modules are previously allocated by MasterTool Hadron XE:

- P-CICUSR.170: User cyclic logics
- P-GPS.171: treatment of the GPS
- P-DGCPU.172: diagnostics of AL-2004 CPU
- P-3406.173: treatment of PROFIBUS DP communication with the expansion racks.
- P-EVRX.174: events reception of AL-313X modules from expansion racks
- P-3130.175: treatment of AL-313X modules
- P-3202.176: treatment of AL-3202 modules
- P-3150.177: treatment of AL-315X and AL-315X/8 modules
- P-BUFCMD.178: managing of command buffers
- P179: reserved
- P-AL341X.180: interface with AL-341X module in slot 0
- ...
- P-AL341X.187: interface with AL-341X module in slot 7
- P188 ... P189: reserved

- P-IED.190: interface with IEDs master modules in slot 0 (AL-2005 or AL-3414)
- ...
- P-IED.197: interface with de IEDs master modules in slot 7 (AL-2005 or AL-3414)
- P198 ... P199: reserved

Logics automatically created by MasterTool Hadron XE

All cyclic logics automatically generated by MasterTool Hadron XE are located on the P171 to P199 modules. User may not modify these modules.

User Logic in P-CICUSR.170

All user cyclic logics must be located within the P-CICUSR.170 module.

Obviously, it is possible to structure this module in several P or F sub-modules, since such modules are not previously allocated by MasterTool Hadron XE.

If P-CICUSR.170 module does not exist, MasterTool Hadron XE creates it with a logic containing a NEG instruction. This logic can be erased later by the user.

E018 Module

User can create, if desired, a module E018 (Time Interruption), noting the restrictions and precautions that are typical of this kind of practice. The period of interruption can be configured in module C000.

P Modules Reserved for MasterTool Hadron XE

As described in previous sections, MasterTool Hadron XE reserves, by default, the range from P150 to 199.

F Modules Reserved for MasterTool Hadron XE

Hadron MasterTool XE uses F modules previously developed in assembly language, whose suffixes should not be used by other F modules developed by the user.

ATTENTION: These F modules have fixed suffixes that may not be changed, not even in configurations of the MasterTool Hadron XE.

Next, a list of these F modules:

- F-3416.011: communication with AL-3416 (PROFIBUS slave module). This F module is called only in expansion racks, so that a module F011 can be used in the main rack.
- F-2005.016: communication with AL-2005 module, used by the DNP3 serial master driver (AL-2743) and MODBUS RTU serial master driver (AL-2734).
- F-CBO.018: access to AL-3202 CBO modules.
- F-3150.023: communication with modules AL-315x and AL-315x/8
- F-STCP.044: AL-2004 CPU diagnostics
- F-UTR_S.068: command for outputs of AL-3202 module
- F-3406.085: Communication with AL-3406 module (Master PROFIBUS DP)
- F-GPSTMB.086: communication with Trimble Acutime 2000 GPS, or other generator of NMEA/PPS compatible with this model of GPS
- F-EV313X.116: access to AL-313x module
- F-EVTREM.117: event reading from expansion racks
- F-RELEVT.118: clock for internal events
- F-AL3415.120: interface with AL-3415 modules
- F-AL3417.121: interface with AL-3417 modules

Allocations of Operands

The allocation of the operands in Hadron RTU is no longer made by type of operand, but by function ranges. Each range is used in a specific function that can be changed to allocate more operands to a function or to release unused operands of a function.

Use Functions for Operands

The use functions define what is the purpose of use for each operand range in a Hadron RTU project. The possible use ranges are detailed in the following sections.

Free for User

Are operands that can be freely used by user in its own programs, and the MasterTool Hadron XE does not refer to them in the generated modules.

The user can freely change the number of operands for this function, respecting the physical limit supported by the AL-2004 CPU and the amount already allocated by other ranges.

It is possible to configure *Free for User* operand for the types %M, %I, %F, %D, %A e %TM.

Diagnostics and Configuration of the RTU

These are operands reserved for the use in groups of diagnostic points and configuration of the RTU.

The minimal amount of operands must respect to the formula: 6 + 4 x B. Where B is the amount of expansion racks configured.

Used only for operands %M.

ATTENTION Changing the values within this range of operands automatically changes the operands used by the configuration diagnostics groups of the RTU.

I/O Modules

Operands reserved for the use of the groups related to I/O modules AL-313x, AL-315x e AL-3202. When a module is inserted, for each group of the module are assigned the last unused operands of this range. These operands can be edited later, but must remain within this range.

User can freely change the number of operands for this function, respecting the physical limit supported by the AL-2004 CPU and the amount already allocated by other ranges.

The amount of operands that each module allocates is detailed in the next table.

Module	Groups	Group type	Amount of operands for group
AL-3130, AL-3132 or AL-3138	1	D1QC, 32 points	3 operands %M
AL-3150 or AL-3151	1	AIQE, 16 points	24 operands %M
AL-3150/8 or AL-3151/8	1	AIQE, 8 points	12 operands %M
AL-3202	4	D1QC, 8 points	2 operands %M
		NQC, 4 points	1 operands %M

Table 4-2. Amount of operands allocated in I/O module

AL-3202 module has four groups that can be individually configured as D1QC, *latch* mode, and QNC, *trip/close* mode.

ATTENTION:
It is important to note that, after changing the allocation of I/O modules operands, the configuration of the groups that were out of range will become invalid and must be adjusted manually by the user.

Internal Points

These are operands reserved for the use by the internal groups.

User can freely change the number of operands for this function, respecting the physical limit supported by the AL-2004 CPU and the amount already allocated by other ranges.

It is possible to configure operands of internal points for the type %M, %I and %F.

ATTENTION:
It is important to note that, after changing the allocation of internal points, the configuration of the groups that were out of range will become invalid and must be adjusted manually by the user.

IEDs

These are operands reserved for the use by the IEDs groups used by MODBUS RTU, TCP and DNP3 drivers to storage the values of the configured groups.

User can freely change the number of operands for this function, respecting the physical limit supported by the AL-2004 CPU and the amount already allocated by other ranges.

It is possible to configure internal points operands for the types %M, %I and %F.

ATTENTION:
It is important to note that, after changing the allocation of IEDs operands, the configuration of the groups that were out of range will become invalid and must be adjusted manually by the user.

PROFIBUS I/O Interface

The operands of the PROFIBUS I/O interface are used for the exchange of information between the main and the expansion racks.

Each expansion rack uses 310 %M operands.

General Operands

General operands store common information used by the ladder modules generated by MasterTool Hadron XE, having a fixed size of 160 operands. The following table describes the positions of the general operands.

Operand	Position	Name	Description
%M6240	0	INIFILA	Reports the initial address of the block of operands %I that implements the event queue.
%M6241	1	TAMFILA	Reports the total number of events that the event queue supports. Each event uses four operands %I, so the size of the event queue is 4 * TAMFILA operands %I. The value recommended for TAMFILA is around of 1000 events (4000% operands %I).
%M6242	2	PTR_WR	Pointer to insert the next event in the event queue. Informs the position on the event queue, which can vary between 0 (the position addressed by INIFILA) and TAMFILA - 1 "(at the address with" INIFILA + TAMFILA * 4 - 4 ").
%M6243	3	SEQ_WR	Number of times the event queue was completely filled. This operand, together with PTR_WR, enables the client who is removing events from the queue to check whether there was loss of events. The SEQ_WR value is incremented every time PTR_WR is incremented by "TAMFILA -1" to 0. When the value of SEQ_WR reaches 32767, when incremented again, it should return to 0.
%M6244	4	DESCR_EVT	Initial operand %I in the area of event descriptors.

Operand	Position	Name	Description
%M6245	5	TAM_DSCEVT	Size of the operand descriptors area.
%M6246 a %M6249	6 to 9		Reserved.
%M6250	10	RUNNING	Cycle counter. It is incremented every new RTU execution cycle. The value varies between 0 and 32767.
%M6251	11	ENGCTRL	Control of engineering conversion. This operand is reset at the beginning of each cycle and the first active AL-3415/17 interface in the bus writes "1" in this operand, indicating who performed the engineering conversion operation and the next interfaces that do not need to perform this task again.
%M6252 a %M6255	12 a 15	RELOGPLC	Date and time of the RTU, with resolution of 10 ms, corresponding to the start time of this cycle. It is updated by module F-RELEVT, described later, and serves to date the slow events. Its format is: *Position 12* bits 0 to 5: minutes (0 to 59) bits 6 to 7: zeros bits 8 to 12: hour (0 to 23) bits 13 to 15: zeros *Position 13* bits 0 to 9: milliseconds (0 to 999) bits 10 to 15: seconds (0 to 59) *Position 14* bits 0 to 14: year (0 to 32767) bit 15: zero *Position 15* bits 0 to 4: day (1 to 31) bits 4 to 7: zeros bits 8 to 11: month (1 to 12) bits 12 to 15: zeros
%M6256	16	LEFATOR	Reports to the modules AL-3415/17 that they should read, in this scan, the multiplicative and additive factors to the engineering conversion. Lasts a single scan. bit 0: 0 = not read the factors, 1 = read the factors
%M6257	17	RQRSTEV	Some AL-3415/17 can set the bit 0 of this operand to request that the AL-2004 main rack to clear the event queues in the expansion rack.
%M6258	18	EXRSTEV	The AL-2004 can set the bit 0 of this operand to request for all AL-3415/17 modules to clear its internal event queues, and also clear the queue of the AL-2004 of the main rack.
%M6259	19		Reserved.
%M6260	20	PTR_RD0	Pointer that AL-3415/17 installed in the slot 0 uses to read the next event in the event queue.
%M6261	21	SEQ_RD0	Pointer that the AL-3415/17 installed in the slot 0 uses to read the next event in the event queue, in particular, to manage the overflow situations.
%M6262	22	PTR_RD1	Pointer that AL-3415/17 installed in slot 1 uses to read the next event in the event queue.
%M6263	23	SEQ_RD1	Pointer that the AL-3415/17 installed in the slot 1 uses to read the next event in the event queue, in particular, to manage the overflow situations.
%M6264	24	PTR_RD2	Pointer that AL-3415/17 installed in slot 2 uses to read the next event in the event queue.
%M6265	25	SEQ_RD2	Pointer that the AL-3415/17 installed in the slot 2 uses to read the next event in the event queue, in particular, to manage the overflow situations.
%M6266	26	PTR_RD3	Pointer that AL-3415/17 installed in slot 3 uses to read the next event in the event queue.

Operand	Position	Name	Description
%M6267	27	SEQ_RD3	Pointer that the AL-3415/17 installed in the slot 3 uses to read the next event in the event queue, in particular, to manage the overflow situations.
%M6268	28	PTR_RD4	Pointer that AL-3415/17 installed in slot 4 uses to read the next event in the event queue.
%M6269	29	SEQ_RD4	Pointer that the AL-3415/17 installed in the slot 4 uses to read the next event in the event queue, in particular, to manage the overflow situations.
%M6270	30	PTR_RD5	Pointer that AL-3415/17 installed in slot 5 uses to read the next event in the event queue.
%M6271	31	SEQ_RD5	Pointer that the AL-3415/17 installed in the slot 5 uses to read the next event in the event queue, in particular, to manage the overflow situations.
%M6272	32	PTR_RD6	Pointer that AL-3415/17 installed in slot 6 uses to read the next event in the event queue.
%M6273	33	SEQ_RD6	Pointer that the AL-3415/17 installed in the slot 6 uses to read the next event in the event queue, in particular, to manage the overflow situations.
%M6274	34	PTR_RD7	Pointer that AL-3415/17 installed in slot 7 uses to read the next event in the event queue.
%M6275	35	SEQ_RD7	Pointer that the AL-3415/17 installed in the slot 7 uses to read the next event in the event queue, in particular, to manage the overflow situations.
%M6276 a %M6279	36 to 39		Reserved.
%M6280	40		Inform the position of the AL-3415/17 where there will be the performance diagnostic: 10 to slot 0, 11 to slot 1, ... 17 to slot 7. At the end of the test, the AL-3415/17 writes 0 in the selected operand.
%M6281	41		Indicates the number of cycles of AL-3415/17 during which it will be made performance tests, and 32,767 is the maximum. Values equal to or less than 0 keeps the test off.
%M6282	42		Indicates the number of tests already executed.
%M6283 a %M6285	43 a 45		Wait idle time before the communication with AL-2004. - Position 43: instant time - Position 44: average time - Position 45: maximum time
%M6286 a %M6288	46 a 48		Time taken during the window of communication with AL-2004. - Position 46: instant time - Position 47: average time - Position 48: maximum time
%M6289 a %M6291	49 a 51		Time taken for processing after the communication window. - Position 49: instant time - Position 50: average time - Position 51: maximum time
%M6292 a %M6323	52 a 67		Identifier of the AL-3415/17 interfaces. Represents the four least significant bytes of the interface MAC address. Positions 52 to 53: AL-3415/17 installed on position 0 Positions 54 to 55: AL-3415/17 installed on position 1 Positions 56 to 57: AL-3415/17 installed on position 2 Positions 58 to 59: AL-3415/17 installed on position 3 Positions 60 to 61: AL-3415/17 installed on position 4 Positions 62 to 63: AL-3415/17 installed on position 5 Positions 64 to 65: AL-3415/17 installed on position 6 Positions 66 to 67: AL-3415/17 installed on position 7
%M6324 a %M6329	68 a 89		Reserved.
%M6330 a %M6333	90 a 93	WR_REL	Date and time for RTU time update. Its format is: Position 90

Operand	Position	Name	Description
			bits 0 to 5: minutes (0 to 59) bits 6 to 7: zeros bits 8 to 12: hour (0 to 23) bits 13 to 15: zeros Position 91 bits 0 to 9: milliseconds (0 to 999) bits 10 to 15: seconds (0 to 59) Position 92 bits 0 to 14: year (0 to 32767) bit 15: zero Position 93 bits 0 to 4: day (1 to 31) bits 4 to 7: zeros bits 8 to 11: month (1 to 12) bits 12 to 15: zeros
%M6334	94	WR_RELCM	RTU time setting command. - Bit 0: sets the RTU time with the WR_REL values - Bits 1 to 15: not used
%M6335 a %M6399	95 a 159		Reserved.

Table 4-3. Details of the general operands

AL-3415/17 Commands Buffer

The AL-3415/17 buffer command corresponds to a block of operands %M reserved to the AL-3415/17 interfaces installed in racks to put the buffered commands received from the user. This range reserves operands for eight buffers, one for each possible position where it can be installed one AL-3415/17. The number of operands is fixed at 160 operands %M (20 operands for each command buffer).

The buffered commands are detailed in the Commands section.

Command Buffer – User Input

The Input User Command Buffer corresponds to a block of operands %M reserved for the user to enter a buffered command manually. The number of operands is fixed in 20 %M operands.

The buffered commands are detailed in the Commands section.

Command Buffer – User Output

The Output User Command Buffer corresponds to a block of operands %M reserved for the user application (P-CICUSR.170) to receive a buffered command from the AL-3415/17 mapped to internal points. The number of operands is fixed in 20 %M operands.

The buffered commands are detailed in the Commands section.

IED Commands Buffer

The IED command buffer corresponds to a block of operands %M reserved for each IED module. Currently only the DNP3 Master AL-2743 driver uses these buffers. This range reserves eight buffers for each possible position where they can be installed on the coprocessor AL-2005 module which runs the DNP3 Master AL-2743 driver. The number of operands is fixed at 160 operands %M (20 operands for each command buffer).

The buffered commands are detailed in the Commands section.

AL-3202 Command Buffer

The AL-3202 command buffer corresponds to a block of operands %M reserved for each one AL-3202 digital output modules. This range reserves five buffers, the first for the AL-3202 modules that are installed on the main rack, and four for the other AL-3202 modules installed in the expansion racks. The number of operands is fixed at 100 %M operands (20 operands for each command buffer).

The buffered commands are detailed in the Commands section.

Draft Operands

The draft operands are used for the generation of the modules created by the MasterTool Hadron XE (see section *Allocation of Program Modules*). The range size is set automatically by MasterTool Hadron XE during the generation of modules and includes both the main rack and the expansion racks. That is, some draft operands are not used in the main rack but are used in the expansion rack. Therefore, the use of a operand search tool can result in no operand found, since these operands are being used only in the ladder in the expansion racks.

The draft operands always use the latest operands declared in the AL-2004 CPU. The draft operands are declared for %M, %I, %F, %D, %A and %TM.

ATTENTION: As the draft operands are automatically allocated to each design verification, it is not recommended that the user accesses these operands, both for writing and reading, because the desired operand may be not in the same address in the verification itself.

Events Queue

The operands of the event queue stores the events received from IED devices and from AL-313x modules. The capacity for storing events is directly proportional to the number of operands reserved. Each event uses four operands %I.

ATTENTION: Modifying this parameter changes the size of the events queue of the AL-2004 CPU in the main rack and in the expansion racks.

The structure of how an event is stored in the queue is detailed in the following table.

Operand	Description
%Ixxxxx +0	Identification of the point and quality: - bits 0 to 15: address of the point (0 to 9999) - bits 0 to 15: address of the point (0 to 9999) - bit 16 to 19 – type code: - value 0 = DI - value 1 = AI - value 2 = DO - value 3 = AO - value 4 = CN - value 5 = FC - values 6 to 15 = reserved - bits 20 to 23: not used (zeros) - bits 24 to 31: quality
%Ixxxxx +1	Less significant part of the time stamping: - bits 0 to 9: milliseconds (0 to 999) - bits 10 to 15: seconds (0 to 59) - bits 16 to 21: minutes (0 to 59) - bits 22 to 23: zeros - bits 24 to 28: hour (0 to 23) - bits 29 to 31: zeros
%Ixxxxx +2	Most significant part of the time stamping: - bits 0 to 4: day (1 to 31) - bits 5 to 7: zeros - bits 8 to 11: month (1 to 12) - bits 12 to 15: zeros - bits 16 to 30: year (0 to 32767) - bit 31: zero
%Ixxxxx +3	Value, which the format depends on the type and variation.

Table 4-4. Details of an event in the events queue of the AL-2004 CPU

AL-313X Descriptors

The AL-313X descriptors are used to configure the AL-313X modules storing options for disabling events, operands %M to store values and addresses of the points. Each AL-313X module uses five operands %I. The minimum value to configure must support the configuration of the rack (main or expansion) with the highest number of modules.

AL-313X Parameters

The AL-313X parameters are used to complement the configuration of AL-313X modules storing filter and debounce values. Each AL-313X module uses one operand %I. The minimum value to configure must support the configuration of the rack (main or expansion) with the highest number of modules.

Standard Operands Allocation

This section details the standard allocation of the operands on a newly created project. The tables below, besides detailing the range of standard operands, also indicate whether a range is editable by the user, may vary in options:

- **Yes**: the range can be edited by user
- **Fixed**: the operands range is fixed and cannot be edited by the user
- **Automatic**: the operands range is defined automatically by MasterTool Hadron XE according to the needs and cannot be changed by user

Ranges of operands that can be edited by user accept only a change in the number of operands. The initial operand of the range is the following operand of the previous range. The order that the ranges are presented in the following tables determine this definition.

Operands %M

Description	Range	Editable
Free for the User	%M0000 to %M2999	Yes
RTU Diagnostics and Configuration	%M3000 to a %M3099	Yes
I/O Modules	%M3100 to %M3499	Yes
Internal Points	%M3500 to %M4299	Yes
IEDs	%M4300 to %M4999	Yes
PROFIBUS I/O Interfaces	%M5000 to %M6239	Yes
General Operands	%M6240 to %M6399	Fixed
Command Buffers – AL-3415/17	%M6400 to %M6559	Fixed
Command Buffers – User Input	%M6560 to %M6579	Fixed
Command Buffers – IEDs	%M6580 to %M6739	Fixed
Command Buffers - AL3202	%M6740 to %M6839	Fixed
Draft Operands	%M6840 to %M7053	Automatic

Table 4-5. Operands %M allocated by MasterTool Hadron XE

Operands %I

Description	Range	Editable
Free for the User	%I0000 to %I0499	Yes
Internal Points	%I0500 to %I0799	Yes
IEDs	%I0800 to %I0999	Yes
Events Queue	%I1000 to %I4999	Yes
AL-313X Descriptors	%I5000 to %I5079	Yes
AL-313X Parameters	%I5080 to %I5095	Yes
Draft Operands	%I5096 to %Ixxxx	Automatic

Table 4-6. Operands %I allocated by MasterTool Hadron XE

Operands %F

Description	Range	Editable
Free for the User	%F0000 to %F0499	Yes
Internal Points	%F0500 to %F0799	Yes
IEDs	%F0800 to %F0999	Yes
Draft Operands	%F0000 to %Fxxxx	Automatic

Table 4-7. Operands %F allocated by MasterTool Hadron XE

Operands %D

Description	Range	Editable
Free for the User	%D0000 to %D0063	Yes
Draft Operands	%D0064 to %Dxxxx	Automatic

Table 4-8. Operands %D allocated by MasterTool Hadron XE

Operands %A

Description	Range	Editable
Free for the User	%A0000 to %A0383	Yes
Draft Operands	%A0384 to %Axxxx	Automatic

Table 4-9. Operands %A allocated by MasterTool Hadron XE

Operands %E

The following table shows the summary of the allocation of operands% E made by MasterTool Hadron XE with its default configuration. In this case, such allocations are intended to operands %E of the various racks (main and expansion) to always have different addresses. This is useful for purposes of documentation and execution input points force.

Description	Range
First input byte in Main Rack	%E0000 to %E0023
First input byte in rack 0	%E0024 to %E0047
First input byte in rack 1	%E0048 to %E0071
First input byte in rack 2	%E0072 to %E0095
First input byte in rack 3	%E0096 to %E0119

Table 4-10. Operands %E allocated by MasterTool Hadron XE

Operands %S

The following table shows the summary of the allocation of operands % S made by MasterTool Hadron XE with its default configuration. In this case, such allocations are intended to operands %S of the various racks (main and expansion) to always have different addresses. This is useful for purposes of documentation and execution of output points force.

Description	Range
First input byte in Main Rack	%S0120 to %S0143
First input byte in rack 0	%S0144 to %S0167
First input byte in rack 1	%S0168 to %S0191
First output byte in rack 2	%S0192 to %S0215
First output byte in rack 3	%S0216 to %S0239

Table 4-11. Operands %S allocated by MasterTool Hadron XE

Operands %TM

The following table shows the summary of the allocation of the operands %TM made by MasterTool Hadron XE in its standard configuration:

Description	Range
Free for the User	%TM0000 to %TM0199
Draft Operands	%TM0200 to %TM0201

Table 4-12. Operands %TM allocated by MasterTool Hadron XE

Operands %TI, %TF e %TD

The Master Tool Hadron XE does not use such operands. Therefore, they can be freely allocated by the user application, limited only by the number of table operands type supported by the used CPU.

Size of the Event Queue of AL-2004 CPU

The maximum number of events stored in event queue of the AL-2004 CPU in the main rack, as in the expansion racks, is configurable through the configuration of operands %I allocation. See section *Standard Operands Allocation*. This configuration affects the size of the event queue of the AL-2004 CPU in the main rack, and also the queues of the expansion racks CPUs.

The number of events supported are defined by the number of operands %I allocated for the event queue. Each event uses 4 operands %I. Therefore, for an area of 4000 operands %I, it will be possible to store up to 1000 events.

Allocation of the Addresses of the Communication Points

Although in this case there is no risk of conflict, MasterTool Hadron XE allocates the communication points on 4 main ranges of addressing, according to the functions of communication groups. The groups of communication points are classified into 4 types:

- Diagnostics and configuration points of the RTU: automatically created by MasterTool Hadron XE, from the RTU architecture
- Points associated to I/O modules: automatically created by MasterTool Hadron XE, from the RTU architecture
- Points associated do IEDs: created by user and associated to master communication channels (AL-2005 with MODBUS RTU, AL-3414 with MODBUS TCP or AL-2005 with serial DNP3)
- RTU internal points: created by user

ATTENTION:
It is important to note that, after changing the allocation of the amount of points in the *Hadron Configurations* window, the configuration of the groups that were out of range will become invalid and must be adjusted manually by the user.

The following table shows the summary of the allocation of addresses of communication points made bay MasterTool Hadron XE with its standard configurations:

Description	Range
RTU Diagnostics and Configurations	DI0000 ... DI0999
	AI0000 ... AI0999
	DO0000 ... DO0999
	AO0000 ... AO0999
	CN0000 ... CN0999
	FC0000 ... FC0999
I/O Modules	DI1000 ... DI2999
	AI1000 ... AI2999
	DO1000 ... DO2999
	AO1000 ... AO2999
	CN1000 ... CN2999
	FC1000 ... FC2999
Internal Points	DI3000 ... DI4999
	AI3000 ... AI4999
	DO3000 ... DO4999
	AO3000 ... AO4999
	CN3000 ... CN4999

	FC3000 ... FC4999
IEDs	DI5000 ... DI6999
	AI5000 ... AI6999
	DO5000 ... DO6999
	AO5000 ... AO6999
	CN5000 ... CN6999
	FC5000 ... FC6999

Table 4-13. Communication points allocated by MasterTool Hadron XE

Properties of the Groups of Communication Points

The groups of communication points are grouped in tables according to their use. Such tables may be:

- **Diagnostics and Commands Groups:** Used for RTU diagnostic and command groups. These groups are generated automatically by MasterTool Hadron XE according to the configuration of its architecture. The diagnostic and command groups are displayed in the item *Diagnostic and Commands Groups* of the module C in MasterTool Hadron XE, and the manual editing is not allowed.
- **Internal Groups**: Used for groups of Internal Points defined by the User. The internal groups are edited in the item *Internal Groups* of the module C000 in the MasterTool Hadron XE.
- **I/O Groups**: Used for groups of I/O points. The groups are automatically associated to the modules configured in the architecture of RTU. Groups of I/O modules are edited in item *I/O Groups* of the module C000 in MasterTool Hadron XE.
- **Serial DNP3 IEDs Groups**: Used for DNP3IEDs points groups. They are groups defined by the user in the configuration of AL-2743 DNP3 master driver which is run by AL-2005. Serial IEDs DNP3 groups are edited in the configuration window of AL-2005 accessed in the item *Architecture* of MasterTool Hadron XE.
- **IEDs MODBUS RTU Groups**: Used for groups of IEDs MODBUS RTU points. They are groups defined by the user in the configuration of master AL-2734 MODBUS RTU driver, which is run by AL-2005. IEDs MODBUS RTU groups are edited in the configuration window of AL-2005 accessed the item *Architecture* of MasterTool Hadron XE.
- **IEDs MODBUS TCP Groups**: Used for groups of IEDs MODBUS TCP points. They are groups defined by the user in the configuration of master MODBUS TCP driver that runs on AL-3414Ethernet interface. Groups MODBUS TCP IEDs are edited in the configuration window of AL-3414 accessed in item *Architecture* of the MasterTool Hadron XE.

Each group of points has several properties, most of them repeated among the groups. In this section, we describe all the properties that appear in groups of communication points. Considering one of these properties specifically, it should be noted that:

- Some groups may not use it, because it has no meaning within it. In this case, the property is no longer exhibited in the window.
- The possible values of configuration for some properties are depends of the configurations of other properties. In this case the configuration options are limited to the available options, or even can be disabled if there is only one option. Example: the type DI only accepts data formats D1, D2 and D8, so in the format property only these options will appear.

- Some groups also restrict the options of configuration of some properties. In this case the configuration options are limited to the options available, or even can be disabled if there is only one option. Example: quality format for the DNP3 group will only show DNP3format options.
- In some groups of communication points, the property can be disabled, because the value of other property of the group makes this property to be meaningless. For example, the property *Initial AO Dead Band* is meaningless for a group whose property *Type of Point* is DI.

The following subsections define each one of the properties that can be present in the screens of groups of communication points.

Common Properties of all Groups

Description

Description of the communication point group objective.

Type of Point

Type of communication points of the group, according to the definition made in the section *Types of Communication Points*.

Address of the Initial Point

Address of the first point of the group, according to the definition made in section *Addresses of Communication Points*.

Number of Points

Number of communication points contained in the group. The limit of point for a group varies from one type of group to another or, also, can have a fixed value.

Range of Points

Shows the range of point of the group, for example, DI2000 … DI2099 for a group of type DI, which initial address is 2000 and which number of points is100.

ATENÇÃO: The range of points must be within the range of points declared for the function of which the group is part of.

Type of Operand

Indicates the type of operand used to store values and qualities of the group points on the AL-2004 CPU memory (%M, %I, or %F). The operand type used is automatically set depending on the storage format of the values (N, D1, D2, D8, I16, UI16, I32, UI32, and F32) and quality (QA, QC, QE).

In the case of the combination NQA (no values and no quality), no operand memory is allocated.

Address of the Initial Operand

Indicates the address of the first operand used to store values and qualities of the points of the group in the memory of the CPU of AL-2004.

ATTENTION: The range of operands must be within the range of operands declared for the function to which the group is part of.

Number of Operands

Indicates the number of operands used to store values and qualities of the points in the group in memory of the AL -2004 CPU. It is set automatically depending on the storage format of the values (N, D1, D2, D8, I16, UI16, I32, ui32, F32), quality (QA, QC, QE) and the amount of points in the group.

Operands Range

Shows the range of operands used to store values and qualities of the group in memory of the AL -2004 CPU. For example, %M3000 ... %M3199 defines a range of operands of type %M, which the starting address is 3000, and which the number of operands is 200.

Data Format

Data format of the group communication points, according to the definition made in the section *Formats of the Communication Points*.

Quality

Defines if the quality is absent (QA), common for the entire group (QC) or specific for each point (QE).

Quality Format

Quality is always stored in 8 bits, however the format can be different, depending on the source of the point.

- I/O modules use of formats derived from the OPC standard
- IEDs MODBUS RTU or TCP use formats derived from the OPC standard
- IEDs DNP3 use formats derived from the DNP3 standard
- Internal points of the CPU typically make use of standard formats derived from the OPC standard, but it may eventually use other formats. For example, if the internal point derives from a read point from DNP3 IED, the internal point typically will copy the quality of the DNP3 point, keeping its format (e.g. conversion of an analog DNP3 IED point in field scale to an internal point in engineering scale).

Events Generation

Options of events generation for the points, according to is described in section *Events Generation*.

ATENÇÃO: Events generated in IEDs are not affected by this type of events generation.

Interface Detection Methods

Configures the options of events detection by AL-3415/17 modules, according to detailed in the section *Detection Methods of Internal Events in a AL-3415/17 Module*.

DO Disabling

Configures the DO point or the range of DO points in order to disable the events of the group. Its use is defined by the property *Interface Detection Methods*, previously described.

Dead Band

For groups of type AI, CN or FC it is possible to configure the type of dead band that will be used to generate events according to detailed in section *Types of Dead Band.*

AO Dead Band

Configures the AO point or the range of points AO that stores the value of the dead band. Its use is defined by the property *Dead Band* previously described.

Retain

This property specifies if the group of points is retain, i.e., the values of the points should be preserved in any eventual interruption of power in the AL-2004 CPU.

The values are maintained through a battery installed in the power supply and a super capacitor installed in AL-2004. If the energy runs out in these two ways, the retentive groups are initialized with the values configured in **Initial Value** and **Initial Quality** properties, described in the following sections.

For more information about the battery and the super capacitor, consult AL-2002 / AL-2003 / AL-2004 User Manual.

Initial Value

This property informs a value to initialize all the points of not retentive group, or that has lost its retentiveness, as *Retain* property described above.

Initial Quality

This property informs a quality to initialize all the points of a not retentive group, or that has lost its retentiveness, as *Retain* property described above.

Common Properties of the I/O Groups

Rack

This property informs the rack where is installed the I/O module associated to the group. It can have the following values:

- Main
- Expansion 0
- Expansion 1
- Expansion 2
- Expansion 3

Module

This property informs the I/O module associated to the group. It can have the following values:

- AL-3130
- AL-3132
- AL-3138
- AL-3150
- AL-3151
- AL-3150/8
- AL-3151/8
- AL-3202

Position

This property informs the slot in the rack where is installed the I/O module associated to the group. It can have values from 0 to 15.

Byte

This property informs the byte of an AL-3202 I/O module associated to the group. It can have values from 0 to 3.

Operand %E or %S

This property shows:

- The range of operands %E allocated for an AL-313X module
- The range of operands %S allocated for an AL-3202 module

These operands can be used to force digital inputs (%E) or digital outputs (%S).

In the case of digital outputs, you can force only outputs associated to AL-3202 bytes configured in *latched* mode.

Operation Mode

This property informs the operation mode for a byte of an AL-3202 I/O module associated to the group. It can have the following values:

- latched
- trip/close

A byte of the module AL-3202 corresponds, physically, to 8 normally open relays.

A byte of the AL-3202 module in latched mode has the following features:

- It is associated with 8 points of the type DO and variation D1QC (one relay output for each DO point)
- It receives only immediate commands in order to enable or disable the output
- It can be associated with ASDUs "Single Command" (C_SC_NA_1) of IEC 60870-5-104 clients connected to the AL-3415 module, from which it can accept commands such as ON or OFF, with persistent output.
- It can be associated with Control Relay Output Bock (CROB) DNP3TCP objects of clients connected to the AL-3417, from which it can accept commands such as latch-on or latch-off.

A byte of the AL-3202 module in trip/close mode has the following characteristics:

- It is associated with 4 DO type points and variation NQC (two relay outputs for each DO point)
- It receives only buffered commands in order to command trip or close, specifying the duration of the pulse
- It can be associated with ASDUs "Double Command" (C_DC_NA_1) of IEC 60870-5-104 client connected to the AL-3415 module, which can accept commands such as ON or OFF, with pulses of long or short duration
- Can be associated with Control Relay Output Bock (CROB) objects of DNP3 TCP clients connected to the AL-3417 module, which can accept commands like trip/pulse-on or close/pulse-on, with pulse duration specified in On -Time.

Common Properties of the IEDs Groups

This section describes the common properties of the IEDs groups of protocols:

- Master serial DNP3, executed by AL-2743 driver in AL-2005 module
- Master serial MODBUS RTU, executed by AL-2741 driver in AL-2005 module
- MODBUS TCP client, executed in AL-3414 module

Device Address

This property informs the address of the client/server device. Values may vary depending on the type of protocol used, and can be:

- Serial DNP3: may vary from 0 to 65.519
- MODBUS RTU: may vary from 1 to 247
- MODBUS TCP: may vary from 1 to 247

Initial Address

Corresponds to the first point address of the group of points that will be read in the slave/device server. Values may vary depending on the type of protocol used, and can be:

- Serial DNP3: may vary from 0 to 65.535
- MODBUS RTU: may vary from 1 to 65.535
- MODBUS TCP may vary from 1 to 65.535

Polltime

This property configures the period that the relation will be executed, both for writing relations and for reading relations. Values may vary depending on the type of protocol used, and can be:

- Serial DNP3: may vary from 0 a 65.535 tenths of a second (or 100 ms)
- MODBUS RTU: may vary from 0 a 10.000 tenths of a second (or 100 ms)
- MODBUS TCP: may vary from 0 a 10.000 tenths of a second (or 100 ms)

For DNP3 IEDs, the polltime with the value zero means that polling scan will not be executed to the points of the group. It is used when reading the points occurs only through the polling of events or the integrity polling. In addition, for the Block objects (Objects 12 and 41) this property is disabled.

For MODBUS IEDs the polltime with value zero means that they will be continuously executed, with no intervals between them.

Exclusive Properties of the DNP3 Groups

This section describes the exclusive properties of the DNP3 groups.

DNP3Object

This property configures the object and the variation used for reading and writing requests. Possible choices of objects and variations and their association with the types and formats of Hadron RTU are detailed in the following table:

Object	Variation	Description	Request Type	Supported Types	Supported Formats	Supported Qualities
1	**1**	Single-bit Binary Input	Reading	DI	D1	QA, QC, QE
1	**2**	Binary Input with Status	Reading	DI	D1	QE
10	**2**	Binary Output Status	Reading	DI	D1	QE
12	**1**	Control Relay Output Block	Writing	DO	N	QA
30	**1**	32-bit Analog Input	Reading	AI	I32	QE
30	**2**	16-bit Analog Input	Reading	AI	I16	QE
30	**3**	32-bit Analog Input without Flags	Reading	AI	I32	QA, QC, QE
30	**4**	16-bit Analog Input without Flags	Reading	AI	I16	QA, QC, QE
40	**1**	32-bit Analog Output Status	Reading	AI	I32	QE
40	**2**	16-bit Analog Output Status	Reading	AI	I16	QE
41	**1**	32-bit Analog Output Block	Writing	AO	N	QA
41	**2**	16-bit Analog Output Block	Writing	AO	N	QA

Table 4-14. List of objects and variations for DNP3 groups

The association of Objects 10 and 40 for input type must be used to read their respective outputs. To execute the commands it must be used Objects 12 and 41 respectively. Only asynchronous commands are accepted.

Common Properties of MODBUS IEDs Groups

This section describes the common properties of the MODBUS RTU and MODBUS TCP groups.

Function

This property corresponds to the function that will be used to request the points of the group. Possible options are detailed in the table below.

Function	Description	Request Type	Supported Types	Supported Formats	Supported Qualities
01	Read Coil Status	Reading	DI	D1, D2, D8	QC
02	Read Input Status	Reading	DI	D1, D2, D8	QC
03	Read Holding Registers	Reading	DI AI	D1, D2, D8 I16, UI16, I32, UI32, F32	QC QC
04	Read Input Registers	Reading	DI AI	D1, D2, D8 I16, UI16, I32, UI32, F32	QC QC
05	Force Single Coil	Writing	DO	D1	QC
06	Preset Single Register	Writing	DO AO	D1, D2, D8 I16, UI16	QC QC
15	Force Multiple Coils	Writing	DO	D1, D2, D8	QC

Function	Description	Request Type	Supported Types	Supported Formats	Supported Qualities
16	Preset Multiple Register	Writing	DO	D1, D2, D8	QC
			AO	I16, UI16, I32, UI32, F32	QC

Table 4-15. List of MODBUS functions for the MODBUS RTU or TCP groups

Swap Word

This property is available only when using one of the 32-bit formats, i.e. formats I32, UI32 or F32. These formats always perform the reading of pairs of holding registers or input registers. This option is used to control the way that both MODBUS registers are read or written to the operand associated with the group.

If the property is checked, the first register of the message corresponds to less significant word or the associated operand, and the second registers of the message corresponds to more significant word of the associated operand.

Exclusive Properties for the MODBUS TCP Groups

This section describes the common properties of the MODBUS TCP groups

IP

This property informs the IP address of the MODBUS TCP server.

It can vary according to IPV4 standard values.

Port

This property informs the port number of the listen connection of the MODBUS TCP server.

Timeout

This property informs the timeout of the MODBUS relation.

Exclusive Properties for the Groups of Engineering Conversion

This section describes the common properties of the groups of engineering conversion. These groups are always internal groups of AI type with F32Q* format.

The groups of engineering conversion points informs if this group of communication points are a result of automatic conversion of engineering units, applied to other group of points AI. For other information about engineering conversion, please see the section *Engineering Conversion*.

AI Field Unit

Informs the address of the first AI point of the group of communication points that contains the analog inputs represented in field units. This group should have the same number of points than the group in engineering units and the format must be I16, I32 or F32. The group must also have the same configuration of quality (DNP3 or OPC). Regarding the type, it is possible to use one of the following combinations:

- For the QA quality on the field unit, the group can have QA, QC or QE quality. In this case, the values of the quality of the points will be always OK, i.e., will have the value 1 in the case of DNP, or value 192 in the case of OPC.
- For the QC quality on the field unit, the group can have QC or QE quality
- For the QE quality on the field unit, the group can have only QE quality

Multiplicative Factor %F

Informs the address of a block of N operands %F used as multiplicative factors for the conversion of engineering units, where N is the number of points in the group of communication points. This block of operands %F must be in the area of free operands for the user.

Additive Factor %F

Informs the address of a block of N operands %F used as additive factors for the conversion of engineering units, where N is the number of points in the group of communication points. This block of operands %F must be in the area of free operands for the user.

Exclusive Properties for the Alarm Digital Input Groups

This section describes the common properties of groups of alarm digital inputs. These groups are always internal groups of type DI with D1QA format.

For further information about alarm digital inputs, please see the section *Alarms Calculation*.

Alarm Type

The type of alarm property configures the type of calculation to be used.

- **Upper**: The DI point is turned on when the corresponding point AI is greater than the preset of the correspondent AO alarm, indicating the alarm (high, very high, etc..)
- **Lower**: The DI point is turned on when the corresponding point AI is lower than the preset of the correspondent AO alarm, indicating the alarm (low, very low, etc.)

To create high and very high alarms for the same AI group it is only necessary to create two groups of **Upper** type alarms with the different preset values. The same occurs to create alarm low or very low.

AI Alarms

Informs the address of first AI point of the group of communication points that contains the analog inputs corresponding to the alarms. This group should have the same number of points that the group of DI point.

AO Limits

Informs the address of the first AO point of the group of communication points that contains the alarm limits. This group must have the same number of points that the group of DI point. In addition, the storage format of the value must be the same as the group of AI points (I16, UI16, I32, UI32, and F32). This group of points must not have quality (quality QA).

5. Diagnostics and Configuration Commands

Diagnostics

The HD3002 RTU provides diagnostics:

- Embedded in quality of communication points
- Embedded in status reported for commands over communication points
- For the main and expansion racks
- For the AL-3415 and AL-3417 interfaces (internal diagnostics)

Diagnostics Embedded in the Quality of the Communication Points

There are diagnostics embedded in the quality of the communication points, which can show:

- Failures in I/O modules, or in specific points of these modules
- Failures in IEDs, or in specific points of them

Diagnostics Embedded in the Command Status

Commands requested by SCADA (IEC104, DNP3 TCP) systems for the AL-3415 or AL-3417 modules have a status return, which indicates the success or failure of the same.

More details about these diagnostics can be found in the section *Buffers and Command Status Formats*.

Diagnostics for the Main Rack

ATTENTION: Several diagnostics listed below are referred to the PROFIBUS A and B networks, used for communication between the main rack and expansion racks. When there is no redundancy, the network A corresponds to the single network and the network B does not exist. Therefore, all diagnostics of network B will be zero.

ATTENTION: As described in the section *Intelligent Modules* of chapter *Technical Description*, in each PROFIBUS network (A or B) can be up to two AL-3416 slave interfaces in the expansion rack. One of them is always present in the expansion rack, being designated as **PROFIBUS default**. The second one exists only when there is AL-313X modules in the rack, and it is used to transfer events, being designated as **PROFIBUS events**.

There are 64 points of type DI with variation D1QC reserved for general diagnostics of the main rack. The following table describes the points of this group.

Point	Diagnostic	Description
DI0000	GPS synchronism error	Indicates that the GPS is not synchronizing correctly the main rack. Further details about the cause can be obtained by observing the diagnostic %M operand returned by the F-GPSTMB.086 module, as described in the F-GPSTMB.pdf file (this file comes with the product AL-1422 used to mount the synchronism network with GPS).
DI0001	AL-313X date/time discontinuity	Indicates that there was discontinuity of time on the AL-313X module. This discontinuity is generated when the NMEA synchronism is enabled on the following situations: setting of time via NMEA 0183/PPS protocol (synchronization via GPS), selection of daylight or return to normal time (DO0000 point), or time zone change. This indication will be cleared if the NMEA synchronism is disabled or with failure (DI0000 point is set).
DI0002	Event overflow in some AL-313X	Indicates that the F-EV313X.116 module, responsible for the removal of events from the AL-313X module, has detected a loss of events in at least one of the AL-313X of this rack.
DI0003	Date/time discontinuity in internal events	Indicates that there was a discontinuity of time on the main rack CPU. The discontinuity may have been generated for the following reasons: Setting the time via NMEA 0183/PPS (synchronization via GPS), time setting via DNP3 (DNP3 synch command), selection of daylight or return to normal time (point DO0000), time zone change, or always to run a cycle with the CPU in cycled mode.
DI0004	Some error message in CPU AL-2004	There is at least one error message in this AL-2004 CPU. These messages can be visualized using the Communication / PLC Information menu of the MasterTool Hadron XE.
DI0005	Retain loss in AL-2004 CPU	There was loss of retain on the AL -2004 CPU, detected by modification of an operand that is usually kept with a constant and retentive value. Retentive groups will be initialized with the values set in the Initial Value and Initial Quality fields as detailed in the section *Retain*.
DI0006 ... DI0007		Reserved.
DI0008	AL-3406 PROFIBUS A fatal error	Internal problem in the AL-3406 that acts as a master in the PROFIBUS network (if there is redundancy), or in the single PROFIBUS network (if there is no redundancy).
DI0009	Inactive AL-3406 PROFIBUS A network	The AL-3406 that acts as a master in the PROFIBUS network (if there is redundancy), or the single PROFIBUS network (if there is no redundancy) is not detecting any traffic in the network.
DI0010	AL-3406 PROFIBUS B fatal error	Internal problem in the AL-3406 that acts as master in PROFIBUS B network (if there is redundancy). If there is no redundancy, this diagnostic is always zero.
DI0011	Inactive AL-3406PROFIBUS B network	The AL-3406 that acts as a master in PROFIBUS B (if there is redundancy) is not detecting any traffic in the network. If there is no redundancy, this diagnostic is always zero.
DI0012 ... DI0015		Reserved.
DI0016	Communication failure of PROFIBUS A default with expansion rack. 0	The AL-3406 of the PROFIBUS A network is not able to communicate with the AL-3416 of the PROFIBUS A default network of the expansion rack 0.
DI0017	Communication failure of PROFIBUS A events with expansion rack 0	The AL-3406 PROFIBUS A network is not able to communicate with the AL-3416 of the PROFIBUS A events network of the expansion rack 0.
DI0018	Communication failure of PROFIBUS A default with expansion rack. 1	The AL-3406 of the PROFIBUS A network is not able to communicate with the AL-3416 of the PROFIBUS A default

Point	Diagnostic	Description
		network of the expansion rack 1.
DI0019	Communication failure of PROFIBUS A events with expansion rack 1	The AL-3406 PROFIBUS A network is not able to communicate with the AL-3416 of the PROFIBUS A events network of the expansion rack 1.
DI0020	Communication failure of PROFIBUS A default with expansion rack. 2	The AL-3406 of the PROFIBUS A network is not able to communicate with the AL-3416 of the PROFIBUS A default network of the expansion rack 2.
DI0021	Communication failure of PROFIBUS A events with expansion rack 2	The AL-3406 PROFIBUS A network is not able to communicate with the AL-3416 of the PROFIBUS A events network of the expansion rack 2.
DI0022	Communication failure of PROFIBUS A default with expansion rack. 3	The AL-3406 of the PROFIBUS A network is not able to communicate with the AL-3416 of the PROFIBUS A default network of the expansion rack 3.
DI0023	Communication failure of PROFIBUS A events with expansion rack 3	The AL-3406 PROFIBUS A network is not able to communicate with the AL-3416 of the PROFIBUS A events network of the expansion rack 3.
DI0024	Communication failure of PROFIBUS B default with expansion rack. 0	The AL-3406 of the PROFIBUS B network is not able to communicate with the AL-3416 of the PROFIBUS B default network of the expansion rack 0.
DI0025	Communication failure of PROFIBUS B events with expansion rack 0	The AL-3406 PROFIBUS B network is not able to communicate with the AL-3416 of the PROFIBUS B events network of the expansion rack 0.
DI0026	Communication failure of PROFIBUS B default with expansion rack. 1	The AL-3406 of the PROFIBUS B network is not able to communicate with the AL-3416 of the PROFIBUS B default network of the expansion rack 1.
DI0027	Communication failure of PROFIBUS B events with expansion rack 1	The AL-3406 PROFIBUS B network is not able to communicate with the AL-3416 of the PROFIBUS B events network of the expansion rack 1.
DI0028	Communication failure of PROFIBUS B default with expansion rack. 2	The AL-3406 of the PROFIBUS B network is not able to communicate with the AL-3416 of the PROFIBUS B default network of the expansion rack 2.
DI0029	Communication failure of PROFIBUS B events with expansion rack 2	The AL-3406 PROFIBUS B network is not able to communicate with the AL-3416 of the PROFIBUS B events network of the expansion rack 2.
DI0030	Communication failure of PROFIBUS B default with expansion rack. 3	The AL-3406 of the PROFIBUS B network is not able to communicate with the AL-3416 of the PROFIBUS B default network of the expansion rack 3.
DI0031	Communication failure of PROFIBUS B events with expansion rack 3	The AL-3406 PROFIBUS B network is not able to communicate with the AL-3416 of the PROFIBUS B events network of the expansion rack 3.
DI0032	Communication Failure with the intelligent module slot 0	The AL-2004 CPU is not able to communicate properly with the intelligent module located in slot 0, when the module in this position is a AL-3414, AL-3415, AL-3417 or AL-2005 module.
DI0033	Communication Failure with the intelligent module slot 1	The AL-2004 CPU is not able to communicate properly with the intelligent module located in slot 1, when the module in this position is a AL-3414, AL-3415, AL-3417 or AL-2005 module.
DI0034	Communication Failure with the intelligent module slot 2	The AL-2004 CPU is not able to communicate properly with the intelligent module located in slot 2, when the module in this position is a AL-3414, AL-3415, AL-3417 or AL-2005 module.
DI0035	Communication Failure with the intelligent module slot 3	The AL-2004 CPU is not able to communicate properly with the intelligent module located in slot 3, when the module in this position is a AL-3414, AL-3415, AL-3417 or AL-2005 module.
DI0036	Communication Failure with the intelligent module slot 4	The AL-2004 CPU is not able to communicate properly with the intelligent module located in slot 4, when the module in this position is a AL-3414, AL-3415, AL-3417 or AL-2005 module.
DI0037	Communication Failure with the intelligent module slot 5	The AL-2004 CPU is not able to communicate properly with the intelligent module located in slot 5, when the module in this position is a AL-3414, AL-3415, AL-3417 or AL-2005 module.
DI0038	Communication Failure with the intelligent module slot 6	The AL-2004 CPU is not able to communicate properly with the intelligent module located in slot 6, when the module in

Point	Diagnostic	Description
		this position is a AL-3414, AL-3415, AL-3417 or AL-2005 module.
DI0039	Communication Failure with the intelligent module slot 7	The AL-2004 CPU is not able to communicate properly with the intelligent module located in slot 7, when the module in this position is a AL-3414, AL-3415, AL-3417 or AL-2005 module.
DI0040 ... DI0063		Reserved.

Table 5-1. Points of the diagnostic Group of the main rack

Diagnostics for the Expansion Rack 0

There are 16 DI type points with variation D1QC reserved for general diagnostics of the expansion rack 0. The following table describes the points for this group.

Point	Diagnostic	Description
DI0064	GPS synchronism error	Indicates that the GPS is not synchronizing correctly the expansion rack 0. Further details about the cause can be obtained by observing the diagnostic %M operand returned by the F-GPSTMB.086 module, as described in the F-GPSTMB.pdf file (this file comes with the product AL-1422.
DI0065	AL-313X date/time discontinuity	Indicates that there was discontinuity of time on the AL-313X module. This discontinuity is generated when the NMEA synchronism is enabled on the following situations: setting of time via NMEA 0183/PPS protocol (synchronization via GPS), selection of daylight or return to normal time (DO0000 point), or time zone change. This indication will be cleared if the NMEA synchronism is disabled or with failure (DI0000 point is set).
DI0066	Overflow events in any AL-313X	Indicates that the F-EV313X.116 module, responsible for the removal of events from the AL-313X module, has detected a loss of events in at least one of the AL-313X of this rack.
DI0067	Overflow in the events queue of the expansion rack	Indicates that the event queue of the AL -2004 CPU of the expansion rack had an overflow. Events in this queue are transferred to the queue of the AL-2004 CPU in the main rack.
DI0068	Any error message in CPU AL-2004	There is at least one error message in this AL-2004 CPU. These messages can be visualized using the Communication / PLC Information menu of the MasterTool Hadron XE.
DI0069	Retain loss in AL-2004 CPU	There was loss of retain on the AL -2004 CPU, detected by modification of an operand that is usually kept with a constant and retentive value.
DI0070 .. DI0079		Reserved.

Table 5-2. Points of the diagnostic group of the expansion rack 0

Equivalence of Diagnostic Addresses of the Expansion Racks

All expansion racks have the same diagnostic points, changing only the address of the points between racks. The table below shows the equivalence of the diagnostic addresses for each expansion rack.

Diagnostic	Expansion 0	Expansion 1	Expansion 2	Expansion 3
GPS synchronism error	DI0064	DI0080	DI0096	DI0112
AL-313X date/time discontinuity	DI0065	DI0081	DI0097	DI0113
Overflow events in some AL-313X	DI0066	DI0082	DI0098	DI0114
Overflow in the events queue of the expansion rack	DI0067	DI0083	DI0099	DI0115
Some error message in AL-2004 CPU	DI0068	DI0084	DI0100	DI0116
Retain loss in AL-2004 CPU	DI0069	DI0085	DI0101	DI0117
Reserved	DI0070 ... DI0079	DI0086 ... DI0095	DI0102 ... DI0111	DI0118 ... DI0127

Table 5-3. Equivalence of diagnostic points addresses of the of the expansion rack

Internal Diagnostics of AL-3415/17 Modules

The diagnostics of any AL-3415/17 module can be read only by the clients that are connected to this module.

There are nine internal diagnostics defined for a AL-3415/17 module, in DI points with D1QA variation.

Point	Diagnostic	Description
DI10000	Event Overflow on AL-3415/17 - Client 0	The client 0 of this AL-3415/17 module has lost events. It is activated automatically indicating overflow and deactivated in the next cycle, indicating the end of the overflow.
DI10001	Event Overflow on AL-3415/17 - Client 1	The client 1 of this AL-3415/17 module has lost events. It is activated automatically indicating overflow and deactivated in the next cycle, indicating the end of the overflow.
DI10003	Event Overflow on AL-3415/17 - Client 2	The client 2 of this AL-3415/17 module has lost events. It is activated automatically indicating overflow and deactivated in the next cycle, indicating the end of the overflow.
DI10003	Event Overflow on AL-3415/17 - Client 3	The client 3 of this AL-3415/17 module has lost events. It is activated automatically indicating overflow and deactivated in the next cycle, indicating the end of the overflow.
DI10004	Change in the AL-3415/17interface identifier	The condition to generate this alarm is checked on power-on, in case of a replacement of AL-3415/17 modules between racks or between slots in the same rack. It is used the MAC address of the interface to detect this change. When this alarm occurs, the event queues of clients (AL 3415/17) are reset to avoid sending invalid events.
DI10005	There was some change in the project, which can cause a change in the extended C modules (C-HADRON.006 to C-HADRON.009)	This alarm is triggered at every change in configuration that affects the extended C modules. When this alarm occurs, the event queues of clients (AL 3415/17) and the event queue of the AL-2004 are reset to avoid sending invalid events.
DI10006	It was executed a general clear of the event queue of the HD3002 RTU command	This alarm is triggered when the event queue clearing command (DO0003) is executed.
DI10007	Overflow of events in the external queue of the AL-2004	When an overflow of the main AL-2004 event queue occurs (occurrence of a greater number of events than the maximum configured, in the same cycle) it is

		generated a diagnostic through this DI.
DI10008	Overload of events that are processed by the interface at each RTU execution cycle	When an event overload occurs, the event processing continues on the next RTU cycle. In this case, fast transitions of internal communication points can be not captured, just like the event indication with delayed timestamp for internal points which transition occurred during the overload cycle(s).
DI10009 ... DI10015		Reserved.

Table 5-4. Points of the internal diagnostics group of the AL-3415/17 modules

Configuration Commands

Configuration Commands for the Main Rack

There are 16 point of DO type with variation D1QA reserved for configuration commands in the main rack. Between these 16 points, the following have been identified so far:

Points	Diagnostic	Description
DO0000	Select daylight time	Selects the time zone for daylight saving time, when is 1, or normal time when it is at 0. This command is only valid if the RTU is connected to a GPS. This command is used by both the main rack and the expansion rack. The time stamp of events generated after the selection of time will follow the new time, valid for internal events, events generated by AL-313X, AL-315x interfaces and IEDs. The change between daylight saving time and standard time generates discontinuity events of time, both internal and AL-313X (points DI0001and DI0003) module.
DO0001	Reset retain alarm	Clears the alarm for retain loss, when enabled. It is automatically disabled after the alarm is cleared.
DO0002	Read engineering conversion factors in this cycle	Reports to the AL-3415/17 module that the engineering unit conversion factors (several operands %F) must be updated, that is, read again from the AL-2004. Typically the reading of all the engineering conversion factors is done only at startup of the RTU. This is an instantaneous command and not permanent, that is, as soon as it runs, it is reset (as opposed to command DO0000).
DO0003	Clearing the events queue	Clears all the event queues (queues on AL-2004 CPUs of the main and expansion racks, and internal queues of all AL-3415/17 modules). The event queues of AL-313X modules and in IEDs are not cleared. This is an instantaneous command and not permanent, that is, as soon as it runs, it is reset (as opposed to command DO0000).
DO0004	*Cold Restart*	Executes the *Cold Restart* command for the rack. Please see the *Cold Restart Command* section for more information.
DO0005 ... DO0015		Reserved.

Table 5-5. Points of the group of commands of the main rack

Configuration Commands for the Expansion Rack 0

There are 16 points of the DO type with variation D1QC reserved for configuration commands of the expansion rack 0. Between these 16 points, the following ones have been identified so far:

Point	Diagnostic	Description
DO0016		Reserved.
DO0017	Clears retain alarm	Clears the loss of retain alarm, when enabled. It is automatically disabled after the alarm is turned off.
DO0018 ... DO0031		Reserved.

Table 5-6. Points of the commands group of the expansion rack 0

Equivalence of the Diagnostics Addresses of the Expansion Racks

All expansion racks have the same diagnostic points, changing only the address of the points between the racks. The table below shows the equivalence of the addresses of diagnostics for each expansion rack.

Diagnostic	Expansion 0	Expansion 1	Expansion 2	Expansion 3
Reserve	DO0016	DO0032	DO0048	DO0064
Retain reset alarm	DO0017	DO0033	DO0049	DO0065
Reserves	DO0018 ... DO0031	DO0034 ... DO0047	DO0050 ... DO0063	DO0066 ... DO0079

Table 5-7. Equivalence of diagnostic points addresses of the expansion rack

6. Diagnostics of the AL-3415 and AL-3417 Interfaces

The AL-3415 and AL-3417 Ethernet interfaces generate basically two different types of diagnostics to indicate the status of its operation: through LEDs and in operands of the PLC.

The diagnostics through LEDs of both interfaces are practically the same, so we'll refer to them here as AL3415/17 to explain its common behaviors.

The first type of diagnostic is purely visual, generated through two sets of LEDs on its panel - ETH and NET. For the second, the diagnostics are stored directly on operands of PLC, and may be used by the user application, for example, presented in a supervision system. The latter are available only when the AL-2004 CPU and the AL 3415/17 interfaces are already communicating through the bus.

The function of these diagnostics is to identify possible problems in installation or configuration of the interface, and problems or deficiencies in the communication network. The maintenance chapter should be consulted by the user always when necessary.

ATTENTION: After the start of the system, the CPU starts the process of configuring the AL-3415/17 interfaces, which is indicated on the panel by LED CM flashing intermittently. The time that the interface remains in this state depends on the number of mapped points and can take no more than 6 seconds.

Panel Diagnostics

The following legend must be used for the identification of the LED status:

Status	Symbol
On	●
Intermittent blinking	X
Blinking once	1X
Off	○
Any state	-

Table 6-1. Identification legend of the LED status

Intermittent blinking - X: the LED starts to blink and keeps blinking while the interface remains in a state that was determined by a specific event.

Blinking once - 1X: the LED blinks once for each event occurred. If the event rate is higher than the blinking time, the status may be confused with the intermittent flashing.

RJ45 Connector LEDs

Both LEDs present on the RJ45 connector, identified as NET, helps the user to detect problems in the physical network installed, indicate the speed of the network LINK and if there is communication traffic with the interface. The meaning of the LEDs is shown in the table below.

Orange	Green	Meaning
○	○	No network LINK
●	○	10 Mbits/s Network LINK
●	●	100 Mbits/s Network LINK
X	–	Occurrence of transmit or receive actions on the Ethernet network, by or to this IP address. It blinks by demand of the AL-3415/17 CPU, and not at every transmission or reception, so it can flash with a frequency lower than the real frequency of transmission or reception.

Table 6-2. Meaning of the NET LEDs

Panel LEDs

The AL-3415/17 Ethernet interfaces have in their front panels four LEDs in line identified by ETH, which indicate its operation state and the most common diagnostics. After the configuration of the interface by the AL-2004 CPU, it can generate more precise diagnostics in individual operands of PLC (see chapter *Diagnostics in Operands*).

The four panel LEDs, identified by ETH, have the following meaning:

EX	PG	CM	ER	Meaning of the indication
●	●	●	●	Interface is powered: running initialization tests (consistency of RAM). Should remain in this state for less than a second.
○	●	●	●	Interface in load mode, unable to be configured by the CPU and to communicate over the Ethernet network. Shut down the system and remove the jumper from the PA3.
○	●	○	●	Interface in test mode, unable to be configured by the CPU and to communicate over the Ethernet network. Shut down the system and remove the jumper from PA4.
X	X	X	●	Failure in the initialization of the interface. Indicates hardware problems, with RAM memory.
●	○	–	●	The firmware is incompatible with the hardware/FPGA model.
○	○	–	●	The interface does not have MAC address recorded in its memory, which is necessary for communication in Ethernet networks. Contact Altus support.

–	–	○	–	The interface is not being accessed by the CPU. Check the module declaration in the CPU bus with MasterTool Hadron XE. This situation can occur during startup of the CPU.
–	–	X	–	The interface being accessed by the CPU. This LED blinks by demand of the AL-3415/17 CPU, and not at every access of the CPU, so it can blink with a frequency lower than the actual frequency of CPU access. It can also blink faster and not synchronized to the other LEDs of the panel.
X	○	–	○	Initializing LAN controller and detecting the network LINK (10 or 100 Mbps)
○	○	–	○	Interface successfully initialized: waiting for the CPU configuration.
X	○	–	X	Failure in the initialization of the LAN controller or network LINK not detected during the interface configuration. Check if the type of network cable plugged into NET port of the interface is adequate, and if the other end is connected. This situation may occur for a short time (less than a second) if the LAN controller takes longer than usual to detect the network LINK, according to the characteristics of the network in that the interface is connected. In such cases this indication should be not considered.
○	○	–	X	Invalid configuration received from the CPU: waiting for new configuration. This indication will only occur if the AL-3415/17 configuration modules (modules C-HADRON.00X) are corrupted. When this diagnostic indication occurs it is suggested that the user reload the configuration modules of the interfaces.
●	○	–	○	Interface properly configured and in run mode, ready to communicate on the Ethernet network with other equipment.
●	○	–	1X	Error detected in the transmission of a message over the Ethernet network. Please consult the transmission diagnostics returned in operands for more information about the error that occurred.

Table 6-3. Meaning of the ETH LEDs

Diagnostics in Operands

During and after the configuration of the AL 3415 and AL-3417 interfaces by AL-2004 CPU, interfaces can generate diagnostics directly on the PLC operands, since that the user has enabled it in the configuration parameters of the module.

The diagnostics are updated by the interface at each RTU execution cycle, in the range of operands reserved and defined by the user, so they can then be used in the application or read by the supervisory systems.

Although the diagnoses are stored in a single range of operands, it was divided into small groups, as shown in the following tables.

Diagnostics for AL-3415

MAC e IP Control and Addressing

Operand	Description
Mxxxx + 0	User commands operand for the Ethernet interface. The respective bit of the command is cleared by the interface when the command is executed. **BIT 0**: reserved **BIT 1**: reserved **BIT 2**: clear the diagnostic counters **BIT 3 to15**: reserved
Mxxxx + 1 to Mxxxx + 3	MAC address of the interface, composed by 6 bytes (two per operand/position) Example = 00.80.A0.05.12.34 Mxxxx + 1 = 0x0080 Mxxxx + 2 = 0xA005 Mxxxx + 3 = 0x1234
Mxxxx + 4 to Mxxxx + 5	IP Address of the interface, composed by 4 bytes (two bytes per operand/position). Example = 192.168.0.12 Mxxxx + 4 = 0xC0A8 Mxxxx + 5 = 0x000C
Mxxxx + 6 to Mxxxx + 7	Sub-net mask of the interface, composed by 4 bytes (two per operand/position). Example = 255.255.255.0 Mxxxx + 6 = 0xFFFF Mxxxx + 7 = 0xFF00
Mxxxx + 8 to Mxxxx + 9	Default Gateway Address of the interface, composed by 4 bytes (two bytes per operand/position). Example = 192.168.0.1 Mxxxx + 8 = 0xC0A8 Mxxxx + 9 = 0x0001
Mxxxx + 10 to Mxxxx + 15	Reserved operands.

Table 6-4. Control and parameters area of MAC and IP addressing

Transmission

Operand	Description
Mxxxx + 16	Number of Ethernet control packets transmitted with no error. The value varies between 0 and 32767. Includes the Ethernet messages with no IEC104 data, such as ARP (Address resolution protocol), ICMP (PING) and some of the transport layer (TCP of type ACK).
Mxxxx + 17	Number of IEC104 control packets transmitted with no error. The value varies between 0 and 32767. Includes the Ethernet messages with IEC104 data (all of TCP type).

Mxxxx + 18	Code of the last error occurred in the communication of the IEC104 protocol. 00: Transmission Error 01: Inter-character timeout 02: Connection closed by remote equipment 03: Received frame exceeded the size of the buffer 09: Did not received the initial synchronism character 10: Frame not received in the specified time 19: Did not received confirmation from a APDU with U format 20: Did not received confirmation form an APDU with I format 21: Received a confirmation with unknown sequence
Mxxxx + 19	Number of errors caused by collision. The value varies between 0 and 32767. Collision of the frame in transmission with other frame being transmitted by other equipment. Can occur due to high levels of traffic on the Ethernet network. Is automatically resolved by the LAN controller of the Ethernet interface.
Mxxxx + 20	Number of errors caused by underrun. The value varies between 0 and 32767. Transfer speed of one frame to the memory of the LAN controller was less than its rate of transmission. When it occurs, a new attempt to transmit the frame is automatically initiated by the Ethernet interface.
Mxxxx + 21	Number of errors caused by loss of carrier. The value varies between 0 and 32767. Loss of carrier signal ("carrier sense") during the transmission of a frame (Preamble). When it occurs, a new attempt to transmit the frame is automatically initiated by the Ethernet interface.
Mxxxx + 22	Number of events generated by the LAN controller to indicate situations of exception during the transmission of frames. The value varies between 0 and 32767. Events that may increase this counter are: - Detected a collision in the last frame transmission - Reached 16 collisions - Lost carrier sense - Underrun in transmission
Mxxxx + 23	Number of errors due to transmission timeout. The value varies between 0 and 32767. The time limit for the transmission of a packet has been reached, without confirmation that it has been concluded by the Ethernet controller. When it occurs, a new attempt to transmit the frame is automatically initiated by the Ethernet interface.
Mxxxx + 24	Number of errors due to lack of transmit buffers. The value varies between 0 and 32767. There was the attempt to allocate a buffer for Ethernet transmission of a frame, but there was none available. Can occur eventually, without negative consequences, when the simultaneous occurrence (burst) of multiple BROADCAST messages. When it occurs, the transmission of the frame is delayed until the release of a buffer.
Mxxxx + 25 to Mxxxx + 31	Operands reserved.

Table 6-5. Area with transmission diagnostics

Reception

Operand	Description
Mxxxx + 32	Number of Ethernet control packets received without errors. The value varies between 0 and 32767. Includes the Ethernet messages with no IEC104 data, such as ARP (Address resolution protocol), ICMP (PING) and some of the transport layer (TCP of type ACK).
Mxxxx + 33	Number of IEC104 packets received without errors. Value varies between 0 and 32767. Includes Ethernet messages with IEC104 data (all are of type TCP).
Mxxxx + 34	Number of IEC104 packets transmitted with error. Value varies between 0 and 32767. includes Ethernet messages with IEC104 data (all are of type TCP).
Mxxxx + 35	Number of IEC104 packets received with error. Value varies between 0 and 32767. Includes Ethernet messages with IEC104 data (all of type TCP).
Mxxxx + 36	Number of errors due to overrun. Value varies between 0 and 32767. The reading speed of the frame received by the LAN controller is below the rate of reception. Therefore, overrun can occur when a new frame is received before the last has been completely read. This error can occur due to the high volume of incoming messages (BROADCAST addressed or to the CPU) in a short time. The communication retries made by the TCP layer are responsible for sending new requests, so that this failure is not perceived by the applications. The use of Ethernet in enterprise networks contributes to the occurrence of overrun.
Mxxxx + 37	Number of errors due to invalid CRC. Value varies between 0 and 32767. Frame received with incorrect CRC information, and this information is what ensures the integrity of the message.
Mxxxx + 38	Number of errors due to alignment. Value varies between 0 and 32767. Frame received with alignment error (inconsistent fields of the frame).
Mxxxx + 39	Number of errors due to invalid packet size. Value varies between 0 and 32767. Receiving an invalid frame size (different from the standard).
Mxxxx + 40	Number of errors of other origin in IEC104 communication. See the code in the operand Mxxxx + 18
Mxxxx + 41	Number of errors due to lack of reception buffers. Value varies between 0 and 32767. There was the attempt to allocate an Ethernet buffer for reading a frame already received by the LAN controller, but there was none available. Can occur eventually, without negative consequences, when the simultaneous occurrence (burst) of multiple BROADCAST messages. When it occurs, the frame reading is delayed until the release of a buffer.
Mxxxx + 42 to Mxxxx + 47	Operands reserved

Table 6-6. Area with reception diagnostics

Resources

Operand	Description
Mxxxx + 48	Number of Ethernet buffers available (transmission and reception). Values between 0 and 39.
Mxxxx + 49	Number of available IEC104 transmission buffers (of application interface) Values between 0 and 20.
Mxxxx + 50	Number of available IEC104 reception buffers (of application interface) Values between 0 and 20.
Mxxxx + 51	Reserved.
Mxxxx + 52	Reserved.
Mxxxx + 53	Number of releases of IEC104 transmission buffers due to the existence of other identical in the transmission queue. Value varies between 0 and 32767. Can occur due to problems in the specification of parameters of the interface in MasterTool Hadron XE.
Mxxxx + 54	Number of releases of transmission buffers due to lack of active connection (client) established with the destination address. Value varies between 0 and 32767. Can occur if the connection has been or is being closed/aborted by the server.
Mxxxx + 55	Number of releases of transmission buffers due to the lack of passive connection (server) established with the destination address. Value varies between 0 and 32767. Can occur if the connection has been or is being closed/aborted by the client.
Mxxxx + 56	Reserved.
Mxxxx + 57	Reserved.
Mxxxx + 58	FPGA version. The value read in this operand is the digit after the point that indicates the version. Ex: for version 1.00, the value of field = 00.
Mxxxx + 59	Firmware Version (executive sw). Ex: for version 1.10, the value of field = 110.
Mxxxx + 60 to Mxxxx + 63	Reserved operands.

Table 6-7. Area with resources diagnostics

Connectivity

Operand	Description
Mxxxx + 64	Reserved.
Mxxxx + 65	Number of connections allocated to the Ethernet level, including connections established in server mode and LISTEN connections (standby). Values between 1 and 4.
Mxxxx + 66	Number of Ethernet connections closed due to inactivity. Value varies between 0 and 32767. Internal protection: open but inactive connections (no exchange of messages) for a longer time than configured, are aborted automatically by the Ethernet interface.
Mxxxx + 67	Number of Ethernet buffers released due to existence timeout. Value varies between 0 and 32767. Internal protection: buffers that remain in the queue without being processed for more than 60 seconds are discarded automatically, regardless of the configured parameters for the initial TCP timeout and Number of retries of TCP.
Mxxxx + 68	BITs of connectivity diagnostic: **BIT 0**: there is a listen connection for the client 0 **BIT 1**: there is a listen connection for the client 1 **BIT 2**: there is a listen connection for the client 2 **BIT 3**: there is a listen connection for the client 3 **BIT 4**: there is a established connection for the client 0 **BIT 5**: there is a established connection for the client 1 **BIT 6**: there is a established connection for the client 2 **BIT 7**: there is a established connection for the client 3 **BIT 8**: will not open connection for the client 0 **BIT 9:** will not open connection for the client 1 **BIT 10**: will not open connection for the client 2 **BIT 11**: will not open connection for the client 3 **BIT 12 to 15**: reserved When a connection is established with one client, it LISTEN port is closed.
Mxxxx + 69	Client 0 status: 0: not configured 1: configured but not connected 2: configured and client connected
Mxxxx + 70	Client 1 status: 0: not configured 1: configured but not connected 2: configured and client connected
Mxxxx + 71	Client 2status: 0: not configured 1: configured but not connected 2: configured and client connected
Mxxxx + 72	Client 3status: 0: not configured 1: configured but not connected 2: configured and client connected
Mxxxx + 73	General errors diagnostics **BIT 0**: Interface was reset by Watchdog **BIT 1 to 15**: reserved
Mxxxx + 74 to Mxxxx +79	Reserved operands.

Table 6-8. Area with connectivity diagnostics

Database

Operand	Description
Mxxxx + 80	Number of configured points.
Mxxxx + 81	Number of groups of communication points.
Mxxxx + 82	Number of alarm groups.
Mxxxx + 83	Number of groups of engineering conversion.
Mxxxx + 84	Number of free events for the client 0.
Mxxxx + 85	Number of free events for the client 1.
Mxxxx + 86	Number of free events for the client 2.
Mxxxx + 87	Number of free events for the client 3.
Mxxxx + 88 to Mxxxx + 89	Reserved operands.

Table 6-9. Area with the database diagnostics

Diagnostics for AL-3417

Control and MAC e IP Addressing

Operand	Description
Mxxxx + 0	User commands operand for the Ethernet interface. The respective bit of the command is cleared by the interface when the command is executed. **BIT 0**: reserved **BIT 1**: reserved **BIT 2**: clear the diagnostic counters **BIT 3 to15**: reserved
Mxxxx + 1 to Mxxxx + 3	MAC address of the interface, composed by 6 bytes (two per operand/position) Example = 00.80.A0.05.12.34 Mxxxx + 1 = 0x0080 Mxxxx + 2 = 0xA005 Mxxxx + 3 = 0x1234
Mxxxx + 4 to Mxxxx + 5	IP Address of the interface, composed by 4 bytes (two bytes per operand/position). Example = 192.168.0.12 Mxxxx + 4 = 0xC0A8 Mxxxx + 5 = 0x000C
Mxxxx + 6 to Mxxxx + 7	Sub-net mask of the interface, composed by 4 bytes (two per operand/position). Example = 255.255.255.0 Mxxxx + 6 = 0xFFFF Mxxxx + 7 = 0xFF00
Mxxxx + 8 to Mxxxx + 9	Default Gateway Address of the interface, composed by 4 bytes (two bytes per operand/position). Example = 192.168.0.1 Mxxxx + 8 = 0xC0A8 Mxxxx + 9 = 0x0001
Mxxxx + 10 to Mxxxx + 15	Reserved operands.

Table 6-10. Control and parameters area of MAC and IP addressing

Transmission

Operand	Description
Mxxxx + 16	Number of Ethernet control packets transmitted with no error. The value varies between 0 and 32767. Includes the Ethernet messages with no DNP3 data, such as ARP (Address resolution protocol), ICMP (PING) and some of the transport layer (TCP of type ACK).
Mxxxx + 17	Number of DNP3 packets transmitted with no error. The value varies between 0 and 32767. Includes the Ethernet messages with DNP3 data (all of TCP type).
Mxxxx + 18	Number of DNP3 packets transmitted with error. The value varies between 0 and 32767. Includes the Ethernet messages with DNP3 data (all of TCP type).
Mxxxx + 19	Code of the last error occurred in the communication of the DNP3 protocol. 00: Transmission Error 01: Inter-character timeout 02: Connection closed by remote equipment 03: Received frame exceeded the size of the buffer 04: Received frame with unknown address 05: Received frame with invalid function code. 06: CRC or checksum error. 07: Link was not reset, rejected frame. 08: Received frame with invalid bit count (FCB) 09: Did not received the initial synchronism character 11: Confirmation not received within the specified time 12: Link status not received within the specified time 23: Invalid sequence number (transport layer).
Mxxxx + 20	Number of errors caused due to collision. The value varies between 0 and 32767. Collision of the frame in transmission with other frame being transmitted by other equipment. Can occur due to high levels of traffic on the Ethernet network. Is automatically resolved by the LAN controller of the Ethernet interface.
Mxxxx + 21	Number of errors caused due to underrun. The value varies between 0 and 32767. Transfer speed of one frame to the memory of the LAN controller was less than its rate of transmission. When it occurs, a new attempt to transmit the frame is automatically initiated by the Ethernet interface.
Mxxxx + 22	Number of errors caused by loss of carrier. The value varies between 0 and 32767. Loss of carrier signal ("carrier sense") during the transmission of a frame (Preamble). When it occurs, a new attempt to transmit the frame is automatically initiated by the Ethernet interface.
Mxxxx + 23	Other errors in LAN controller. It is a counter that informs the number of errors that occurred due to any one of the following reasons: - Detected a collision in the last frame transmission - Reached 16 collisions - Lost carrier sense - Underrun in transmission
Mxxxx + 24	Number of errors due to transmission timeout. The value varies between 0 and 32767. The time limit for the transmission of a packet has been reached, without confirmation that it has been concluded by the Ethernet controller. When it occurs, a new attempt to transmit the frame is automatically initiated by the Ethernet interface.

Mxxxx + 25	Number of errors due to lack of transmit buffers. The value varies between 0 and 32767. There was the attempt to allocate a buffer for Ethernet transmission of a frame, but there was none available. Can occur eventually, without negative consequences, when the simultaneous occurrence (burst) of multiple BROADCAST messages. When it occurs, the transmission of the frame is delayed until the release of a buffer.
Mxxxx + 26 to Mxxxx + 31	Reserved operands.

Table 6-11. Area with transmission diagnostics

Reception

Operand	Description
Mxxxx + 32	Number of Ethernet control packets received without errors. The value varies between 0 and 32767. Includes the Ethernet messages with no DNP3 data, such as ARP (Address resolution protocol), ICMP (PING) and some of the transport layer (TCP of type ACK).
Mxxxx + 33	Number of DNP3 packets received without errors. Value varies between 0 and 32767. Includes Ethernet messages with DNP3 data (all are of type TCP).
Mxxxx + 34	Number of received DNP3 packets with invalid function error code.
Mxxxx + 35	Number of timeouts of data link layer confirmation message.
Mxxxx + 36	Number of timeouts of link status messages.
Mxxxx + 37	Number of received DNP3 packets with other errors on the data link layer.
Mxxxx + 38	Number of received DNP3 packets with error on the transport layer.
Mxxxx + 39	Number of errors due to overrun. Value varies between 0 and 32767. The reading speed of the frame received by the LAN controller is below the rate of reception. Therefore, overrun can occur when a new frame is received before the last has been completely read. This error can occur due to the high volume of incoming messages (BROADCAST addressed or to the CPU) in a short time. The communication retries made by the TCP layer are responsible for sending new requests, so that this failure is not perceived by the applications. The use of Ethernet in enterprise networks contributes to the occurrence of overrun.
Mxxxx + 40	Number of errors due to invalid CRC. Value varies between 0 and 32767. Frame received with incorrect CRC information, and this information is what ensures the integrity of the message.
Mxxxx + 41	Number of errors due to alignment. Value varies between 0 and 32767. Frame received with alignment error (inconsistent fields of the frame).
Mxxxx + 42	Number of errors due to invalid packet size. Value varies between 0 and 32767. Receiving an invalid frame size (different from the standard).
Mxxxx + 43	Number of errors due to lack of reception buffers. Value varies between 0 and 32767. There was the attempt to allocate an Ethernet buffer for reading a frame already received by the LAN controller, but there was none available. Can occur eventually, without negative consequences, when the simultaneous occurrence (burst) of multiple BROADCAST messages. When it occurs, the frame reading is delayed until the release of a buffer.
Mxxxx + 44 to Mxxxx + 47	Reserved operands.

Table 6-12. Area with reception diagnostics

Resources

Operand	Description
Mxxxx + 48	Number of Ethernet buffers available (transmission and reception). Values between 0 and 39.
Mxxxx + 49	Number of available DNP3 transmission buffers (of application interface) Values between 0 and 20.
Mxxxx + 50	Number of available DNP3 reception buffers (of application interface) Values between 0 and 20.
Mxxxx + 51	Reserved.
Mxxxx + 52	Reserved.
Mxxxx + 53	Number of releases of DNP3 transmission buffers due to the existence of other identical in the transmission queue. Value varies between 0 and 32767. Can occur due to problems in the specification of parameters of the interface in MasterTool Hadron XE.
Mxxxx + 54	Reserved operand.
Mxxxx + 55	Number of releases of transmission buffers due to the lack of passive connection (server) established with the destination address. Value varies between 0 and 32767. Can occur if the connection has been or is being closed/aborted by the client.
Mxxxx + 56	Reserved.
Mxxxx + 57	Reserved.
Mxxxx + 58	FPGA version. The value read in this operand is the digit after the point that indicates the version. Ex: for version 1.00, the value of field = 00.
Mxxxx + 59	Firmware Version (executive sw). Ex: for version 1.10, the value of field = 110.
Mxxxx + 60	Time spent on the engineering conversion processing on the last cycle (ms)
Mxxxx + 61	Time spent on the event detection processing on the last cycle (ms)
Mxxxx + 62	Time spent on DNP3 stack processing on the last cycle (ms)
Mxxxx + 63	Reserved operands.

Table 6-13. Area with resources diagnostics

Connectivity

Operand	Description
Mxxxx + 64	Reserved.
Mxxxx + 65	Number of connections allocated to the Ethernet level, including connections established in server mode and LISTEN connections (standby). Values between 1 and 4.
Mxxxx + 66	Number of Ethernet connections closed due to inactivity. Value varies between 0 and 32767. Internal protection: open but inactive connections (no exchange of messages) for a longer time than configured, are aborted automatically by the Ethernet interface.
Mxxxx + 67	Number of Ethernet buffers released due to existence timeout. Value varies between 0 and 32767. Internal protection: buffers that remain in the queue without being processed for more than 60 seconds are discarded automatically, regardless of the configured parameters for the initial TCP timeout and Number of retries of TCP.
Mxxxx + 68	BITs of connectivity diagnostic of DNP3 clients: **BIT 0**: there is a established connection with client 0 **BIT 1**: there is a established connection with client 1 **BIT 2**: there is a established connection with client 2 **BIT 3**: there is a established connection with client 3 **BIT 4 to 15**: reserved
Mxxxx + 69	BITs of connectivity diagnostic: Operand in client IP connection mode: **BIT 0**: there is listen connection for the configured server port Operand in server port address connection mode: **BIT 0**: there is a listen connection for the address of port of client 0 **BIT 1**: there is a listen connection for the address of port of client 1 **BIT 2**: there is a listen connection for the address of port of client 2 **BIT 3**: there is a listen connection for the address of port of client 3 **BIT 4 to 15**: reserved
Mxxxx + 70 to Mxxxx + 72	Reserved operands.
Mxxxx + 73	General errors diagnostics **BIT 0**: Interface was reset by Watchdog **BIT 1 to 15**: reserved
Mxxxx + 74 to Mxxxx +79	Reserved operands.

Table 6-14. Area with connectivity diagnostics

Database

Operands	Description
Mxxxx + 80	Number of points configured.
Mxxxx + 81	Number of groups of communication points.
Mxxxx + 82	Number of alarms groups.
Mxxxx + 83	Number of groups of engineering conversion.
Mxxxx + 84	Number of free events to the client 0.
Mxxxx + 85	Number of free events to the client 1.
Mxxxx + 86	Number of free events to the client 2.
Mxxxx + 87	Number of free events to the client 3.
Mxxxx + 88 to Mxxxx + 89	Operands reserved.

Table 6-15. Area with diagnostics of the database

7. RTU Performance

The HD3002 RTU is a modular and expansible system that performs multiple tasks distributed into multiple processors. The main performance indicator of the RTU is defined by the execution cycle time of the main rack AL-2004 CPU, which determines important factors like the time for updating the local I/O and the time resolution of the events that are detected internally on the RTU. Therefore, the objective of this section is to explain the influence of the execution of these tasks on the RTU execution cycle time, and also to show some good configuration and operation practices for obtaining a good RTU performance and the satisfaction of its users.

However, the intention of this section is neither to limit the application of the HD3002 RTU solution nor to cover all the aspects that are involved and have impact on the solution performance. Other points not related here can also have influence and limit the performance of the RTU.

Main Tasks that Influence the RTU Cycle Time

Number of Points Configured on the RTU

Each configured communication point, specially with event detection and generation enabled, requires some minimal processing power from the AL-3415/17 interfaces which, when summed all together, can result on a total time that is representative for the process. Thus, declaring a lot of point groups, just like declaring points without a real need, must be avoided. Communication points for test purposes must be eliminated when the system goes to the definitive operation.

Some types of communication points requires even an extra processing power from the AL-3415/17 interfaces due to the use of complex arithmetic functions. Between these kind of points, there are the following ones:

- Analog inputs with engineering conversion: each declared point requires the execution of some floating point arithmetic operations (sum and multiplying) at each RTU execution cycle
- Alarm digital inputs: each declared point requires the execution of an arithmetic operation (subtraction or comparison) at each RTU execution cycle
- Analog inputs with integrated dead band. Each declared point requires the execution of some floating point or 16/32 bit integer arithmetic operations at each RTU execution cycle

Number of Gaps of Mapped Points on AL-3417 Interface

Gaps are intervals of DNP3 point indexes, for some client, that are not mapped. For example: if there are two groups of binary inputs mapped, the first one with 16 points (index 0 to 15) and the second one with 10 points (index 20 to 29), the resulting gap is 4 points, i.e., from index 16 to index 19.

The gaps, although being not recommended by the DNP3 standard, are supported by the HD3002 RTU within a certain limit, however they reduce the system performance, because the AL-3417 interface behaves just like if these points were mapped, even not reporting them to the clients.

As seen on the previous item, points mapped on the clients requires a minimal processing power from the Al-3417 interface, which results in a wasted time for the final system result.

General Interrogation and Integrity Polling Commands

The execution of general interrogation (IEC104 protocol/AL-3415 interface) and integrity polling (DNP3 protocol/AL-3417 interface) commands results in an intense processing load, because the RTU performs a reading of the entire configured database. During the execution of these commands, it can be observed an instantaneous increase of the RTU cycle time which depends specially of the total number of mappings for that specific client which requested the command.

The suggestion for minimizing the interference of such commands is to maximize the time interval which the commands are requested by the supervision systems, except on situations where it is indispensable (startup conditions, communication failures or event queues overflow situations).

Whatever the protocol used, it is strongly recommended the use of non-solicited messages for updating the databases through events of value and/or quality change of the mapped communication points.

Such procedure minimize and distributes the time spent for processing the points, since only the points that have it state changed will be reported through messages to the several clients (control and supervision systems)

Limit of Processed Events per RTU Execution Cycle

The HD3002 RTU have a limit for the number of events that can be processed at each cycle. This limit does not have an absolute and fixed value, being based on a kind of counter and this way depends of the kind of configuration used. This limit works on the following way:

- When an event occurrence is detected (value change, for example), the counter is incremented in one unit.
- For each client (IEC104 or DNP3 for which the point is mapped, the counter is incremented in one unit.
- When the counter reach the limit of 2,500 units, the RTU finishes that execution cycle and continue the event processing on the next cycle keeping the RTU internal time freeze until the processing of all events is completely finished.

The events can come from the AL-2004 internal queue (modules AL-313x, DNP3 IEDs, etc…) or from the internal detection performed on the AL-3415/17 interfaces. Although there is only one counter, there are limits defined for each case. First are processed the events from the AL-2004 queue, which counter limit is 2,000 units, and after are processed the events detected internally on the interfaces, and the total of the both process cannot be greater than 2,500 units. Below there are some examples of this limit mechanism:

Example 1 – AL-2004 Event Queue:

This first example shows how the event counter works, considering the situation where there are only point groups that generate value events through the main rack AL-2004 event queue.

Communication Point Groups:

	Description	Group	Variation	Quality Format	Events Detection at Interface
1	Diagnostics Main Rack	DI0000..DI0063	D1QC	OPC_D	V_Q
2	AL-3138 pos 0 - 32 DIs	DI1000..DI1031	D1QC	OPC_D	Q
3	AL-3138 pos 1 - 32 DIs	DI1032..DI1063	D1QC	OPC_D	Q
4	DNP3 Slave 1 - 250 DIs	DI5000..DI5249	D1QE	DNP_DI	QC
5	DNP3 Slave 2 - 250 DIs	DI5250..DI5499	D1QE	DNP_DI	QC
6	Diagnostics of AL-3415/3417 Modules	DI10000..DI10015	D1QA	NA	V
7	DNP3 Slave 1 - 250 AIs	AI5000..AI5249	I16QE	DNP_AI	QC
8	Commands Main Rack	DO0000..DO0015	D1QA	NA	Disabled

For the analysis of this example, consider the groups 2 and 3, AL-3138 digital input modules, groups 4, 5 and 7, slave DNP3 accessed through AL-2743 driver on a AL-2005 coprocessor.

Mappings for AL-3417 Client 0:

	Index	Group	DNP Group
1	0..31	DI1000..DI1031	Binary Input
2	32..63	DI1032..DI1063	Binary Input
3	64..313	DI5000..DI5249	Binary Input
4	314..563	DI5250..DI5499	Binary Input
5	0..249	AI5000..AI5249	Analog Input

Mappings for AL-3417 Client 1:

	Index	Group	DNP Group
1	0..31	DI1000..DI1031	Binary Input
2	32..63	DI1032..DI1063	Binary Input

Functioning of Event Counter:

Imagine that, in a certain cycle, some value change events are inserted into the AL-2004 event queue for all points of groups 2, 3, 4, 5 and 7 (814 communication points). In this situation, the event counter of the AL-3417 module will behave as follows:

Counter	Counting description
0	The counter is cleared at the start of each processing cycle of the interface
32	Detection of the 32 events of group 2 (AL-3138 pos 0 - 32 DIs)
64	Insertion of the 32 events of group 2 on event queue of client 0
96	Insertion of the 32 events of group 2 on event queue of client 1
128	Detection of the 32 events of group 3 (AL-3138 pos 0 - 32 DIs)
160	Insertion of the 32 events of group 3 on event queue of client 0
192	Insertion of the 32 events of group 3 on event queue of client 1
442	Detection of the 250 events of group 4 (DNP3 Slave 1 - 250 DIs)
692	Insertion of the 250 events of group 4 on event queue of client 0
942	Detection of the 250 events of group 5 (DNP3 Slave 2 - 250 DIs)
1192	Insertion of the 250 events of group 5 on event queue of client 0
1442	Detection of the 250 events of group 7 (DNP3 Slave 1 - 250 AIs)
1692	Insertion of the 250 events of group 7 on event queue of client 0

As the event counting limit that come from AL-2004 queue is 2,000 units, all the events of this example are processed in one cycle only, and it remains a positive balance of 308 (2,000 – 1,692) for events of the AL-2004 queue or 808 (308 + 500) for events detected internally that still could be processed on this same cycle.

Example 2 – Events Detected by the Interface:

This second example shows the functioning of the event counter, considering a situation where there are only internal points that generate value and/or quality events from interface internal detection, which does not depends on the AL-2004 event queue.

Communication Points Group:

	Description	Group	Variation	Quality Format	Events Detection at Interface
1	Diagnostics Main Rack	DI0000..DI0063	D1QC	OPC_D	V_Q
2	Internal digital - 200 DIs	DI3000..DI3199	D1QC	OPC_D	V_Q
3	Diagnostics of AL-3415/3417 Modules	DI10000..DI10015	D1QA	NA	V
4	Internal Analog - 100 AIs	AI3000..AI3099	I16QC	OPC_A	V
5	Internal conversion - 100 AIs	AI3100..AI3199	F32QC	OPC_A	V_Q
6	Commands Main Rack	DO0000..DO0015	D1QA	NA	Disabled
7	Internal counters - 100 CNs	CN3000..CN3099	I32QC	OPC_C	V_Q

For the analysis of this example, consider the internal point groups 2, 4, 5 and 7.

Mappings for AL-3417 Client 0:

	Index	Group	DNP Group
1	0..199	DI3000..DI3199	Binary Input
2	0..99	AI3000..AI3099	Analog Input
3	100..199	AI3100..AI3199	Analog Input
4	0..99	CN3000..CN3099	Counter

Mappings for AL-3417 Client 1:

	Index	Group	DNP Group
1	0..99	DI3000..DI3099	Binary Input
2	0..49	AI3000..AI3049	Analog Input
3	50..99	AI3100..AI3149	Analog Input
4	0..49	CN3000..CN3049	Counter

Mappings for AL-3417 Client 2:

	Index	Group	DNP Group
1	0..19	DI3000..DI3019	Binary Input
2	0..9	AI3000..AI3009	Analog Input
3	10..19	AI3100..AI3109	Analog Input
4	0..9	CN3000..CN3009	Counter

Functioning of the Event Counter:

Imagine that, in a certain cycle, there are value change for all points of groups 2, 4, 5 and 7 (500 communication points). In this situation, the event counter of the AL-3417 module will behave as follows:

Counter	Counting description
0	The counter is cleared at the start of each processing cycle of the interface
200	Detection of the 200 events of group 2 (digital internal - 200 DIs)
400	Insertion of the 200 events of group 2 on event queue of client 0
500	Insertion of the 100 events of group 2 on event queue of client 1
520	Insertion of the 20 events of group 2 on event queue of client 2
620	Detection of the 100 events of group 4 (analog internal - 100 AIs)
720	Insertion of the 100 events of group 4 on event queue of client 0
770	Insertion of the 50 events of group 4 on event queue of client 1
780	Insertion of the 10 events of group 4 on event queue of client 2
880	Detection of the 100 events of group 5 (conversion internal - 100 AIs)
980	Insertion of the 100 events of group 5 on event queue of client 0
1030	Insertion of the 50 events of group 5 on event queue of client 1
1040	Insertion of the 10 events of group 5 on event queue of client 2
1140	Detection of the 100 events of group 7 (counter internal - 100 CNs)
1240	Insertion of the 100 events of group 7 on event queue of client 0
1290	Insertion of the 50 events of group 7 on event queue of client 1
1300	Insertion of the 10 events of group 7 on event queue of client 2

As the event counting limit that come from AL-3417 internally detected events is 2,500 units (not considering the occurrence of events on the AL-2004 queue), all the events of this example are processed in one cycle only, and it remains a positive balance of 1200 (2,500 – 1,300) for events detected internally that still could be processed on this same cycle.

Example 3 – AL-2004 Event Queue and Events Detected by the Interface:

This third example shows the functioning of the event counter for a situation where there are points that generate value events through the AL-2004 event queue and also for internal points that generate value and/or quality events through the interface internal detection. This example will show also the behavior of the interface when an event processing overload occurs.

Communication Point Groups:

	Description	Group	Variation	Quality Format	Events Detection at Interface
1	Diagnostics Main Rack	DI0000..DI0063	D1QC	OPC_D	V_Q
2	AL-3138 pos 0 - 32 DIs	DI1000..DI1031	D1QC	OPC_D	Q
3	AL-3138 pos 1 - 32 DIs	DI1032..DI1063	D1QC	OPC_D	Q
4	Internal digital - 500 DIs	DI3000..DI3499	D1QC	OPC_D	V_Q
5	DNP3 Slave 1 - 200 DIs	DI5000..DI5199	D1QE	DNP_DI	QC
6	DNP3 Slave 2 - 200 DIs	DI5200..DI5399	D1QE	DNP_DI	QC
7	Diagnostics of AL-3415/3417 Modules	DI10000..DI10015	D1QA	NA	V
8	Internal analog - 200 AIs	AI3000..AI3199	I16QC	OPC_A	V
9	DNP3 Slave 1 - 100 AIs	AI5000..AI5099	I16QE	DNP_AI	QC
10	DNP3 Slave 2 - 100 AIs	AI5100..AI5199	I16QE	DNP_AI	QC
11	Commands Main Rack	DO0000..DO0015	D1QA	NA	Disabled

For the analysis of this example, consider the groups 2 and 3, the AL-3138 digital input modules, the groups 5, 6, 9 and 10, slave DNP3 accessed through the AL-2743 driver on a AL-2005 coprocessor, and the internal groups 4 and 8.

Mappings for AL-3417 Client 0:

	Index	Group	DNP Group
1	0..31	DI1000..DI1031	Binary Input
2	32..63	DI1032..DI1063	Binary Input
3	64..563	DI3000..DI3499	Binary Input
4	564..763	DI5000..DI5199	Binary Input
5	764..863	DI5200..DI5299	Binary Input
6	0..199	AI3000..AI3199	Analog Input
7	200..299	AI5000..AI5099	Analog Input
8	300..399	AI5100..AI5199	Analog Input

Mappings for AL-3417 Client 1:

	Index	Group	DNP Group
1	0..31	DI1000..DI1031	Binary Input
2	32..63	DI1032..DI1063	Binary Input
3	64..163	DI3000..DI3099	Binary Input
4	164..363	DI5000..DI5199	Binary Input
5	364..413	DI5200..DI5249	Binary Input
6	0..99	AI3000..AI3099	Analog Input
7	100..199	AI5000..AI5099	Analog Input
8	200..249	AI5100..AI5149	Analog Input

Functioning of the Event Counter:

Imagine that, in a certain cycle, value events for groups 2, 3, 5 and 6 (464 communication points) are inserted in to the AL-2004 event queue and value change for all internal groups 4 and 8 (700 communication points), and that in the following cycle there are inserted value change events for groups 9 and 10 (200 communication points) on AL-2004 event queue. In this situation, the event counter of the AL-3417 module will behave as follows:

Counter	Counting description
0	The counter is cleared at the start of each processing cycle of the interface
32	Detection of the 32 events of group 2 (AL-3138 pos 0 - 32 DIs)
64	Insertion of the 32 events of group 2 on event queue of client 0
96	Insertion of the 32 events of group 2 on event queue of client 1
128	Detection of the 32 events of group 3 (AL-3138 pos 0 - 32 DIs)
160	Insertion of the 32 events of group 3 on event queue of client 0
192	Insertion of the 32 events of group 3 on event queue of client 1
392	Detection of 200 events of group 5 (DNP3 Slave 1 - 200 DIs)
592	Insertion of the 200 events of group 5 on event queue of client 0
792	Insertion of the 200 events of group 5 on event queue of client 1
992	Detection of the 200 events of group 6 (DNP3 Slave 2 - 200 DIs)
1092	Insertion of the 100 events of group 6 on event queue of client 0
1142	Insertion of the 50 events of group 6 on event queue of client 1
1642	Detection of the 500 events of group 4 (Internal digital - 500 DIs)
2142	Insertion of the 500 events of group 4 on event queue of client 0
2242	Insertion of the 100 events of group 4 on event queue of client 1
2328	Detection of 86 from 200 events of group 8 (internal analog - 200 AIs)
2414	Insertion of the 86 events of group 8 on event queue of client 0
2500	Insertion of the 86 events of group 8 on event queue of client 1
	Overload of event processing ocurred
0	The counter is cleared at the start of each processing cycle of the interface
100	Detection of the 100 events of group 9 (DNP3 Slave 1 - 100 AIs)
200	Insertion of the 100 events of group 9 on event queue of client 0
300	Insertion of the 100 events of group 9 on event queue of client 1
400	Detection of the 100 events of group 10 (DNP3 Slave 2 - 100 AIs)
500	Insertion of the 100 events of group 10 on event queue of client 0
550	Insertion of the 50 events of group 10 on event queue of client 1
664	Detection of 114 from 200 events of group 8 (internal analog - 200 AIs)
778	Insertion of the 114 events of group 8 on event queue of client 0
792	Insertion of the 14 events of group 8 on event queue of client 1

As the event counting limit for the AL-3417 interface is 2,500 for each cycle, some part of the events related to the internal points are going to be processed only in one second cycle. For this example it would occur the event processing overload indication through the DI 10008 point.

Also, it can be observed that the events that come from the AL-2004 event queue have priority over the events detected through internal points, because the events of groups 9 and 10, inserted on the AL-2004 event queue only on the second cycle, were processed before the 114 remaining points of the group 8.

8. Maintenance

The maintenance information should be consulted in the documentation of each product, which is listed in the document Technical Characteristics of the Hadron 3002 RTU (CT108302).

9. Glossary

Active CPU	In a redundant system is the CPU that is controlling the system – reading the inputs, executing the application program and activating the outputs.
Adjustment Bridge	Switch for addresses or configuration composed by pins present in the circuit plate and a small removable connector, used for selection.
Algorithm	Finite and well defined sequence of instructions with the goal to solve problems
Altus relays and blocks language	Set of instructions and operands, which allow the edition of an applicative program to be used in a PLC
Application Program	Program downloaded into the PLC and has the instructions that define how the machinery or process will work.
Assembly Language	Microprocessor programming language, it is also known as machine language
BT	Battery test.
Bus	Set of electrical signals that are part of a logic group with the function of transferring data and control between different elements of a subsystem
Bus	Set of electrical signals that are part of a logic group with the function of transferring data and control between different elements of a subsystem
Byte	Information unit composed by eight bits.
C-Module	See Configuration Module.
Commercial Code	Product code formed by the letters PO and followed by four digits.
Configuration Module	Also referred to as C-Module. Unique module in a remote application program that carries several needed parameters for its operation, such as the operands quantity and disposition of I/O modules in the bus
CPU	Central Processing Unit. It controls the data flow, interprets and executes the program instructions as well as monitors the system devices.
Diagnostic	Procedures to detect and isolate failures. It also relates to the data set used for such tasks, and serves for analysis and correction or problems.
E2PROM	Electrically Erasable Programmable Read-Only Memory. Non-volatile memory that may be electrically erased by the electronic circuit.
E-Module	See execution module.
Encoder	Normally refers to position measurement transducer.
ER	Acronym used on LEDs to indicate error
ESD	Electrostatic Discharge.
Execution Module	Application program modules. May be one of three types: E000, E001 and E018. The E000 module is executed just once upon system powering or when setting programming into execution mode. The E001 module has the main program that is executed cyclically, while the E018 module is activated by the time interruption.
Flash EPROM	Non volatile memory that may be electrically erased and programmed..
F-Module	See Function Module.
Function Module	Application software module called from the main module (E-module) or from another function module or procedure module. It passes parameters and return values. Works as a subroutine.
Hardware	Physical equipment used to process data where normally programs (software) are executed
Hot swap	Procedure of replacing modules in a system without powering it off. It is a normal procedure for I/O modules.
I/O	See Input/Output.
I/O Module	Hardware module that is part of the Input/Output (I/O) subsystem.
I/O Subsystem	Set of digital or analog I/O modules and interfaces of a PLC
IEC 61131	Generic international standard for operation and use of programmable controllers.
IEC Pub. 144 (1963)	International standard for protection of accidental access and sealing the equipment from water, dust and other foreign objects.
IEC-536-1976	International standard for electrical shock protection.
IEC-801-4	International standard for tests of immunity against interference by pulses burst
IEEE C37.90.1 (SWC)	SWC stands for Surge Withstand Capability. This is the international standard for oscillatory wave noises protection.
Input/Output	Also known as I/O. Data input or output devices in a system. In PLCs these are typically the digital or analog modules that monitor or actuate the devices controlled by the system.
Interface	Normally used to refer to a device that adapts electrically or logically the transferring of signals between two equipments.
Interruption	Priority event that temporarily halts the normal execution of a program. The interruptions are divided into two generic types: hardware and software. The former is caused by a signal coming from a peripheral, while the later is caused within a program

ISOL.	Acronym used to indicate isolation or isolated.
Kbytes	Memory size unit. Represents 1024 bytes.
LED	Light Emitting Diode. Type of semiconductor diode that emits light when energized. It's used for visual feedback.
Logic	A graphic matrix in Altus Relay and Blocks Language where are inserted the relay diagram language instructions that are part of an application program are inserted. A set of sequentially organized logics makes up a program module.
Menu	Set of available options for a program, they may be selected by the user in order to activate or execute a specific task
Module (hardware)	Basic element of a system with very specific functionality. It's normally connected to the system by connectors and may be easily replaced.
Module (software)	Part of a program capable of performing a specific task. It may be executed independently or in conjunction with other modules through information sharing by parameters.
Module address:	Address used by the CPU in order to access a specific I/O module.
Nibble	Information unit composed of four bits.
Not-operant CPU	In a redundant system this is the CPU that is neither active nor backup. May not take control of the system.
Byte	Byte or 8-bit sequence
Operands	Elements on which software instructions work. They may represent constants, variables or set of variables.
PA	See Jumpers.
PLC	See Programmable Controller.
P-Module	See Procedure Module.
Procedure Module	PLC application software module called from the main module (E-module) or from another procedure module or function module that does not have parameters.
PROFIBUS PA	Means PROFIBUS Process Automation.
Executive Program	Operational system of a programmable controller. It controls the basic functions of controlling and executing applicative programs.
Programmable Controller	Also know as PLC. Equipment controlling a system under the command of an application program. It is composed of a CPU, a power supply and I/O modules.
Programming Language	Set of rules, conventions and syntaxes utilized when writing a program.
RAM	Random Access Memory. Memory where all the addresses may be accessed directly and in random order at the same speed. It is volatile, in other words, its content is erased when powered off, unless there is a battery to keep its contents.
Redundant system	System with a backup or double elements to execute specific tasks. Such system may suffer certain failures without stopping the execution of its tasks.
Redundant system	System with backup or double elements to execute specific tasks. Such system may suffer certain failures without stopping the execution of its tasks.
Spare CPU	In a redundant system is the CPU that monitors the active CPU, not realizing the control f the system, but is ready to take control in the event of a failure in an active CPU.
Ripple	Oscillation present in continuous voltages.
RX	Acronym used to indicate serial reception.
Scan Cycle	A complete execution of the PLC application program.
Sockets	Part to plug in integrated circuits or other components, thus facilitating their substitution and maintenance.
Software	Computer programs, procedures and rules related to the operation of a data processing system
Supervisory Station	Equipment connected to a PLC network with the goal of monitoring and controlling the process variables
Tag	Name associated to an operand or to logic that identifies its content.
Toggle	Element with two stable states that are switched at every activations.
TX	Acronym used to indicate serial transmission.
Upload	Reading a program or configuration from the PLC.
Varistor	Protection device against voltage spikes.
Watchdog timer	Electronic circuit that checks the equipment operation integrity.
WD	Acronym for watchdog. See Watchdog timer
Word	Information unit composed by 16 bits.

Annex A. Formats and Conversions of Quality

Usually, the user do not need to worry about how to decode the formats of quality because the RTU automatically calculates the quality information, and send them to clients of the AL-3415 (IEC 60870-5-104) and AL-3417 (DNP3) interfaces.

However, in some situations, the user may need to decode this information:

- When the application needs to reference a communication point, and want to know if the information is reliable
- When the application wants to insert quality information on calculated internal communication points
- For the purpose of debugging

There are three basic formats of quality used inside the HD3002 RTU:

- DNP3
- OPC
- IEC104

Following are defined conversions of format that can be needed inside the HD3002 RTU:

DNP3 Quality Formats

This quality formats can be used in the communication points of:

- DNP3 IEDs Serial groups
- Internal groups

Next, we define the DNP3 quality sub format. It should be noted that such formats apply only to read variables, never written or controlled variables.

DNP_DI Subformat

This applies to sub format communication points of type DI.

The following defines the bits used in quality byte:

Bit	Tag	Name	Description
0	OL	On-line	When off, indicates that the point cannot be read from the originator device.
1	RS	Restart	Indicates that IED is associated with the point being rebooted, so the point value is still not reliable.
2	CL	Communication lost	Indicates failure to communicate with the IED. Therefore, the point may never have been read, or reading may be obsolete.
3	RF	Remote forced	Indicates that the point is being forced by other device, other than IED.
4	LF	Local forced	Indicates that the point is being forced inside the IED.
5	CF	Chatter filter	Indicates that the point was filtered to remove unwanted transitions.
6	-	-	Not used. Fixed at 0.
7	-	-	Not used. Fixed at 0.

Table A-1. DNP_DI Quality

DNP_DO Subformat

This Sub format applies to points of communication of the type DO.

The following defines the bits used in byte of quality:

Bit	Tag	Name	Description
0	OL	On-line	When off, indicates that the point cannot be read from the origin device, or is inactive or out of service.
1	RS	Restart	Indicates that IED is associated with the point is being rebooted, so the point value is still not reliable.
2	CL	Communication lost	Indicates failure to communicate with the IED. Therefore, the point may never have been read, or reading may be obsolete.
3	RF	Remote forced	Indicates that the point is being forced by another device, other than IED.
4	LF	Local forced	Indicates that the item is being forced inside the IED.
5	-	-	Not used. Fixed at 0.
6	-	-	Not used. Fixed at 0.
7	-	-	Not used. Fixed at 0.

Table A-2. DNP_DO quality

DNP_AI Subformat

This sub format applies to communication points of type AI.

The following defines the bits used in byte of quality:

Bit	Tag	Name	Description
0	OL	On-line	When off, indicates that the point cannot be read from the origin device.
1	RS	Restart	Indicates that IED associated to the point is being restarted, so the point value is still not reliable.
2	CL	Communication lost	Indicates failure to communicate with the IED. Therefore, the point

Bit	Tag	Name	Description
			may never have been read, or reading may be obsolete.
3	RF	Remote forced	Indicates that the point is being forced by other device, other than IED.
4	LF	Local forced	Indicates that the point is being forced inside the IED.
5	OR	Overrange	The value exceeds the range of representation (integer with sign) of 16 or 32 bits, or the measuring range of the A / D converter.
6	RE	Reference check	Error in the conversion process from analog to digital, resulting in accuracy out of specification.
7	-	-	Not used. Fixed at 0.

Table A-3. DNP_AI Quality

DNP_AO Subformat

This sub format applies to communication points of type AO.
The following defines the bits used in byte of quality:

Bit	Tag	Name	Description
0	OL	On-line	When off, indicates that the point cannot be read from the origin device.
1	RS	Restart	Indicates that IED associated to the point is being restarted, so the point value is still not reliable.
2	CL	Communication lost	Indicates failure to communicate with the IED. Therefore, the point may never have been read, or reading may be obsolete.
3	RF	Remote forced	Indicates that the point is being forced by other device, other than IED.
4	LF	Local forced	Indicates that the point is being forced inside the IED.
5	OR	Overrange	The value exceeds the range of representation.
6	RE	Reference Err	Error in the conversion process from analog to digital, resulting in accuracy out of specification.
7	-	-	Not used. Fixed at 0.

Table A-4. DNP_AO quality

DNP_C Subformat

This sub format applies to communication points of type CN and FC.

The following defines the bits used in byte of quality:

Bit	Tag	Name	Description
0	OL	On-line	When off, indicates that the point cannot be read from the origin device.
1	RS	Restart	Indicates that IED associated to the point is being restarted, so the point value is still not reliable.
2	CL	Communication lost	Indicates failure to communicate with the IED. Therefore, the point may never have been read, or reading may be obsolete.
3	RF	Remote forced	Indicates that the point is being forced by other device, other than IED.
4	LF	Local forced	Indicates that the point is being forced inside the IED.
5	RO	Rollover	Indicates a shift of the counter, i.e., the passage of the maximum value to zero. This flag is no longer used by DNP3, it was kept here only for historical reasons. Its value is always zero.
6	DC	Discontinuity	Indicates that the counter value should not be compared for getting changes in counting.
7	-	-	Not used. Fixed at 0.

Table A-5. DNP_C Quality format

OPC Quality Formats

These formats of quality can be used in the communication points of:

- Groups of diagnostics and commands
- Internal groups
- Groups of I/O modules
- IEDs MODBUS RTU groups
- IEDs MODBUS TCP groups

Following, are defined the OPC sub formats of quality.

OPC_D Sub- format

This sub format applies to points DI and DO. The following table shows the possible values and their descriptions.

OPC Value	Description
12	Failure in the device (for example, I/O module with problems)
16	Sensor failure (e.g. diagnostic at the input point).
24	Communication failure.
192	OK, the value is correctly read from the sensor
216	OK, but value forced or replaced..
Other	Illegal quality.

Table A-6. OPC_D quality format

OPC_A Sub format

This sub format applies to points AI and AO. The following table shows the possible values and their descriptions.

OPC value	Description
12	Failure in the device (for example, I/O module with problems)
16	Failure in the sensor, with no limitation.
17	Failure in sensor, with lower limit reached (for example, current <<4 mA in an input of 4-20 mA.)
18	Failure in sensor, with lower limit reached (for example, current >>20 mA in an input of 4-20 mA.)
24	Communication failure.
192	OK, the value is correctly read from the sensor
193	OK with a lower limit reached (e.g., current slightly less than 4 mA on a 4-20 mA input).
194	OK with the upper limit reached (e.g., slightly above the current 20 mA on a 4-20 mA input).
216	OK, but value forced or replaced..
Other	Illegal quality.

Table A-7. OPC_A quality format

OPC_C Sub format

This sub format applies to points CN and FC. The following table shows the possible values and their descriptions.

OPC value	Description
12	Failure in the device (for example, I/O module with problems)
16	Failure in the sensor, with no limitation
24	Communication failure.
192	OK, the value is correctly read from the sensor
193	OK with a lower limit reached (for example, “roll under” of a counter)
194	OK with the upper limit reached (for example, “roll over” of a counter
216	OK, but value forced or replaced...
Other	Illegal Quality

Table A-8. Quality format OPC_C

Formats in IEC 60870-5-104 Protocol

These formats of quality are not used within any screen of groups of communication points. They are used only within the AL-3415, to report information objects to the master IEC104.

The main purpose of these formats described in this manual is to inform how the AL-3415 interface converts the quality information of communication points (formats DNP3 or OPC) for the IEC104 format.

All quality formats are made up of several individual fields of a bit, detailed in the table below.

Flag	Name	Description
OV	**OVERFLOW**	The value of the information is out of a default range. This flag is typically used in analog values.
BL	**BLOCKED**	The value of the information is blocked for transmission, and the value remains in the state it was before being blocked. The AL-3415 interface never turns on this flag.
SB	**SUBSTITUTED**	The value of the information is being replaced or forced.
NT	**NOT TOPICAL**	The latest update of the information object was not successful, due to a failure of communication with the source device.
IV	**INVALID**	The last update of the information object has not been done successfully due to a failure in the source device (e.g. failure of an I/O module).
CY	**CARRY**	Counter roll-over or roll-under.
CA	**COUNTER ADJUSTED**	The counter was changed (reset, preset, frozen, etc.).

Table A-9. IEC104 qualities

Further, this manual tells you how these flags are converted from the information quality of communication points, represented in either OPC or DNP3 formats.

Conversions of Quality from DNP3 to IEC60870-5-104

When a group of communication points with DNP3 quality format should be reported through an AL-3415 module, this module must perform conversions of quality from DNP3 to IEC104.

Following, it is defined how such conversions are performed for each type of object IEC104.

Single-point information

The below shows the calculation of each bit of quality IEC104, depending on the bit of quality sub format DNP_DI.
The following bits are calculated:

- BL: fixed 0
- SB: must be plugged into any one of the following situations:
    - bit 3 (remote forced) = 1
    - bit 4 (local forced) = 1
- NT: same as bit 2 (communication lost)
- IV: must be plugged in any of the following situations:
    - bit 0 (on-line) = 0
    - bit 1 (restart) = 1
    - bit 5 (chatter filter) = 1

Double-point information

Uses the same procedure of the **single-point information** object.

Step position information

Uses the same procedure of the **single-point information** object for the bits BL, SB, NT and IV. Moreover, there is a bit OV, which is always zero.

Measured value, normalized value

Following, it is shown the calculation of each bit of IEC104 quality, depending on the bit of quality DNP_AI sub format.
The following bits are calculated:

- BL: fixed in 0
- SB: must be plugged into any one of the following situations:
    - bit 3 (remote forced) = 1
    - bit 4 (local forced) = 1
- NT: the same as bit 2 (communication lost)
- IV: must be plugged into any of the following situations:
    - bit 0 (on-line) = 0
    - bit 1 (restart) = 1
    - bit 6 (reference check) = 1
- OV: the same as bit 5 (over range)

Measured value, scaled value

Measured value, normalized value object.

Measured value, short floating point value

We use the same procedure of the **measured value, normalized value** object.

Integrated totals

As the driver AL-2743 (DNP3 serial master) does not support counters, this conversion is unnecessary.

Conversions of Quality from OPC to IEC60870-5-104

When a group of communication points with OPC quality format should be reported through an AL-3415 module, this module must perform conversions from OPC to IEC104.

Then it is shown how such conversions are performed for each type of IEC104 object.

Single-point information

The following table shows the logic of calculation of each bit of IEC104quality, depending on the values of quality of OPC_D sub format.

OPC_D		IEC 60870-5-104			
Value	**Description**	**BL**	**SB**	**NT**	**IV**
12	Failure in the device (for example, I/O module with problems	0	0	0	1
16	Failure in the sensor (for example, diagnostic in the input point)	0	0	0	1
24	Communication failure	0	0	1	0
192	OK, the value was correctly read from the sensor.	0	0	0	0
216	OK, but with value forced or replaced.	0	1	0	0
Other	Illegal quality	0	0	0	1

Table A-10. OPC_D to IEC104 Conversion

Double-point information

We use the same procedure of the **single-point information** object.

Step position information

We use the same procedure of the **single-point information** object for the bits BL, SB, NT and IV. Moreover, there is a bit OV, which is always zero.

Measured value, normalized value

The following table shows the calculation logic of each bit of quality IEC104, depending on the values of OPC_A quality sub format.

OPC_A		IEC 60870-5-104				
value	**Description**	**BL**	**SB**	**NT**	**IV**	**OV**
12	Device failure (e.g., module I / O problems).	0	0	0	1	0
16	Sensor Failure, without limitation.	0	0	0	1	0
17	Sensor failed, with a lower limit reached (e.g., current <4 mA on a 4-20 mA input).	0	0	0	1	0
18	Sensor failed, with the upper limit reached (e.g., current> 20 mA on a 4-20 mA input).	0	0	0	1	0
24	Communication failure.	0	0	1	0	0
192	The value is correctly read from the sensor.	0	0	0	0	0
193	OK with a lower limit reached (e.g., current slightly less than 4 mA on a 4-20 mA input).	0	0	0	0	1
194	OK with the upper limit is reached (e.g., slightly above the current 20 mA on a 4-20 mA input).	0	0	0	0	1

OPC_A		IEC 60870-5-104				
value	Description	BL	SB	NT	IV	OV
216	OK, but with value forced or replaced.	0	1	0	0	0
Other	Illegal quality	0	0	0	1	0

Table A-11. OPC_A to IEC104 Conversion

Measured value, scaled value

Used the same procedure do **measured value, normalized value** object.

Measured value, short floating point value

Used the same procedure of **measured value, normalized value** object.

Integrated totals

The following table shows the logic of calculation of each bit of quality IEC104, depending on the values of OPC_C quality sub format

OPC_C		IEC 60870-5-104		
Value	Description	CY	CA	IV
12	Device failure (e.g., module I / O problems).	0	0	1
16	Sensor Failure, without limitation.	0	0	1
24	Communication failure.	0	0	1
192	OK, the value is correctly read from the sensor.	0	0	0
193	OK with a lower limit reached e.g., “roll under” of a counter).	1	0	0
194	OK with a lower limit reached (e.g., “roll over” of a counter).	1	0	0
216	OK, but with value forced or replaced. .	0	0	0
Other	Illegal quality	0	0	1

Table A-12. Conversion OPC_C to IEC104

ATTENTION:
The configuration of counters with the detection method QC or QNC has no effect for the AL- 3415, because the protocol does not have the NT flag used by the other IEC104 format to indicate a communication failure. This flag is also used by AL 3417 to generate these types of events.

Conversions of Quality from OPC to DNP3

When a group of communication points with OPC quality format should be reported through an AL-3417 module, this module must perform quality conversions from DNP3to OPC.

Following, it is defined as such conversions are performed for each type of quality DNP3.

DNP_DI e DNP_DO Sub formats

The following table shows the calculation logic of each bit of quality DNP3, depending on the values of quality sub format OPC_D.

OPC_D		DNP3					
Value	Description	CF	LF	RF	CL	RS	OL

OPC_D		DNP3					
Value	**Description**	**CF**	**LF**	**RF**	**CL**	**RS**	**OL**
12	Device failure (e.g., I/O module problems).	0	0	0	0	0	0
16	Sensor failed (e.g. diagnostic in input point).	0	0	0	0	0	0
24	Communication Failure	0	0	0	1	0	0
192	OK, the value is correctly read from the sensor.	0	0	0	0	0	1
216	OK, but with value forced or replaced.	0	1	0	0	0	1
Other	Illegal quality	0	0	0	0	0	0

Table A-13. Conversion from OPC_D to DNP3

DNP_AI Sub format

The following table shows the logic of calculation of each bit of quality DNP3, depending on the values of quality sub format OPC_A.

OPC_A		DNP3					
Valor	**Description**	**OR**	**LF**	**RF**	**CL**	**RS**	**OL**
12	Device failure (e.g., I/O module problems).	0	0	0	0	0	0
16	Failure in sensor, with no limitation.	0	0	0	0	0	0
17	Sensor failed, with a lower limit reached (e.g., current <4 mA on a 4-20 mA input).	1	0	0	0	0	0
18	Sensor failed, with the upper limit is reached (e.g., current 20 mA on a 4-20 mA input). mA).	1	0	0	0	0	0
24	Communication Failure	0	0	0	1	0	0
192	OK, OK, the value is correctly read from the sensor.	0	0	0	0	0	1
193	OK with a lower limit reached (e.g., current slightly less than 4 mA on a 4-20 mA input).	1	0	0	0	0	1
194	OK with the upper limit reached (e.g., slightly above the current 20 mA on a 4-20 mA input).	1	0	0	0	0	1
216	OK, but with value forced or replaced.	0	1	0	0	0	1
Other	Illegal quality	0	0	0	0	0	0

Table A-14. OPC_A to DNP3 conversion

DNP_C Subformat

The following table shows the calculation logic of each bit of quality DNP3, depending on the values of quality sub format OPC_C.

OPC_C		DNP3						
Value	**Description**	**DC**	**RO**	**LF**	**RF**	**CL**	**RS**	**OL**
12	Device failure (e.g., I/O module problems).	0	0	0	0	0	0	0
16	Sensor Failure, without limitation.	0	0	0	0	0	0	0
24	Communication Failure	0	0	0	0	1	0	0
192	OK, the value is correctly read from the sensor.	0	0	0	0	0	0	1
193	OK with a lower limit reached e.g., “roll under” of a counter).	0	0	0	0	0	0	1
194	OK with a lower limit reached (e.g., “roll over” of a counter).	0	0	0	0	0	0	1
216	OK, but with value forced or replaced.	0	0	1	0	0	0	1
Other	Illegal Quality.	0	0	0	0	0	0	0

Table A-15. OPC_C to DNP3 conversion

Annex B. Buffers and Command Status Formats

Before reading this section, it is recommended the rereading of the *Commands* section of chapter *Basic Concepts*.

Regarding the source of commands, it is known that commands executed by the HD3002 RTU can come through the AL-3415 (IEC104) interfaces, the AL-3417 (DNP3 Ethernet) interfaces or can be generated internally, by user application of the AL-2004 CPU.

These commands can be classified as immediate or buffered.

Immediate commands can be destined to:

- Internal points resident in memory of operands of the AL-2004 CPU. These commands are executed by writing about one or more operands of AL-2004 CPU (M%, %I or F %), associated with points of types DO, AO, CN or CF that are configured as internal points. The status returned to the origin equipment of the command depends on the quality (diagnostic) of the respective point, but if the point is of quality QA, command always returns success.
- Bytes of AL-3202 modules configured in latched mode. These commands are executed by writing over an operand %M of the AL-2004 CPU, associated with the group of 8 point type DO variation D1QC of the byte latched of AL-3202. The status returned to the origin equipment of the command depends on the quality (diagnostic) of the corresponding byte of the module AL-3202 (there may be failure in the module, or failure of communication with expansion racks).
- Commands for IEDs MODBUS RTU and MODBUS TCP. These commands are executed by writing about one or more operands of the AL-2004 CPU (%M, %I or %F), associated with points of type DO or AO which are configured as MODBUS RTU or MODBUS TCP points. The status returned to the original equipment of the command depends on the quality of point MODBUS (there may be failure to communicate with the MODBUS IEDs).

Buffered commands can be destined to:

- Bytes of AL-3202 modules configured in trip/close mode.
- Internal points, through the Output User Command Buffer. The execution of the command must be executed by the user application (P-CICUSR.170).
- Serial IEDs DNP3.

In this section, it is described:

- Formats of commands received by the AL-3415 interface, through the IEC104 protocol, and of the corresponding status returned.
- Formats of commands received by the AL-3417 interface via DNP3 TCP protocol, and the corresponding status returned.
- Format of command buffers sent to bytes trip / close the module AL-3202, and the corresponding status returned.
- Format of buffers command sent to serial IEDs DNP3 (AL-2743 driver in the AL-2005), and the corresponding status returned.
- Format of the Output User Command Buffer passed to the user application on P-CICUSR.170, and associated to internal points of AO or DO type.
- Conversions between the various formats of commands and status, previously mentioned.

Commands Received Through AL-3415 (IEC 60870-5-104 Protocol)

In this section, it is discussed the IEC104 format of the commands that can be received by AL-3415, and their respective return codes.

Single Command (C_SC_NA_1)

In control direction, this command is described by two main fields:

- COT (Cause of Transmission - 8 bits), which is composed of 3 subfields:
    - Cause (bits 0 to 5), being acceptable the following reasons in sense of control:
        - 6 = activation
        - 8 = deactivation (used only to cancel a **select** previously sent)
    - P/N = positive/negative (bit 6), which should be 0 in control direction (0 = positive confirmation, 1 = negative confirmation)
    - T = test (bit 7), which should be 0 in the control direction (0 = no test, 1 = test).
- SCO (8 bits), composed of four subfields:
    - SCS (Single Command State – bit 0), which represents the command value:
        - 0 = OFF
        - 1 = ON
    - Reserved (bit 1)
    - QU (bits 2 to 6):
        - 0: no additional definition, that is, the RTU knows all the details to execute the command. In the case of HD3002 RTU, this code generates a persistent command. It is accepted only for immediate commands; for buffered commands for this command is not accepted.
        - 1 pulse of short duration, where the duration of this pulse is an internal parameter programmed to the HD3002 RTU. The value of SCS in this case, is ignored. Is only supported for buffered commands.
        - 2 pulse of long duration, where the duration of this pulse is an internal parameter set to the RTU HD3002. The value of SCS in this case, is ignored. Is only supported for buffered commands.
        - 3: persistent output (latched), using the value of SCS for the command. In the case of HD3002 RTU, this code is accepted only for commands immediate, for buffered commands this command is not accepted.
        - 4 ... 31: return invalid commands
    - S/E (bit 7):
        - 0: execute
        - 1: select

In monitoring direction, the status return for this command takes in consideration only the following field:

- COT (Cause of Transmission), composed by three subfields:
    - Cause (6 bits), being acceptable the following causes in monitoring direction:
        - 7: activation confirmation
        - 9: deactivation confirmation (only confirm the canceling of a previous **select**)
        - 44: unknown type identification (return error in the format of the command)
        - 45: unknown cause of transmission (return error in the format of the command)
        - 46: unknown common address of ASDU (return error in the format of the command)
        - 47: unknown information object address (return error in the format of the command)

- P / N = positive / negative (1 bit): This command may be denied because of a fault in one I/O module or communication module with an IED, as well as due to an incorrect parameter in fields *data unit identifier* or *information object address*. In the latter case should be returned to the field cause values between 44 and 47, identifying the inconsistent parameter.
  - 0 = positive confirmation
  - 1 = negative confirmation
- T = test (1 bit), that must be 0 in the monitoring sense (0 = no test, 1 = no test)

Double Command (C_DC_NA_1)

In control sense, this command is composed by three fields:

- COT (Cause of Transmission), already explained previously for **Single Command**.
- DCO (8 bits), composed of three subfields:
  - DCS (Double Command State – bits 0 to 1):
    - 0 = not allowed
    - 1 = OFF
    - 2 = ON
    - 3 = not allowed
  - QU (bits 2 to 6):
    - Without further definition, that is, the RTU know all the details to execute the command. In the case of RTU HD3002, this code generates a persistent command. It is accepted only for commands immediate; buffered commands for this command are not accepted.
    - Pulse of short duration, where the duration of this pulse is an internal parameter set to the RTU HD3002. The value of SCS in this case, is ignored. It is accepted only for buffered commands.
    - 2 pulse of long duration, where the duration of this pulse is an internal parameter set to the HD3002 RTU. The value of SCS in this case, is ignored. It is accepted only for buffered commands.
    - 3: persistent output (latched), using the value of SCS for the case. It is accepted only for immediate control.
    - 4 ... 31: return status invalid returns invalid status
  - S/E (bit 7):
    - 0: execute
    - 1: select

In order to monitor the status return for this command takes into account only the following field:

- COT (Cause of Transmission), already explained for **Single Command**.

Regulating Step Command (C_RC_NA_1)

In control sense, this command is composed by three fields:

- COT (Cause of Transmission), already explained for **Single Command**..
- RCO (8 bits), composed of three subfields:
  - RCS (Regulating Step Command State – bits 0 a 1):
    - 0 = not allowed
    - 1 = next step lower
    - 2 = next step upper
    - 3 = not allowed
  - QU (bits 2 to 6):
    - 0: no further definition, that is, the RTU knows all the details to execute the command. In the case of RTU HD3002, this code generates a persistent

command. It is accepted only for commands immediate; buffered commands for this command are not accepted.
        - 1: pulse of short duration. This command is not accepted by Hadron RTU.
        - 2: pulse of long duration. This command is not accepted by Hadron RTU.
        - 3: persistent output (latched), using the value of SCS for the command. It is accepted only for buffered command.
        - 4 ... 31: returns invalid status.
    - S/E (bit 7):
        - 0: execute
        - 1: select

In sense of monitoring, the return of status for this command takes under consideration only the following field

- COT (Cause of Transmission), already explained for **Single Command**.

Set-point Command, Normalized Value (C_SE_NA_1)

In direction of control, this command is composed by three fields:

- COT (Cause of Transmission), already explained for **Single Command**.
- NVA (Normalized Value), which is represented in 16 bits with signal in the range between -1 and $+1-2^{-15}$
- QOS (Qualifier of Set-point Command), composed by two subfields:
    - QL (bits 0 to 6): must be 0.
    - S/E (bit 7):
        - 0: execute
        - 1: select

In sense of monitoring, the return of status for this command takes in consideration only the following field:

- COT (Cause of Transmission), already explained for **Single Command**.

Set-point Command, Scaled Value (C_SE_NB_1)

In sense of control, this command is composed for three fields:

- COT (Cause of Transmission), already explained for **Single Command**.
- SVA (Scaled Value), which is represented in 16 bits with signal within the range between -32768 and +32767
- QOS (Qualifier of Set-point Command), already previously explained for **Set-point Command, Normalized Value**.

In the direction of monitoring, the return of status for this command takes in consideration only the following field:

- COT (Cause of Transmission), already previously explained for **Single Command**.

Set-point Command, Short Floating Point Value (C_SE_NC_1)

In the direction of control, this command is composed by three fields:

- COT (Cause of Transmission), already previously explained for **Single Command**.
- IEEE STD 754 (Short Floating Point), according to the referred IEEE STD 754 rule.
- QOS (Qualifier of Set-point Command), already previously explained for **Set-point Command, Normalized Value**.

In the direction of monitoring, the return of status for this command takes in consideration only the following field:

- COT (Cause of Transmission), already previously explained for **Single Command**.

Counter Interrogation Command (C_CI_NA_1)

On RTU HD3002, this command affects all objects of information of type **Integrated Totals**

In sense of control, this command is composed by two fields:

- COT (Cause of Transmission), already previously explained for **Single Command**. Option **deactivation** is not considered, and an error should return to it
- QCC (Qualifier of Counter Interrogation Command), composed by two subfields:
    - RQT (6 bits): must be 5 (general request counter).
    - FRZ (2 bits):
        - 0: read (no freeze or reset)
        - 1: counter freeze without reset
        - 2: counter freeze with reset (not accepted by AL-3415)
        - 3: counter reset (not accepted by AL-3415)

ATTENTION: The frozen counters supports the freeze command only through the IEC104 and DNP3 protocol. Manual freezing commands are not supported (by the user application, for example).

In monitoring direction, the return of status for this command takes in consideration only the following field:

- COT (Cause of Transmission), already previously explained for **Single Command**. **Deactivation confirmation** does not exist.

Interrogation Command (C_IC_NA_1)

In HD3002 RTU, this command affects all of the information objects that can be monitored, except for objects of type **Integrated Totals** for which you use the Counter Interrogation Command.

Commands Received Through AL-3417 (DNP3 Protocol)

In this section, it is discussed the format of the DNP3 commands that can be received by AL-3417, and their respective return codes.

Control Relay Output Block (g12v1)

The object group 12 variation 1 is used to perform control operations on the digital outputs. Each G12v1object contains a block of information applicable to a single point DNP3 and can be used for the following functions:

- Function 3 - select
- Function 4 - operate
- Function 5 – direct
- Function 6 – direct without acknowledgement

The g12v1 object is composed by four fields described next.

- **Control Code (8 bits)**: this field is composed by four subgroups:
    - **Operation Type (OP TYPE – bits 0 to 3)**: is used in conjunction with the TCC field to specify the control operation. Values for this subfield are:
        - 0 = null
        - 1 = pulse on
        - 2 = pulse off
        - 3 = latch on
        - 4 = latch off
        - 5 to 15: undefined
    - **Queue (QU – bit 4)**: this subfield is obsolete and should always be zero. Commands sent with the value 1 in this subfield will not run and will be answered with the response code NOT_SUPPORTED.
    - **Clear (CR- bit 5)**: if this subfield is enabled, the command running to this point will be disabled.
    - **Trip/Close Code (TCC- bits 6 to 7)**: this subfield is used in conjunction with subfield OP TYPE to specify the control operation. Values for this subfield are:
        - 0 = null
        - 1 = close
        - 2 = trip
        - 3 = reserved.
- **Count (8 bits):** reports the number of times that the operation will be performed. This field must contain the value one, different values will be answered with the return code NOT_SUPPORTED.
- **OnTime (32 bits):** duration of pulse ON in milliseconds.
- **OffTime (32 bits):** duration of pulse OFF in milliseconds.
- **Status Code (7 bits):** This field is used only for replies, in requests is zero. The details of this field are described in subsection

Response Codes.

Analog Output Command (g41v1, g41v2 org41v3)

Objects of group 41 and variations 1 to 3 are used to perform control operations on analog outputs. Each g41v object contains a block of information applicable to a single DNP3 point and can be used for the following functions:

- Function 3 - select
- Function 4 - operate
- Function 5 – direct
- Function 6 – direct without acknowledgement

G41v* objects are composed by two fields described as follow:

- **Request Value:** contains the analog value to write in a point of AO type. The size field can vary depending on the variation, which can be:
    - **16 bits:** for variation 2
    - **32 bits:** for variations 1 and 3
- **Control Status (7 bits)**: this field is used only for replies, in requests of value zero. The details of this field are described in subsection *Response Codes*.

Response Codes

The response codes are used in the field Status Code (object g12v1) and Control Status (g41v* objects), when the frame is an answer one. The following table describes the value used in the field.

Identification	Value	Description	Comments
SUCCESS	**0**	Request accepted or started	Returned every time that the command was executed with success. Immediate commands for internal points, rack commands, MODBUS and digital outputs do not consider the quality value of the point. They return SUCCESS every time that the command is write on the respective point.
TIMEOUT	**1**	Request not accepted because the operate request (function 4) was received after the select time expired.	
NO_SELECT	**2**	Request not accepted because there was no previous select request (function 3)	
FORMAT_ERROR	**3**	Request not accepted because there are errors on the request format	It is not used by AL-3417.
NOT_SUPPORTED	**4**	Request not accepted because the operation is not supported for this point.	It is returned by AL-3417 when: - Receives one *Direct* or *DirectNoAck* command for a group of points with the *Select Required* option selected. - Receives one immediate command that the control of object g12v1 does not be *LatchOn* or *LatchOff.* - Receives a command for an object not listed on the interoperability table. - Receives a command for one point that is not configured for AL-3417.
ALREADY_ACTIVE	**5**	Request not accepted because the point is already in command.	It is not used by AL-3417.
HARDWARE_ERROR	**6**	Request not accepted because there are hardware problems.	It is returned by AL-3417 for buffered commands when: - Error in the command execution for an AL-3202 - Timeout on the command execution
LOCAL	**7**	Request not accepted because the Local/Remote switch is on Local position.	It is returned for immediate commands where the point have the quality indicating forced point: - DNP: bit 4 set - OPC: value equal to 216
TOO_MANY_OBJS	**8**	Request not accepted because the request have more than one object.	It is returned when there is a command for more than one point in the same request
OUT_OF_RANGE	**12**	Request not accepted because the value is out of range	It is returned for analog commands when the command value is out of range. For example, if the command value is an 32-bit integer of 40,000 and the point is 16-bit integer format. Values within the range of the points will be accepted.

Table B-1. Description of the response codes

ATTENTION:
Commands for DNP3 devices for which there is an internal error on the command processing will always return the code send by the slave device. The value of this code can even be different from the values described on the previous table.

ATTENTION:
Buffered commands for internal points for which there is an internal error on the command processing will always return the code send by the user. The value of this code can even be different from the values described on the previous table.

Format of P-BUFCMD.178 Input Command Buffers

In this section is described the format of the command buffers that are used as input for P-BUFCMD.178, which are the following:

- 1 Input User Command Buffer
- 8 Command Buffers for AL-3415/17

The format of the P-BUFCMD.178 input buffers was already partially described on the section *Format of Input User Command Buffer*. *Even this description* was made for the Input User Command Buffer, the format for the AL-3415/17 buffers is identical.

On the following sections, it is presented the complementary information about the format of these buffers, which were not provided previously.

These buffers are composed by 20 %M operands:

- The first 15 operands are the *Command Write Area*, which is written by the command source (user application or AL-3415/17 module), and it is read by P-BUFCMD.178.
- The last 5 operands are the *Command Read Area*, which is read by the command source (user application or AL-3415/17 module), and it is written by P-BUFCMD.178.

The command write area (15 %M operands) is divided into two sub-areas:

- The first 3 %M operands (BUSY, SOURCE, DESTINATION) were already described on the section *Format of Input User Command Buffer*.
- The last 12 %M operands (COMMAND DESCRIPTION) will be described on the following sections. It must be careful with the indexing of these 12 operands (numerated from 0 to 11), because the operand 0 of the command description area corresponds, actually, to the operand 3 of the command write area.

The command read area (5 %M operands) is divided into two sub-areas:

- The first %M operand (FINAL) was already described on the section *Format of Input User Command Buffer*.
- The last 4 %M operands (STATUS) are described on the following sections. It must be careful with the indexing of these 4 operands (numerated from 0 to 3), because the operand 0 of the status area corresponds, actually, to the operand 1 of the command read area.

Input User Command Buffer

Through this buffer, the user application on P-CICUSR.170 can send buffered commands to the following type of points:

- Commands for bytes of AL-3202 in mode trip/close
- Commands for serial DNP3 IEDs

Also, it is possible to send buffered commands to the user application, destined to the output user command buffer. However, this situation makes no sense, since the user application would be sending a command for itself.

The objective of this section is to describe the format of the 12 %M Command Descriptor operands (the last 12 %M operands inside the 15 %M operands of the command write area), and also the

format of the 4 %M status operands (the last 4 %M operands inside the 5 % operands of command read area).

As already previously discussed, the module P-BUFCMD.178 never executes a conversion on command buffers, neither when it passes the write area of a input buffer to an output buffer, nor when it passes the read area of an output buffer to an input buffer.

Therefore, the format of an input buffer of P-BUFCMD.178 must be identical to the format of the output buffer for which the command will be passed. For this reason, to find out the format of the 12 %M command descriptor operands and of 4 %M status operands, the user must consult the following subsections, according to the output buffer that he wants to use:

- AL-3202 Command Buffer (Main and Expansion Racks)
- Serial DNP3 IED Command Buffer

AL-3415/17 Command Buffer

Through these buffers, a AL-3415/17 module can send buffered commands for the following type of points:

- Commands for bytes of AL-3202 in mode trip/close
- Commands executed by the user application on module P-CICUSR.170, mapped over internal points.
- Commands for serial DNP3 IEDs

The format of a AL-3415/17 command buffer is identical to the format of an input user command buffer, described on the previous section.

Again, the format of the P-BUFCMD.178 input buffers must be identical to the format of the output buffer for which the command will be passed. For this reason, to find out the format of the 12 %M command descriptor operands and of 4 %M status operands, the user must consult the following subsections, according to the output buffer that he wants to use:

- AL-3202 Command Buffer (Main and Expansion Racks)
- Output User Command Buffer
- Serial DNP3 IED Command Buffer

Format of P-BUFCMD.178 Output Command Buffers

AL-3202 Command Buffer (Main and Expansion Racks)

First, remember that there are 5 command buffers to AL-3202 modules, each one reserved for a rack (main and expansion racks 0 to 3).

The **Command Description Area** of each buffer, which has 12 operands %M reserved for you, uses only 3 operands %M (the first 3), with the following format:

- Operand 0 = command type:
  - 29: select trip
  - 31: select close
  - 33: operate trip
  - 35: operate close
  - 37: cancels (cancels a select, or closes long pulses of trip / close already running) cancels (canceling a select, closed or long pulses of trip / close already running)
- Operand 1 = specification of the point that receives the command, and is calculated by the equation **"position byte * 64 + * 8 + point"**, where:
  - position = position where the AL-3202 is (0 to 15)
  - byte = byte within the AL-3202 where the point (0 to 3)
  - point = point (double) in the byte of the AL-3202 (0 to 3)
- Operand 2 = time of pulse duration in hundredths of seconds, varying between 2 (0.02 s) and 16383 (163.83 s).

The **Status Command Area** of each buffer, which has 4 operands %M reserved for you, uses only 1 operand %M (the first), with the following format:

Errors in module AL-3202																Mnemonic	Description
15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**		
1														1		Nc	Indicates that the AL-3202 was not configured (internal error)
1													1			Fo	Indicates that the lack of 24 Vdc in AL-3202 module
1												1				Sc	The AL-3202 card has received a command "trip" or "close" in 6 or 7 mode, without having received "select".
1											1					Co	The AL-3202 card has received a command that is inconsistent with the configuration.
1										1						Sa	Indicates output (s) in error on the AL-3202 card. This error is determined by the HW board. Positions 1 and 2 indicate that the diagnostic (s) point (s) in error.
1									1							Oc	IAL-3202 is busy (the module can stay busy for a few seconds during startup)
1							1									In	AL-3202 is declared but is not present on the bus (or is faulty)
X	0	0	0	0	0	0		0							0		Always zero

Table B-2. Errors in AL-3202 module

Output User Command Buffer

This buffer is treated by the user application (P-CICUSR.170), which decodes and executes the received commands. The commands are associated to DO or AO type internal points, with N data format (does not allocate memory).

The **Command Description Area** of each buffer, which have 12 %M operands reserved for its use, uses at maximum 10 %M operands (the first 10), with the following format:

- Operand 0 = address of the point (e.g.: 531, if the command was for DO or AO 0531)
- Operand 1 = type of the command object, which can be:
    - 12 = digital command (DO)
    - 41 = analog command (AO)
- Operand 2 = variation of the command object, which depends on the object type:
    - For type 12 (DO), it can be only 1 (one variation only)
    - For type 41 (AO), it can be:
        - 1 = 32-bit integer setpoint
        - 2 = 16-bit integer setpoint
        - 3 = 32-bit floating point setpoint
- Operand 3 = command type:
    - 0 = select command
    - 1 = operate command
    - 2 = direct command
    - 3 = direct command without ack

The following operands depends on the type and variation of the command object:

- Type 12 and Variation 1 (DO):
    - Operand 4 = **control code**, divided on the following bit subfields:
        - Code (bits 0 to 3), which can be:
            - 1 = pulse on
            - 2 = pulse off
            - 3 = latch on
            - 4 = latch off
        - Trip/Close (bits 6 and 7), which can be:
            - 0 = NUL (for points other than the trip/close)
            - 1 = close
            - 2 = trip
        - The other bits of the operand 4 must be zero
    - Operand 5 = **count**, which can be between 0 and 255. Indicate the number of pulses. For single pulses (which is the case of the major part of commands), it can be used values 0 or 1.
    - Operand 6 = least significant part of “On Time”, or the duration of the on pulse, in ms.
    - Operand 7 = most significant part of “On Time”, or the duration of the on pulse, in ms.
    - Operand 8 = least significant part of “Off Time”, or the duration of the off pulse, in ms.
    - Operand 9 = most significant part of “off Time”, or the duration of the off pulse, in ms.
- Type 41 e Variations 1 and 3 (32-bit AO – integer or floating point):
    - Operand 4 = least significant part of the value assigned to the set point
    - Operand 5 = most significant part of the value assigned to the set point
- Type 41 e Variation 2 (16-bit AO - Integer):
    - Operand 4 = value assigned to the set point

The **Command Status Area** of each buffer, which have 4 %M operands reserved for its use, use only 1 %M operand (the first one):

Operand 0: response code. Use the same codes returned by the slave DNP3device according to what is described on *Table B-1. Description of the response codes.*

ATTENTION: The current revision of AL-3415 module does not generates commands destined to the **Output User Command Buffer**, which must be executed by the user application. At the moment, only the AL-3417 module have this functionality.

Serial DNP3 IED Command Buffer

First, remember that there are 8 command buffers for serial DNP3 IEDs, each one reserved for an AL-2005 installed in the position "i" (i in 0 ... 7) of the main rack.

The **Command Description Area** of each buffer, which has 12 operands %M reserved for its use, uses no more than 10 operands %M (first 10), with the following format:

- Operand 0 = point address (e.g. for the DO0531 the address is 531)
- Operand 1 = type of command object, which can be:
    - 12 = control relay output block
    - 41 = analog output block
- Operand 2 = variation of command object, which depends on the type of object:
    - For the type 12 (control relay output block), it may be only 1.
    - For the type 41 (analog output block), it may be:
        - 1 = 32-bit Analog Output Block
        - 2 = 16-bit Analog Output Block
- Operand 3 = command type
    - 0 = select command
    - 1 = Operate command
    - 2 = Direct command
    - 3 = Direct command without ack

The following operands depend on the type and variation of the command object:

- Type 12 and Variation 1 (Control Relay Output Block):
    - Operand 4= **control code** divided into the following subfields:
        - Code (bits 0 to 3), which can be:
            - 1 = pulse on
            - 2 = pulse off
            - 3 = latch on
            - 4 = latch off
        - Trip/Close (bits 6 and 7), which can be:
            - 0 = NUL (for points other than the trip/close)
            - 1 = close
            - 2 = trip
        - the other 4 bits of the operand must be zero
    - Operand 5 = **count**, which can be between 0 and 255. Indicate the number of pulses. For single pulses (which is the case of the major part of commands), it can be used values 0 or 1.
    - Operand 6 = least significant part of "On Time", or the duration of the on pulse, in ms.
    - Operand 7 = most significant part of "On Time", or the duration of the on pulse, in ms.

  - Operand 8 = least significant part of "Off Time", or the duration of the off pulse, in ms.
  - Operand 9 = most significant part of "off Time", or the duration of the off pulse, in ms.
- Type 41 and Variation 1 (32-bit Analog Output Block)
  - Operand 4 = least significant part of the value assigned to the set point
  - Operand 5 = most significant part of the value assigned to the set point
- Type 41 and Variation 2 (16-bit Analog Output Block)
  - Operand 4 = value assigned to the set point

The **Command Status Area** of each buffer, which has 4 operands %M reserved for its use, uses only 1 operand %M (the first), which can be:

- Operand 0: execution status of the command sent by AL-2743 serial DNP3 master driver
  - 0: no command in execution
  - 1: the command is in execution
  - 2: command successfully executed
  - 3: command executed with error: failure in point selection
  - 4: command executed with error: failure in the point operation
  - 5: command executed with error: timeout in communication with the slave device
  - 6: command executed with error: point does not exist in the slave device
  - 10: command error: point not configured in the driver (the address configured in position 0 of the **Command Description Area** is invalid)
  - 11: command error: invalid type of command
  - 12: command error: type of point is invalid
  - 13: command error: timeout in the select/operate command
- Operand 1: response code of slave DNP3 device according to the described on ***Table B-1. Description of the response codes***.

Conversions Performed by AL-3415

The AL-3415 module is responsible for converting the commands received from IEC104 masters, and the status returned to such masters, related to the following types of commands:

- Immediate Command:
  - over internal points of the AL-2004
  - over latched bytes of AL-3202 modules
  - over IEDs MODBUS RTU
  - over IEDs MODBUS TCP
- Buffered commands:
  - over bytes trip/close de AL-3202 modules
  - over serial IEDs DNP3

Following, each of the previous conversions is analyzed.

AL-3415 Conversions for Immediate Commands over Internal Points of AL-2004

To perform an immediate command of this type, the AL-3415 performs reads and/or writes directly over operands of AL-2004. The write operands are basically dependent on the command received from the IEC104 client, as is described below:

- **Single Command (C_SC_NA_1**): It consists of writing to a bit of operand %M, corresponding to the DO point, variation D1Q*, associated with the IEC104 information object. The QU field must specify necessarily persistent output (QU = 3) or without additional definition (QU = 0), otherwise the AL-3415 will return with error status (P/N = 1).

- **Double Command (C_DC_NA_1)**: It consists of writing to two bits of operand %M, corresponding to the DO point with D2Q* variation, associated with the IEC104 information object. The QU field must specify necessarily persistent output (QU = 3) or without additional definition (QU = 0), otherwise AL-3415 will return with error status (P/N = 1).
- **Regulating Step Command (C_RC_NA_1)**: It consists of writing to eight bits of operand %M, corresponding to the DO point with D8Q* variation, associated with the IEC104 information object. The QU field must specify necessarily persistent output (QU = 3) or without additional definition (QU = 0), otherwise AL-3415 will return with error status (P/N = 1).
- **Set-point Command, Normalized Value (C_SE_NA_1):** It consists of writing to an operand %M, corresponding to the AO point, variation I16Q *, associated with the IEC104 information object
- **Set-point command, Scaled Value (C_SE_NB_1)**: It consists of writing to an operand %M, corresponding to the AO point, variation I16Q *, associated with the IEC104 information object.
- **Set-point command, Short Floating Point Value (C_SE_NC_1)**: It consists of writing to an operand %F, corresponding to the AO point, variation F32Q *, associated with the IEC104 information object.
- **Counter Interrogation Command (C_CI_NA_1)**: This command affects several operands %I associated with all points of the type CN, variation I32Q * and/or FC variation I32Q *, which is mapped to IEC104 objects of type Integrated Totals. The field FRZ must be decoded to find the necessary actions, which may be:
    - Freeze: copy all points of the CN type to the corresponding points of the FC type.
    - Reset: reset all the points of CN type (before this, execute the freeze, if also specified).

If all the readings and writings related to the execution of the command have been made successfully, it must be returned the status of the command with "activation confirmation" and with the bit P/N = 0 (positive confirmation). Otherwise, it must be returned the status of the command with "activation confirmation" and with the bit P/N = 1 (negative confirmation).

The above considerations apply to **execute** operations. For **select** operations, it is immediately returned a status of command with "activation confirmation" with the bit P/N = 0 (positive confirmation), and CPU memory of the AL-2004 is not accessed.

AL-3415 Conversions for Immediate Commands over Latched Bytes of AL-3202

This case applies only to commands like Single Command (C_SC_NA_1), which has some restrictions:

- The QU field must be 0 (no additional definition) or 3 (persistent output), otherwise the AL-3415 will return error (P/N = 1).

To perform an immediate command of this type, AL-3415 will perform the following actions:

1. Check the quality of the associated DO point. If ok, the command is executed as described in the following items. Otherwise, the command is terminated and command status is returned with the "activation confirmation" and the bit P/N = 1 (negative confirmation).
2. Write the value to the bit of operand %M associated with the DO.
3. If the write was successful, it must be returned the status of the command with "activation confirmation" with the bit P/N = 0 (positive confirmation). Otherwise, it returns the status of the command with "activation confirmation" and the bit P/N = 1 (negative confirmation).

The above considerations apply to **execute** operations. For **select** operations, it is executed only the step 1.

AL-3415 Conversions for Immediate Commands over IEDs MODBUS RTU or TCP

This case applies only to commands of the types:

- Single Command (C_SC_NA_1), associated to DO points with variation D1QC
- Double Command (C_DC_NA_1), associated to DO points with variation D2QC
- Regulating Step Command (C_RC_NA_1), D8QC associated to DO points with variation D8QC
- Set-point Command, Normalized Value (C_SE_NA_1), associated to points with variation I16QC
- Set-point Command, Scaled Value (C_SE_NB_1), associated to AO points with variation I16QC
- Set-point Command, Short Floating Point Value (C_SE_NC_1), associated to AO points with variation F32QC

Therefore, it is supported almost the same commands for internal points of the AL-2004, except for commands with counters (CN or FC).

The execution of these commands is also almost equal to that used for internal points of the AL-2004, with one difference, which is an additional step, performed at the beginning of the process.

Before starting the execution of the command, the AL-3415 reads the quality of the affected point (DO or AO), which shall be of the QC (common quality) and report failure to communicate with the IED. If the quality is good, normal execution continues in a similar manner to what is done with internal points of the AL-2004. However, if the quality is not good, the command is aborted, and returns the command with the status "activation confirmation" and the bit P/N = 1 (negative confirmation).

The above considerations apply to **execute** operations. For **select** operations, it is only executed the quality check. If this check finds that the quality is good, the command returns immediately with the status "activation confirmation" and the bit P/N = 0.

AL-3415 Conversions for Buffered Commands over Trip/Close Bytes of AL-3202

This case applies only to commands of type Double Command (C_DC_NA_1) associated to a DO point with variation NQC, which is automatically associated by MasterTool Hadron XE for the 4 points of a AL-3202 byte in trip/close mode.

To decide which buffer AL-3202 is going to write the command, it is considered the rack where it is.

The Double Command command must be translated into a buffer from the following sub-fields:

- If COT is **deactivation**, the operand 0 of AL-3202 must specify a “cancel”.

The following considerations are used when COT is **activation**:

- Operand 0 of the AL-3202 is calculated in function of DCS and S/E:
    - DCS:
        - OFF is translated to trip
        - ON is translated to close
        - other values are illegal, returning the error code (P/N = 1).
    - S/E is translated to select or operate
- The operand 1 depends only on the location of the AL-3202 point (position, byte, point)
- The operand 2 is calculated according to the field QU:
    - the value 0 (no additional definition) is considered equivalent to a pulse of short duration, which uses the short duration time defined for this AL-3415
    - the value 1 (short pulse duration) uses the short pulse duration time defined for this AL-3415
    - the value 2 (long pulse duration) uses the long pulse duration time defined for this AL-3415

- any other values cannot be accepted, and returns error code (P/N = 1)

After the end of the command, the status return must have P/N = 1 in case of error, which occurs when the bit 15 of the status operand 0 is different of 0.

AL-3415 Conversions for Buffered Commands over Serial DNP3 IEDs

This case applies only to commands of the types:

- Single Command (C_SC_NA_1), associated to DO points with variation D1QC
- Double Command (C_DC_NA_1), associated to DO points with variation NQC
- Set-point Command, Scaled Value (C_SE_NB_1), associated to AO points with variation I16QC

Conversions Executed by AL-3417

The AL-3417 module is responsible for converting the commands received from Ethernet DNP3 masters, and the status returned to such masters, related to the following types of commands:

- Immediate commands:
  - over internal points of the AL-2004
  - over bytes latched of AL-3202 module
  - over MODBUS RTU IEDs RTU
  - over IEDs MODBUS TCP
- Buffered commands:
  - over trip/close bytes of AL-3202 modules
  - over internal points of AL-2004
  - over serial DNP3IEDs

The following table details the DNP3 commands supported for digital outputs via the DNP3 g12v1object. Received commands that are not listed in this table will not be executed, returning the response code NOT_SUPPORT.

Hadron RTU Point		DNP3 Command					Action
Type	Destinations	OP TYPE	QU	CR	TCC	Count	
DOD1	Internal AL-3202 latched IEDs MODBUS	Null	0	0	Latch on	1	Turns the point on
		Null	0	0	Latch off	1	Turns the point off
DON	AL-3202 trip/close IEDs DNP3 serial	Close	0	0	Pulse on	1	Executes the close command to the point, using the time configured in OnTime. The time set in Off time is ignored.
		Trip	0	0	Pulse on	1	Executes the trip command to the point, using the time set in OnTime. The time set in Offtime is ignored.
		Close	0	1	Pulse on	1	Cancels the close command to the point. Times OnTime and Offtime are ignored.
		Trip	0	1	Pulse on	1	Cancels the trip command to the point. Times OnTime and Offtime are ignored.

Table B-3. Command for the g12v1object supported by AL-3417

The following table describes the DNP3 commands supported for analog outputs through DNP3 objects g41v1, g41v2 and g41v3. Received commands that are not listed in this table will not be executed, returning the response code NOT_SUPPORT.

Hadron RTU Point		DNP3 Object	Action
Destination	Type		
Internal Points	AOI16	Object g41v2 – 16 bits	Write the received 16-bit value to the AO point
	AOUI16		
	AOI32	Object g41v1 – 32 bits	Write the received 32-bit value to the AO point
	AOUI32		
	AOF32	Object g41v3 – floating point	Write the received floating point value to the AO point
Serial DNP3 IEDs	AON	Object g41v1 – 32 bits Object g41v2 – 16 bits Object g41v3 – floating point	Write the command to the AL-3417 command buffer.

Table B-4. Commands for the g41v* object supported by AL-3417

Annex C. IEC 60870-5-104 Interoperability

This chapter describes the implementation of the IEC 60870-5-104 protocol for HD3002 RTUs, providing the information necessary for communication with other equipment through this protocol.

The selected parameters should be marked in the white boxes as follows:

	Function or ASDU is not used
X	Function or ASDU is used as standardized (default)
■	Function or ASDU do not allow by standard

System or device

(system-specific parameter, indicate the station's function by marking one of the following with '**X**')

	System definition
	Controlling station definition (Master)
X	Controlled station definition (Slave)

Network configuration

(Not applicable)

Physical layer

(Not applicable)

Link layer

(Not applicable)

Application layer

Transmission mode for application data

Mode 1 (Least significant byte first), as defined in clause 4.10 of IEC 60870-5-4, is used exclusively in this companion standard.

Common address of ASDU

(System-specific parameter, all configurations that are used are to be marked '**X**')

X	Two bytes

Information object address

(System-specific parameter, all configurations that are used are to be marked '**X**')

	Structured
X	Unstructured

X	Three bytes

Cause of transmission

(System-specific parameter, all configurations that are used are to be marked '**X**')

X	Two bytes (with originator address) Originator address is set to zero if not used

Length of APDU

(System-specific parameter, specify the maximum length of the APDU per system)

The maximum length of the APDU is 253 (default)

Selection of standard ASDUs

Process information in monitor direction

(station-specific parameter, mark each Type ID '**X**' if it is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

X	<1>	Single-point information	M_SP_NA_1
X	<3>	Double-point information	M_DP_NA_1
X	<5>	Step position information	M_ST_NA_1
	<7>	Bitstring of 32 bit	M_BO_NA_1
X	<9>	Measured value, normalized value	M_ME_NA_1
X	<11>	Measured value, scaled value	M_ME_NB_1
X	<13>	Measured value, short floating point value	M_ME_NC_1
X	<15>	Integrated totals	M_IT_NA_1
	<20>	Packed single-point information with status change detection	M_SP_NA_1
	<21>	Measured value, normalized value without quality descriptor	M_ME_ND_1
X	<30>	Single-point information with time tag PLC56Time2a	M_SP_TB_1
X	<31>	Double-point information with time tag PLC56Time2a	M_DP_TB_1
X	<32>	Step position information with time tag PLC56Time2a	M_ST_TB_1
	<33>	Bitstring of 32 bit with time tag PLC56Time2a	M_BO_TB_1
X	<34>	Measured value, normalized value with time tag PLC56Time2a	M_ME_TD_1
X	<35>	Measured value, scaled value with time tag PLC56Time2a	M_ME_TE_1
X	<36>	Measured value, short floating point value with time tag PLC56Time2a	M_ME_TF_1
X	<37>	Integrated totals with time tag PLC56Time2a	M_IT_TB_1
	<38>	Event of protection equipment with time tag PLC56Time2a	M_EP_TD_1
	<39>	Packed start events of protection equipment with time tag PLC56Time2a	M_EP_TE_1
	<40>	Packed output circuit information of protection equipment with time tag PLC56Time2a	M_EP_TF_1

Process information in control direction

(station-specific parameter, mark each Type ID '**X**' if it is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

X	<45>	Single command	C_SC_NA_1
X	<46>	Double command	C_DC_NA_1
X	<47>	Regulating step command	C_RC_NA_1
X	<48>	Set point command, normalized value	C_SE_NA_1
X	<49>	Set point command, scaled value	C_SE_NB_1
X	<50>	Set point command, short floating point value	C_SE_NC_1
	<51>	Bitstring of 32 bit	C_BO_NA_1
	<58>	Single command with time tag PLC56Time 2a	C_SC_TA_1
	<59>	Double command with time tag PLC56Time 2a	C_DC_TA_1
	<60>	Regulating step command with time tag PLC56Time 2a	C_RC_TA_1
	<61>	Set point command, normalized value with time tag PLC56Time 2a	C_SE_TA_1
	<62>	Set point command, scaled value with time tag PLC56Time 2a	C_SE_TB_1
	<63>	Set point command, short floating point value with time tag PLC56Time 2a	C_SE_TC_1
	<64>	Bitstring of 32 bit with time tag PLC56Time 2a	C_BO_TA_1

System information in monitor direction

(station-specific parameter, mark '**X**' if used)

X	<70>	Single command	M_EI_NA_1

System information in control direction

(station-specific parameter, mark each Type ID '**X**' if it is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

X	<100>	Interrogation command	C_IC_NA_1
X	<101>	Counter interrogation command	C_CI_NA_1
	<102>	Read command	C_RD_NA_1
	<103>	Clock synchronization command (option see 7.6)	C_CS_NA_1
	<104>	Reset process command	C_RP_NA_1
	<105>	Test command with time tag PLC56time2a	C_TS_TA_1

Parameter in control direction

(station-specific parameter, mark each Type ID '**X**' if it is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

	<110>	Parameter of measured value, normalized value	P_ME_NA_1
	<111>	Parameter of measured value, scaled value	P_ME_NB_1
	<112>	Parameter of measured value, short floating point value	P_ME_NC_1
	<113>	Parameter activation	P_AC_NA_1

File Transfer

(station-specific parameter, mark each Type ID '**X**' if it is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

	<120>	File ready	F_FR_NA_1
	<121>	Section ready	F_SR_NA_1
	<122>	Call directory, select file, call file, call section	F_SC_NA_1
	<123>	Last section, last segment	F_LS_NA_1
	<124>	Ack file, ack section	F_AF_NA_1
	<125>	Segment	F_SG_NA_1
	<126>	Directory {blank or X, only available in monitor (standard) direction}	F_DR_TA_1

Type identifier and cause of transmission assignments

(station-specific parameters)

Shaded boxes are not required.

Black boxes are not permitted in this companion standard

Blank: functions or ASDU not used.

Mark Type Identification/Cause of transmission combinations:

'**X**' if only used in the standard direction

'**R**' if only used in the reverse direction

'**B**' if used in both directions

Type identification		Cause of transmission																		
		periodic, cyclic	background scan	spontaneous	initialized	request or requested	activation	activation confirmation	deactivation	deactivation confirmation	activation termination	return info caused by a remote cmd	return info caused by a local cmd	file transfer	interrogated by group <number>	request by group <n> counter request	unknown type identification	unknown cause of transmission	unknown common address of ASDU	unknown information object address
		1	2	3	4	5	6	7	8	9	10	11	12	13	20 to 36	37 to 41	44	45	46	47
<1>	M_SP_NA_1														X					
<3>	M_DP_NA_1														X					
<5>	M_ST_NA_1														X					
<7>	M_BO_NA_1																			
<9>	M_ME_NA_1														X					
<11>	M_ME_NB_1														X					
<13>	M_ME_NC_1														X					
<15>	M_IT_NA_1															X				
<20>	M_PS_NA_1																			
<21>	M_ME_ND_1																			
<30>	M_SP_TB_1			X																
<31>	M_DP_TB_1			X																
<32>	M_ST_TB_1			X																
<33>	M_BO_TB_1																			
<34>	M_ME_TD_1			X																
<35>	M_ME_TE_1			X																
<36>	M_ME_TF_1			X																
<37>	M_IT_TB_1			X																
<38>	M_EP_TD_1																			
<39>	M_EP_TE_1																			

Type identification		Cause of transmission																		
		periodic, cyclic	background scan	spontaneous	initialized	request or requested	activation	activation confirmation	deactivation	deactivation confirmation	activation termination	return info caused by a remote cmd	return info caused by a local cmd	file transfer	interrogated by group <number>	request by group <n> counter request	unknown type identification	unknown cause of transmission	unknown common address of ASDU	unknown information object address
		1	2	3	4	5	6	7	8	9	10	11	12	13	20 to 36	37 to 41	44	45	46	47
<40>	M_EP_TF_1																			
<45>	C_SC_NA_1							X		X	X						X	X	X	X
<46>	C_DC_NA_1							X		X	X						X	X	X	X
<47>	C_RC_NA_1							X		X	X						X	X	X	X
<48>	C_SE_NA_1							X		X	X						X	X	X	X
<49>	C_SE_NB_1							X		X	X						X	X	X	X
<50>	C_SE_NC_1							X		X	X						X	X	X	X
<51>	C_BO_NA_1																			
<58>	C_SC_TA_1																			
<59>	C_DC_TA_1																			
<60>	C_RC_TA_1																			
<61>	C_SE_TA_1																			
<62>	C_SE_TB_1																			
<63>	C_SE_TC_1																			
<64>	C_BO_TA_1																			
<70>	M_EI_NA_1*				X															
<100>	C_IC_NA_1							X		X	X						X	X	X	X
<101>	C_CI_NA_1							X			X						X	X	X	X
<102>	C_RD_NA_1																			
<103>	C_CS_NA_1																			
<105>	C_RP_NA_1																			
<107>	C_TS_TA_1																			
<110>	P_ME_NA_1																			
<111>	P_ME_NB_1																			
<112>	P_ME_NC_1																			
<113>	P_AC_NA_1																			
<120>	F_FR_NA_1																			
<121>	F_SR_NA_1																			
<122>	F_SC_NA_1																			
<123>	F_LS_NA_1																			
<124>	F_AF_NA_1																			
<125>	F_SG_NA_1																			
<126>	F_DR_TA_1*																			

Type identification	Cause of transmission																		
	periodic, cyclic	background scan	spontaneous	initialized	request or requested	activation	activation confirmation	deactivation	deactivation confirmation	activation termination	return info caused by a remote cmd	return info caused by a local cmd	file transfer	interrogated by group <number>	request by group <n> counter request	unknown type identification	unknown cause of transmission	unknown common address of ASDU	unknown information object address
	1	2	3	4	5	6	7	8	9	10	11	12	13	20 to 36	37 to 41	44	45	46	47
* Blank or X only																			

Basic application functions

Station initialization

(station-specific parameter, mark '**X**' if function is used)

☐ Remote initialization

Cyclic data transmission

(station-specific parameter, mark '**X**' if function is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

☐ Cyclic data transmission

Read procedure

(station-specific parameter, mark '**X**' if function is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

☐ Read procedure

Spontaneous transmission

(station-specific parameter, mark '**X**' if function is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

☒ Spontaneous transmission

Double transmission of information objects with cause of transmission spontaneous

(station-specific parameter, mark each information type '**X**' where both a Type ID without time and corresponding Type ID with time are issued in response to a single spontaneous change of a monitored object)

The following type identifications may be transmitted in succession caused by a single status change of an information object. The particular information object addresses for which double transmission is enabled are defined in a project-specific list.

☐ Single-point information M_SP_NA_1, M_SP_TA_1, M_SP_TB_1 and M_PS_NA_1
☐ Double-point information M_DP_NA_1, M_DP_TA_1 and M_DP_TB_1
☐ Step position information M_ST_NA_1, M_ST_TA_1 and M_ST_TB_1

☐	Bitstring of 32 bit M_BO_NA_1, M_BO_TA_1 and M_BO_TB_1 (if defined for a specific project)
☐	Measured value, normalized value M_ME_NA_1, M_ME_TA_1, M_ME_ND_1 and M_ME_TD_1
☐	Measured value, scaled value M_ME_NB_1, M_ME_TB_1 and M_ME_TE_1
☐	Measured value, short floating point number M_ME_NC_1, M_ME_TC_1 and M_ME_TF_1

Station interrogation

(station-specific parameter, mark '**X**' if function is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

X	global				
☐	group 1	☐	group 7	☐	group 13
☐	group 2	☐	group 8	☐	group 14
☐	group 3	☐	group 9	☐	group 15
☐	group 4	☐	group 10	☐	group 16
☐	group 5	☐	group 11		
☐	group 6	☐	group 12		

Clock synchronization

(station-specific parameter, mark '**X**' if function is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

	Clock synchronization

Command transmission

(station-specific parameter, mark '**X**' if function is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

X	Direct command transmission
X	Direct set point command transmission
X	Select and execute command
X	Select and execute set point command
	C_SE ACTTERM used
X	No additional definition
X	Short pulse duration (duration determined by a system parameter in the outstation)
X	Long pulse duration (duration determined by a system parameter in the outstation)
X	Persistent output
	Supervision of maximum delay in command direction of commands and set point commands

Configurable	Maximum allowable delay of commands and set point commands

Transmission of integrated totals

(station-specific parameter, mark '**X**' if function is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

	Mode A: Local freeze with spontaneous transmission
X	Mode B: Local freeze with counter interrogation
	Mode C: Freeze and transmit by counter-interrogation commands
	Mode D: Freeze by counter-interrogation command, frozen values reported spontaneously
	Counter read
	Counter freeze with reset
	Counter freeze without reset
	Counter reset

X	General request counter
	Request counter group 1
	Request counter group 2
	Request counter group 3
	Request counter group 4

Parameter loading

(station-specific parameter, mark '**X**' if function is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

	Threshold value
	Smoothing factor
	Low limit for transmission of measured values
	High limit for transmission of measured values

Parameter activation

(station-specific parameter, mark '**X**' if function is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

☐ Act/deact of persistent cyclic or periodic transmission of the addressed object

Test procedure

(station-specific parameter, mark '**X**' if function is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

☒ Test procedure

File transfer

(station-specific parameter, mark '**X**' if function is used)

File transfer in monitor direction

☐ Transparent file
☐ Transmission of disturbance data of protection equipment
☐ Transmission of sequences of events
☐ Transmission of sequences of recorded analog values

File transfer in control direction

☐ Transparent file

Background scan

(station-specific parameter, mark '**X**' if function is only used in the standard direction, '**R**' if only used in the reverse direction, and '**B**' if used in both directions)

☐ Background scan

Acquisition of transmission delay

(Not applicable)

Definition of time-outs

Parameter	Default value	Remarks	Selected value
t_0	30s	Time-out of connection establishment	**Not Applicable**
t_1	15s	Time-out of send or test APDUs	**Configurable**
t_2	10s	Time-out for acknowledges in case of no data messages $t_2 < t_1$	**Configurable**
t_3	20s	Time-out for sending test frames in case of a long idle state	**Configurable**

Maximum range of values for all time outs: 1 to 255 s, accuracy 1 s

Maximum number of outstanding I format APDUs k and latest acknowledge APDUs (w)

Parameter	Default value	Remarks	Selected value
k	12 APDUs	Maximum difference receive sequence number to send state variable	**Configurable**
w	8 APDUs	Latest acknowledge after receiving w I-format APDUs	**Configurable**

Maximum range of values k: 1 to 32767 (2^{15}-1) APDUs, accuracy 1 APDU

Maximum range of values w: 1 to 32767 APDUs, accuracy 1 APDU (Recommendation: w should not exceed two-thirds of k).

Portnumber

Parameter	Default Value	Remarks	Selected Value
Portnumber	2404		**Configurable**

RFC 2200 suite

RFC 2200 is an official Internet Standard which describes the state of standardization of protocols used in the Internet as determined by the Internet Architecture Board (IAB). It offers a broad spectrum of actual standards used in the Internet. The suitable selection of documents from RFC 2200 defined in this standard for given projects has to be chosen by the user of this standard.

X	Ethernet 802.3
	Serial X.21 interface
	Other selection from RFC 2200:

Annex D. DNP3 Interoperability

This chapter describes the implementation of the DNP3 protocol for HD3002 RTUs, providing the information necessary for communication with other equipment through this protocol.

DNP3 Device Profile

<table>
<tr><td colspan="2">DNP3
DEVICE PROFILE DOCUMENT</td></tr>
<tr><td colspan="2">Vendor Name: Altus S/A</td></tr>
<tr><td colspan="2">Device Name: AL-3417</td></tr>
<tr><td>Highest DNP Level Supported:

For Requests: Level 3+
For Responses: Level 3+</td><td>Device Function:

☐ Master
☒ Slave</td></tr>
<tr><td colspan="2">For static (non-change-event) object requests, request qualifier codes 07 and 08 (limited quantity), and 17 and 28 (index) are supported. Static object requests sent with qualifiers 07, or 08, will be responded with qualifiers 00 or 01.

16-bit, 32-bit and Floating Point Analog Change Events with Time may be requested.
Floating Point Analog Output Status and Output Block Objects 40 and 41 are supported.</td></tr>
<tr><td>Maximum Data Link Frame Size (octets):

Transmitted: 292
Received 292</td><td>Maximum Application Fragment Size (octets):

Transmitted: 249
Received 2048</td></tr>
<tr><td>Maximum Data Link Re-tries:

☐ None
☐ Fixed
☒ Configurable from 0 to 10</td><td>Maximum Application Layer Re-tries:

☒ None
☐ Configurable</td></tr>
<tr><td colspan="2">Requires Data Link Layer Confirmation:

☐ Never
☐ Always
☐ Sometimes
☒ Configurable as: Never, Only for multi-frame messages, or Always</td></tr>
<tr><td colspan="2">Requires Application Layer Confirmation:

☐ Never
☐ Always
☒ When reporting Event Data
☒ When sending multi-fragment responses
☐ Sometimes
☐ Configurable as: “Only when reporting event data”, or “When reporting event data or multi-fragment messages.”</td></tr>
</table>

Timeouts while waiting for:

Data Link Confirm:	☐	None	☐	Fixed at ____	☐	Variable	☒	Configurable.
Complete Appl. Fragment:	☒	None	☐	Fixed at ____	☐	Variable	☐	Configurable.
Application Confirm:	☐	None	☐	Fixed at ____	☐	Variable	☒	Configurable.
Complete Appl. Response:	☒	None	☐	Fixed at ____	☐	Variable	☐	Configurable

Others:

Select/Operate Arm Timeout, configurable
Need Time Interval, configurable
Unsolicited Notification Delay, configurable
Unsolicited Response Retry Delay, configurable
Unsolicited Offline Interval, configurable

Sends/Executes Control Operations:

WRITE Binary Outputs	☒	Never	☐	Always	☐	Sometimes	☐ Configurable
SELECT/OPERATE	☐	Never	☒	Always	☐	Sometimes	☐ Configurable
DIRECT OPERATE	☐	Never	☐	Always	☐	Sometimes	☒ Configurable
DIRECT OPERATE – NO ACK	☐	Never	☐	Always	☐	Sometimes	☒ Configurable
Count > 1	☒	Never	☐	Always	☐	Sometimes	☐ Configurable
Pulse On	☐	Never	☐	Always	☒	Sometimes	☐ Configurable
Pulse Off	☐	Never	☐	Always	☒	Sometimes	☐ Configurable
Latch On	☐	Never	☐	Always	☐	Sometimes	☒ Configurable
Latch Off	☐	Never	☐	Always	☐	Sometimes	☒ Configurable
Trip	☐	Never	☐	Always	☐	Sometimes	☒ Configurable
Close	☐	Never	☐	Always	☐	Sometimes	☒ Configurable
Queue	☒	Never	☐	Always	☐	Sometimes	☐ Configurable
Clear Queue	☒	Never	☐	Always	☐	Sometimes	☐ Configurable

Explanation of 'Sometimes' above: Supported Binary Output Control operations depend on the type of point.

Reports Binary Input Change Events when no specific variation requested:

☐ Never
☐ Only time-tagged
☐ Only non-time-tagged
☒ Configurable to send one or the other

Reports time-tagged Binary Input Change Events when no specific variation requested:

☐ Never
☐ Binary Input Change With Time
☐ Binary Input Change With Relative Time
☒ Configurable

Sends Unsolicited Responses: ☐ Never ☒ Configurable ☐ Only certain objects ☐ Sometimes (attach explanation) ☒ ENABLE/DISABLE UNSOLICITED Function codes supported	Sends Static Data in Unsolicited Responses: ☒ Never ☐ When Device Restarts ☐ When Status Flags Change No other options are permitted.
Default Counter Object/Variation: ☐ No Counters Reported ☒ Configurable ☐ Default Object Default Variation: ☐ Point-by-point list attached	Counters Roll Over at: ☐ No Counters Reported ☒ Configurable (16 or 32 Bits) ☐ 16 Bits ☐ 32 Bits ☐ Other Value: _____ ☐ Point-by-point list attached
Sends Multi-Fragment Responses: ☒ Yes ☐ No ☐ Configurable	

DNP V3.0 Implementation Table

The following table identifies which object variations, function codes, and qualifiers the AL-3417 supports in both request messages and in response messages. For static (non-change-event) objects, requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01. Requests sent with qualifiers 17 or 28 will be responded with qualifiers 17 or 28. For change-event objects, qualifiers 17 or 28 are always responded.

In the table below, text shaded as 07, 08 (limited qty) indicates functionality beyond Subset Level 3

OBJECT			REQUEST (Interface will parse)		RESPONSE (Interface will respond with)	
Object Number	Variation Number	Description	Function Codes (dec)	Qualifier Codes (hex)	Function Codes (dec)	Qualifier Codes (hex)
1	0	Binary Input Any Variation	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)		
1	1	Binary Input	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
1	2	Binary Input with Status	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
2	0	Binary Input Change Any Variation	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
2	1	Binary Input Change without Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
2	2	Binary Input Change with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
2	3	Binary Input Change with Relative Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
3	0	Double Bit Input – Any Variation	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)		
3	1	Double Bit Input	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
3	2	Double Bit Input with Status	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
4	0	Double Bit Input Change - Any Variation	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
4	1	Double Bit Input Change without Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
4	2	Double Bit Input Change with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
4	3	Double Bit Input Change with Relative Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
10	0	Binary Output Any Variation	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)		
10	1	Binary Output	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
10	2	Binary Output Status	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)

OBJECT			REQUEST (Interface will parse)		RESPONSE (Interface will respond with)	
Object Number	Variation Number	Description	Function Codes (dec)	Qualifier Codes (hex)	Function Codes (dec)	Qualifier Codes (hex)
12	1	Control Relay Output Block	3 (select) 4 (operate) 5 (direct op) 6 (dir. op, noack)	17, 28 (index)	129 (response)	echo of request
20	0	Binary Counter Any Variation	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)		
			7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty)		
20	1	32-Bit Binary Counter (with Flag)	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
20	2	16-Bit Binary Counter (with Flag)	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
20	5	32-Bit Binary Counter without Flag	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
20	6	16-Bit Binary Counter without Flag	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
21	0	Frozen Counter Any Variation	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)		
21	1	32-Bit Frozen Counter (with Flag)	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
21	2	16-Bit Frozen Counter (with Flag)	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
21	9	32-Bit Frozen Counter without Flag	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
21	10	16-Bit Frozen Counter without Flag	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
22	0	Counter Change Event Any Variation	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
22	1	32-Bit Counter Change Event without Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
22	2	16-Bit Counter Change Event without Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
22	5	32-Bit Counter Change Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
22	6	16-Bit Counter Change Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
23	0	Frozen Counter Event	1 (read)	06(no range, or all) 07, 08 (limited qty)		
23	1	32-Bit Frozen Counter Event	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. Resp)	17,28 (index)
23	2	16-Bit Frozen Counter Event	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17,28 (index)
23	5	32-Bit Frozen Counter Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
23	6	16-Bit Frozen Counter Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)

OBJECT			REQUEST (Interface will parse)		RESPONSE (Interface will respond with)	
Object Number	Variation Number	Description	Function Codes (dec)	Qualifier Codes (hex)	Function Codes (dec)	Qualifier Codes (hex)
30	0	Analog Input Any Variation	1 (read) 22 (assign class)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)		
30	1	32-Bit Analog Input	1 (read)	00, 01(start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
30	2	16-Bit Analog Input	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
30	3	32-Bit Analog Input without Flag	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
30	4	16-Bit Analog Input without Flag	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
30	5	short floating point	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
32	0	Analog Change Event Any Variation	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
32	1	32-Bit Analog Change Event without Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
32	2	16-Bit Analog Change Event without Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
32	3	32-Bit Analog Change Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
32	4	16-Bit Analog Change Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
32	5	short floating point Analog Change Event without Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
32	7	short floating point Analog Change Event with Time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
40	0	Analog Output Status	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)		
40	1	32-Bit Analog Output Status	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
40	2	16-Bit Analog Output Status	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
40	3	short floating point Analog Output Status	1 (read)	00, 01 (start-stop) 06 (no range, or all) 07, 08 (limited qty) 17, 27, 28 (index)	129 (response)	00, 01 (start-stop) 17, 28 (index – see note 1)
41	1	32-Bit Analog Output Block	3 (select) 4 (operate) 5 (direct op) 6 (dir. op, noack)	17, 28 (index) 27 (index)	129 (response)	echo of request
41	2	16-Bit Analog Output Block	3 (select) 4 (operate) 5 (direct op) 6 (dir. op, noack)	17, 28 (index) 27 (index)	129 (response)	echo of request
41	3	short floating point Analog Output Block	3 (select) 4 (operate) 5 (direct op) 6 (dir. op, noack)	17, 27, 28 (index)	129 (response)	echo of request

OBJECT			REQUEST (Interface will parse)		RESPONSE (Interface will respond with)	
Object Number	Variation Number	Description	Function Codes (dec)	Qualifier Codes (hex)	Function Codes (dec)	Qualifier Codes (hex)
50	1	Time and Date	1 (read)	07, (limited qty = 1)	129 (response)	07 (limited qty = 1)
			2 (write)	07 (limited qty = 1)		
50	3	Time and Date Last Recorded Time	2 (write)	07 (limited qty)		
51	1	Time and Date CTO			129 (response) 130 (unsol. resp)	07 (limited qty) (qty = 1)
51	2	Unsynchronized Time and Date CTO			129 (response) 130 (unsol. resp)	07 (limited qty) (qty = 1)
52	1	Time Delay Coarse			129 (response)	07 (limited qty) (qty = 1)
52	2	Time Delay Fine			129 (response)	07 (limited qty) (qty = 1)
60	0	Not Defined				
60	1	Class 0 Data	1 (read)	06 (no range, or all)		
60	2	Class 1 Data	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
			20 (enbl. unsol.) 21 (dab. unsol.) 22 (assign class)	06 (no range, or all)		
60	3	Class 2 Data	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
			20 (enbl. unsol.) 21 (dab. unsol.) 22 (assign class)	06 (no range, or all)		
60	4	Class 3 Data	1 (read) 20 (enbl. unsol.) 21 (dab. unsol.) 22 (assign class)	06 (no range, or all) 07, 08 (limited qty) 06 (no range, or all)		
80	1	Internal Indications	1 (read)	00, 01 (start-stop)	129 (response)	00, 01 (start-stop)
			2 (write) (see note 2)	00 (start-stop) index=4 or 7		
No Object (function code only)			13 (cold restart)			
No Object (function code only)			23 (delay meas.)			
No Object (function code only)			24 (record current time)			

Annex E. Considerations about AL-3417

This section presents some considerations about the user of AL-3417 interface, regarding the functionalities of DNP3 protocol that must be observed.

Select and Operate Functions

The functions 03 and 04, respectively **select** and **operate**, must be executed in sequence and without any other request between them, as is described on DNP3 standard. If this is not respected by the DNP3 client, the **operate** request will not be accepted by AL-3417 module.