CANopen

CFW-11

Communication Manual

Language: English

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Series: CFW-11

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Summary

About this Manual

This manual provides the necessary information for the operation of the CFW-11 frequency inverter using the CANopen protocol. This manual must be used together with the CFW-11 user manual.

Abbreviations and Definitions

CAN	Controller Area Network
CiA	CAN in Automation
COB	Communication Object
COB-ID	Communication Object Identifier
SDO	Service Data Object
PDO	Process Data Object
RPDO	Receive PDO
TPDO	Transmit PDO
NMT	Network Management Object
ro	Read only
rw	Read/write

Numerical Representation

Decimal numbers are represented by means of digits without suffix. Hexadecimal numbers are represented with the letter 'h' after the number.

Documents

The CANopen protocol for the CFW-11 was developed based on the following specifications and documents:

Document	Version	Source
CAN Specification	2.0	CiA
CiA DS 301 CANopen Application Layer and Communication Profile	4.02	CiA
CiA DRP 303-1 Cabling and Connector Pinout	1.1.1	CiA
CiA DSP 306 Electronic Data Sheet Specification for CANopen	1.1	CiA
CiA DSP 402 Device Profile Drives and Motion Control	2.0	CiA

In order to obtain this documentation, the organization that maintains, publishes and updates the information regarding the CANopen network, CiA, must be consulted.

1 Introduction to the CANopen Communication

In order to operate the CFW-11 frequency inverter in a CANopen network, it is necessary to know how the communication is performed. Therefore, this section brings a general description of the CANopen protocol operation, containing the functions used by the CFW-11. For a detailed description of the protocol, refer to the CANopen documentation indicated in the previous section.

1.1 CAN

CANopen is a network based on CAN, which means it uses CAN telegrams to exchange data in the network.

CAN is a serial communication protocol that describes the layer 2 services (data link layer)[1] of the ISO/OSI model. In this layer are defined the different types of telegrams (frames), the error detection form, the validation and arbitration of messages.

1.1.1 Data Frame

In a CAN network data is transmitted by means of a data frame. This frame is composed mainly by an 11 bit[2] identifier field (*arbitration field*), and a *data field* that may contain up to 8 data bytes.

Identifier	8 data bytes							
11 bits	byte 0	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7

1.1.2 Remote Frame

Besides the data frame, there is also the remote frame (RTR frame). This type of frame does not have data field, only identifier. It works as a request, so that another network device transmits the desired data frame.

1.1.3 Access to the Network

In a CAN network any element may try to transmit a telegram in a certain instant. If two elements try to access the network simultaneously, the one that sends the message with the highest priority will be able to transmit. The message priority is defined by the CAN frame identifier, the less the value of that identifier, the higher the message priority. The telegram with an identifier 0(zero) is the one with the highest priority.

1.1.4 Error Control

The CAN specification defines several error control mechanisms, which makes it a very reliable network and with a very low rate of undetected transmission errors. Each device in the network must be able to identify the occurrence of those errors and to inform the other elements that an error was detected.

A CAN network device has internal counters that are incremented every time a transmission or reception error is detected, and decremented when a telegram is sent or received with success. If a considerable amount of errors occurs, the device can be taken to the following conditions:

- ☑ *Warning*: when this counter exceeds a certain limit, the device enters the *warning* state, meaning the occurrence of a high error rate.
- ☑ *Error Passive*: when this value exceeds a higher limit, the device enters the *error passive* state, then it stops acting in the network when detecting that another device sent a telegram with error.
- ☑ *Bus Off*: to conclude, there is the *bus off* state, in which the device will no longer send or receive telegrams.

[1] In the CAN protocol specification the ISO 11898 standard is referred as the definition of the layer 1 (physical layer) of this model.
[2] The CAN 2.0 specification defines two types of data frames: *standard* (11 bits) and *extended* (29 bits). For the CFW-11 CANopen protocol, only *standard* frames are accepted.

1.1.5 CAN and CANopen

Only the definitions on how to detect errors and to create and transmit a frame, are not sufficient to define a meaning for the data that is sent through the network. There must be a specification that indicates how the identifier and the data must be assembled and how the information must be exchanged. In this way the elements of the network can interpret correctly the transmitted data. In this sense, the CANopen specification defines exactly how to exchange data among the equipments, and how each device must interpret these data.

There are several other protocols based on CAN, as DeviceNet, J1939, etc., which also use CAN frames for the communication. Those protocols however cannot co-operate in the same network.

1.2 CANopen Network Characteristics

Because of using a CAN bus as telegram transmission means, all the CANopen network devices have the same right to access the network, where the identifier priority is responsible for solving conflict problems when simultaneous access occurs. This brings the benefit of making direct communication between slaves of the network possible, besides the fact that data can be made available in a more optimized manner without the need of a master that controls all the communication performing cyclic access to all the network devices for data updating.

Another important characteristic is the use of the producer/consumer model for data transmission. This means that a message that transits in the network does not have a fixed network address as a destination. This message has an identifier that indicates what data it is transporting. Any element of the network that needs to use that information for its operation logic will be able to consume it, therefore, one message can be used by several network elements at the same time.

1.3 Physical Medium

The physical medium for signal transmission in a CANopen network is specified by the ISO 11898 standard. It defines as transmission bus a pair of twisted wires with differential electrical signal.

The CFW-11 frequency inverter uses an interface isolated from the network. The power supply for the CANopen interface is shared with the digital and analog inputs and outputs present on the CFW-11 control board. The component responsible for the transmission and reception of the signals is denominated transceiver, which complies with the specified by the ISO 11898.

1.4 Address in the CANopen Network

Every CANopen network must have a master responsible for network management services, and it can also have a set of up to 127 slaves. Each network device can also be called node. Each slave is identified in a CANopen network by its address or Node-ID, which must be unique for each slave and may range from 1 to 127.

The CFW-11 does not have functions for implementing the network management services; therefore, it must be used together with some equipment that has such services, generally a CANopen network master.

1.5 Access to the Data

Each slave of the CANopen network has a list called object dictionary that contains all the data accessible via network. Each object of this list is identified with an index, which is used during the equipment configuration as well as during message exchanges. This index is used to identify the object being transmitted.

A more detailed description on how the dictionary is structured is presented on section 6.

1.6 Data Transmission

The transmission of numerical data via CANopen telegrams is done using a hexadecimal representation of the number, and sending the least significant data byte first.

E.g.: The transmission of a 32 bit integer with sign (12345678h = 305419896 decimal), plus a 16 bit integer with sign (FF00h = -256 decimal), in a CAN frame.

Identifier	6 data bytes					
11 bits	32 bit integer				16 bit integer	
	byte 0	byte 1	byte 2	byte 3	byte 4	byte 5
	78h	56h	34h	12h	00h	FFh

1.7 Communication Objects - COB

There is a specific set of objects that are responsible for the communication among the network devices. Those objects are divided according to the type of data and the way they are sent or received by a device. The CFW-11 supports the following communication objects (COB):

Table 1.1 - Types of Communication Objects (COB)

Type of object	Description
Service Data Object (SDO)	SDO are objects responsible for the direct access to the object dictionary of a device. By means of messages using SDO, it is possible to indicate explicitly (by the object index) what data is being handled. There are two SDO types: Client SDO, responsible for doing a read or write request to a network device, and the Server SDO, responsible for taking care of that request. Since SDO are usually used for the configuration of a network node, they have less priority than other types of message. Only a Server SDO is available for the CFW-11.
Process Data Object (PDO)	PDO are used for accessing equipment data without the need of indicating explicitly which dictionary object is being accessed. Therefore, it is necessary to configure previously which data the PDO will be transmitting (data mapping). There are also two types of PDO: Receive PDO and Transmit PDO. They are usually utilized for transmission and reception of data used in the device operation, and for that reason they have higher priority than the SDO.
Emergency Object (EMCY)	This object is responsible for sending messages to indicate the occurrence of errors in the device. When an error occurs in a specific device (EMCY producer), it can send a message to the network. In the case that any network device be monitoring that message (EMCY consumer), it can be programmed so that an action be taken (disabling the other devices, error reset, etc.). The CFW-11 has only the EMCY producer functionality.
Synchronization Object (SYNC)	In the CANopen network, it is possible to program a device (SYNC producer) to send periodically a synchronization message for all the network devices. Those devices (SYNC consumers) will then be able, for instance, to send a certain datum that needs to be made available periodically. The CFW-11 has the SYNC consumer function.
Network Management (NMT)	Every CANopen network needs a master that controls the other devices (slaves) in the network. This master will be responsible for a set of services that control the slave communications and their state in the CANopen network. The slaves are responsible for receiving the commands sent by the master and for executing the requested actions. The CFW-11 operates as a CANopen network slave and makes available two types of service that the master can use: device control service, with which the master controls the state of each network slave, and error control service (Node Guarding), with which the slave sends periodic messages to the master informing that the connection is active.

All the communication of the inverter with the network is performed using those objects, and the data that can be accessed are the existent in the device object dictionary. The working description of each COB is presented in section 7.

1.8 COB-ID

A telegram of the CANopen network is always transmitted by a communication object (COB). Every COB has an identifier that indicates the type of data that is being transported. This identifier, called COB-ID has an 11 bit size, and it is transmitted in the identifier field of a CAN telegram. It can be subdivided in two parts:

Function Code				Node Address						
bit 10	bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0

- ☑ Function Code: indicates the type of object that is being transmitted.
- ☑ Node Address: indicates with which network device the telegram is linked.

A table with the standard values for the different communication objects available in the CFW-11 is presented next. Notice that the standard value of the object depends on the slave address, with the exception of the COB-ID for NMT and SYNC, which are common for all the network elements. Those values can also be changed during the device configuration stage.

Table 1.2 - *COB-ID for the different objects*

COB	Function code (bits 10 – 7)	Resultant COB-ID (function + address)
NMT	0000	0
SYNC	0001	128 (80h)
EMCY	0001	129 – 255 (81h – FFh)
PDO1 (tx)	0011	385 – 511 (181h – 1FFh)
PDO1 (rx)	0100	513 – 639 (201h – 27Fh)
PDO2 (tx)	0101	641 – 767 (281h – 2FFh)
PDO2 (rx)	0110	769 – 895 (301h – 37Fh)
PDO3 (tx)	0111	897 – 1023 (381h – 3FFh)
PDO3 (rx)	1000	1025 – 1151 (401h – 47Fh)
PDO4 (tx)	1001	1153 – 1279 (481h – 4FFh)
PDO4 (rx)	1010	1281 – 1407 (501h – 57Fh)
SDO (tx)	1011	1409 – 1535 (581h – 5FFh)
SDO (rx)	1100	1537 – 1663 (601h – 67Fh)
Node Guarding/Heartbeat	1110	1793 – 1919 (701h – 77Fh)

1.9 EDS File

Each device in a CANopen network has an EDS configuration file that contains information about the operation of the device in the CANopen network, as well as the description of all the communication objects available. In general, this file is used by a master or by the configuration software for programming of devices present in the CANopen Network.

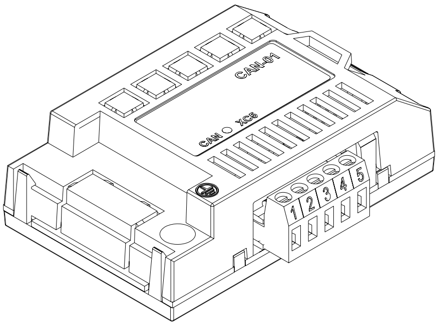
The EDS configuration file for the CFW-11 is supplied together with the product, and it can also be obtained from the website http://www.weg.net. It is necessary to observe the inverter software version, in order to use an EDS file that be compatible with that version.

2 Optional Kits

In order to make the CANopen communication possible with the CFW-11 frequency inverter, it is necessary to use one of the CAN communication kits described next. Information on the installation of the module in the inverter can be obtained in the guide that comes with the kit.

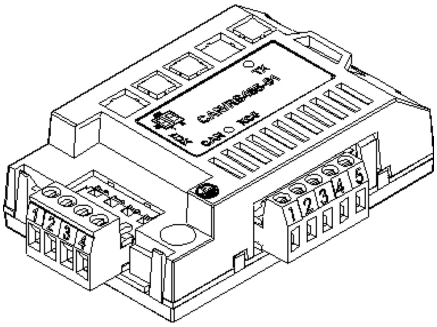
2.1 CAN Interfaces

2.1.1 CAN-01 Kit



- ☑ WEG part number: 10051961.
- ☑ Composed by the CAN communication module (drawing at the left), mounting instructions and fixing screw.
- ☑ The interface is electrically isolated and with differential signal, which grants more robustness against electromagnetic interference.
- ☑ External 24 V power supply.
- ☑ It allows the connection of up to 32 devices to the same segment. More devices can be connected by using repeaters[3].
- ☑ A maximum bus length of 1000 meters.

2.1.2 CAN/RS485-01 Kit



- ☑ WEG part number: 10051960.
- ☑ Composed by the CAN/RS485-01 communication module (drawing at the left), mounting instruction and fixing screw.
- ☑ It has the same characteristics of the CAN-01 interface, plus an RS485 interface, for applications where the operation with both interfaces is necessary.

2.1.3 Connector Pinout

The CAN communication module presents a 5 wire *plug-in* connector (XC5) with the following pinout:

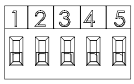


Table 2.1 *- CAN interface (XC5) connector pinout*

Pin	Name	Function
1	V-	Power supply negative pole.
2	CAN_L	CAN_L communication signal.
3	Shield	Cable shield
4	CAN_H	CAN_H communication signal.
5	V+	Power supply positive pole.

2.1.4 Power Supply

The CFW-11 CAN interface needs an external power supply between pins 1 and 5 of the network connector. In order to avoid problems of voltage difference among the devices, it is recommended that the network be fed at only one point, and that the supply be taken to all the devices through the cable. If more than one power supply is necessary, they must be referenced to the same point. The data for individual consumption and the input voltage are presented in the next table.

[3] The maximum number of devices that can be connected to the network depends also on the used protocol.

Table 2.2 - CAN interface supply characteristics

Supply Voltage (V_{DC})		
Minimum	Maximum	Recommended
11	30	24
Current (mA)		
Minimum	Maximum	Medium
20	50	30

The CAN interface modules have a green LED to indicate that the interface is powered.

2.1.5 Termination Resistor

The extremes of the CAN bus must have a termination resistor with a 120 Ω / 0.25 W value, connecting the CAN_H and CAN_L signals if the drive is the first or the last element of the segment.

2.1.6 Baud Rate

The *baud rate* that can be used by equipment in the CANopen network depends on the length of the cable used in the installation. The next table shows the baud rates available for the CFW-11, and the maximum cable length that can be used in the installation, according to the CiA recommendation.

Table 2.2 - Supported baud rates and installation size

Baud Rate	Cable Length
1 Mbit/s	40 m
500 Kbit/s	100 m
250 Kbit/s	250 m
125 Kbit/s	500 m
100 Kbit/s	600 m
50 Kbit/s	1000 m
20 Kbit/s	1000 m
10 Kbit/s	1000 m

2.1.7 Connection of the Inverter in the CAN Network

In order to interconnect the several network nodes, it is recommended to connect the equipment directly to the main line without using derivations. During the cable installation the passage near to power cables must be avoided, because, due to electromagnetic interference, this makes the occurrence of transmission errors possible. In order to avoid problems with current circulation caused by difference of potential among ground connections, it is necessary that all the devices be connected to the same ground point.

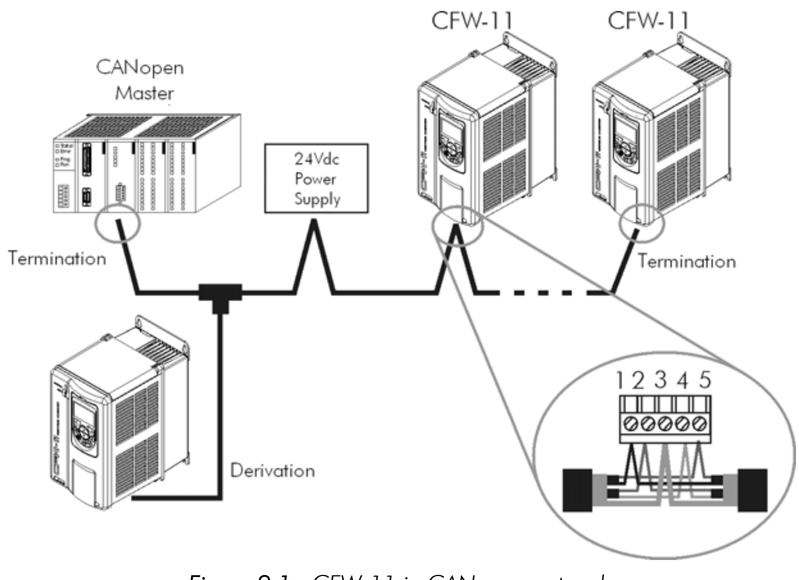


Figure 2-1 - CFW-11 in CANopen network

The cable for the connection of the CAN_L and CAN_H signals must have a characteristic impedance of approximately 120 Ohm, and a maximum propagation delay of 5ns/m. Other characteristics depend on the cable length, which must be according to the next table.

Cable length (m)	Resistance per meter (mOhm/m)	Conductor cross section (mm2)
0 ... 40	70	0.25 ... 0.34
40 ... 300	<60	0.34 ... 0.60
300 ... 600	<40	0.50 ... 0.60
600 ... 1000	<26	0.75 ... 0.80

The maximum number of devices connected to a single segment of the network is limited to 64. Repeaters can be used for connecting a bigger number of devices.

3 Inverter Programming

Next, only the CFW-11 frequency inverter parameters related to the CANopen communication will be presented.

3.1 Symbols for the Proprieties Description

RO	Read-only parameter.
CFG	Parameter that can be changed only with a stopped motor.
Net	Parameter visible on the HMI if the inverter has the network interface installed – RS232, RS485, CAN, Anybus-CC, Profibus – or if the USB interface is connected.
Serial	Parameter visible on the HMI if the inverter has the RS232 or RS485 interface installed.
CAN	Parameter visible on the HMI if the inverter has the CAN interface installed.

P0105 – 1st/2nd Ramp Selection

P0220 – Local/Remote Selection Source

P0221 – Speed Reference Selection – Local Situation

P0222 – Speed Reference Selection – Remote Situation

P0223 – Selection of the Rotation Direction - Local Situation

P0224 – Start/Stop Selection – Local Situation

P0225 – Jog Selection - Local Situation

P0226 – Selection of the Rotation Direction - Remote Situation

P0227 – Start/Stop Selection – Remote Situation

P0228 – Jog Selection - Remote Situation

These parameters are used in the configuration of the source of commands for the local and remote mode of the inverter CFW-11. So that the inverter is controlled through the CANopen interface, one of the available 'CANopen/DNet' in the parameters options must be selected.

The detailed description of these parameters are found in the Programming the CFW-11 Manual.

P0313 – Communication Error Action

Range: 0 = Off
1 = Ramp stop
2 = General disable
3 = Change to LOCAL
4 = Change to LOCAL keeping the commands and the reference
5 = Fault trip

Default: 0

Proprieties: CFG, Net

Access groups via HMI:

01 PARAMETER GROUPS
∟ 49 Communication
∟ 111 Status/Commands

Description:
It allows the selection of the action to be executed by the inverter when a communication error is detected.

Table 3.1 - Values for parameter P0313

Options	Description
0 = Off	No action is taken and the inverter remains in the existing status.

1 = Ramp Stop	A stop command with deceleration ramp is executed and the motor stops according to the programmed deceleration ramp.
2 = General Disable	The inverter is disabled by removing the General Enabling and the motor coasts to stop.
3 = Change to LOCAL	The inverter commands change to LOCAL.
4 = Change to LOCAL keeping the commands and the reference	The inverter is changed to the local mode; However, the enabling and reference commands received via the network , in case the inverter had been programmed for start/stop via HMI or 3-wire and reference via HMI or electronic potentiometer, are kept in the local mode.
5 = Fault Trip	Instead of an alarm, a communication error causes a fault at the inverter, so that it becomes necessary to perform the inverter fault reset in order to get it back to normal operation.

For the CAN interface being used with the CANopen protocol, the following events are considered communication errors:

- ☑ A133 alarm/fault F233: CAN interface without power supply.
- ☑ A134 alarm/fault F234: *bus off*.
- ☑ A135 alarm/fault F235: CANopen communication error (*Node Guarding*)

The description of those alarms/faults is found in the section 7.

The actions described in this parameter are executed by means of the automatic writing of the respective bits on the control via CAN parameter – P0684. In order to be effective, it is necessary that the inverter be programmed to be controlled via CAN interface. This programming is done by means of parameters P0220 to P0228.

P0680 – Logical Status

Range: 0000h – FFFFh **Default:** -

Proprieties: RO

Access groups via HMI:

01 PARAMETER GROUPS
∟ 49 Communication
  ∟ 111 Status/Commands

Description:
It allows the monitoring of the inverter status. Each bit represents one state:

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3 to 0
Function	Fault condition	Manual/ Automatic	Undervoltage	LOC/REM	JOG	Speed Direction	General Enabling active	Ramp enabled	In Alarm condition	In configuration mode	Second Ramp	Quick Stop Activated	Reserved

Table 3.2 - P0680 bit functions

Bits	Values
Bits 0 to 3	Reserved
Bit 4 Quick Stop Activated	0: Quick stop command is not activated. 1: Inverter is executing quick stop command.
Bit 5 Second Ramp	0: The inverter is configured to use as acceleration and deceleration ramp for the motor, the first ramp, programmed at the parameters P0100 and P0101. 1: The inverter is configured to use as acceleration and deceleration ramp for the motor, the second ramp, programmed at the parameters P0102 and P0103.

Bit 6 In configuration mode	**0**: Inverter operating normally. **1**: Inverter in configuration mode. Indicates a special condition when the inverter cannot be enabled: ☑ Executing the self tuning routine. ☑ Executing guided start-up routine. ☑ Executing the HMI copy function. ☑ Executing the flash memory card guided routine. ☑ There is a parameter setting incompatibility. ☑ Without power supply at the inverter power section. **Note**: It is possible to obtain the exact description of the special operation mode at parameter P0692.
Bit 7 Alarm condition	**0**: The inverter is not in alarm condition. **1**: The inverter is in alarm condition. **Note**: The alarm number can be read by means of the parameter P0048 – Current Alarm.
Bit 8 Ramp Enabled (RUN)	**0**: The inverter is driving the motor at the set point speed, or executing either the acceleration or the deceleration ramp. **1**: The motor is stopped.
Bit 9 General Enabling active	**0**: General Enabling is not active. **1**: General enabling is active and the inverter is ready to run the motor.
Bit 10 Speed Direction	**0**: The motor is rotating in reverse mode. **1**: The motor is rotating in direct mode.
Bit 11 JOG	**0**: JOG function inactive. **1**: JOG function active.
Bit 12 LOC/REM	**0**: Inverter in LOCAL situation. **1**: Inverter in REMOTE situation.
Bit 13 Undervoltage	**0**: No Undervoltage. **1**: With Undervoltage.
Bit 14 Manual/ Automatic	**0**: PID in manual mode. **1**: PID in Automatic mode.
Bit 15 Fault condition	**0**: The inverter is not in a fault condition. **1**: Any fault has been registered by the inverter. **Note**: The fault number can be read by means of the parameter P0049 – Current Fault.

P0681 – Motor Speed in 13 bits

Range: -32768 … +32767 **Default:** -

Proprieties: RO

Access groups via HMI:

01 PARAMETER GROUPS.
∟ 49 Communication
∟ 111 Status/Commands

Description:
It allows monitoring the motor speed. This word uses 13 bit resolution with sign to represent the motor synchronous speed:

☑ P0681 = 0000h (0 decimal) → motor speed = 0 rpm
☑ P0681 = 2000h (8192 decimal) → motor speed = synchronous speed

Intermediate or higher speed values in rpm can be obtained by using this scale. E.g. for a 4 pole 1800 rpm synchronous speed motor, if the value read is 2048 (0800h), then, to obtain the speed in rpm one must calculate:

8192 – 1800 rpm
2048 – value read in P0681

$$\text{Speed in rpm} = \frac{1800 \times 2048}{8192}$$

Speed in rpm = 450 rpm

Negative values in this parameter indicate motor rotating in counterclockwise sense of rotation.

P0684 – CANopen/DeviceNet Control Word

Range: 0000h – FFFFh **Default:** 0000h

Proprieties: CAN

Access groups via HMI:

01 PARAMETER GROUPS
∟ 49 Communication
∟ 111 Status/Commands

Description:
It is the inverter CANopen/DeviceNet Control word. This parameter can only be changed via the CAN interface (CANopen or DeviceNet protocols). For the other sources (HMI, USB, Serial, etc.) it behaves like a read-only parameter.

In order that the commands written in this parameter be executed, it is necessary that the inverter be programmed to be commanded via CAN. This programming is done by means of parameters P0105 and P0220 to P0228.

Each bit of this word represents a command that can be executed in the inverter.

Bits	15 to 8	7	6	5	4	3	2	1	0
Function	Reserved	Fault reset	Quick Stop	Second Ramp Use	LOC/REM	JOG	Direction of Rotation	General Enabling	Start/Stop

Table 3.3 - *P0684 Bit functions*

Bits	Values
Bit 0 Start/Stop	**0**: It stops the motor with deceleration ramp. **1**: The motor runs according to the acceleration ramp until reaching the speed reference value.
Bit 1 General Enabling	**0**: It disables the inverter, interrupting the supply for the motor. **1**: It enables the inverter allowing the motor operation.
Bit 2 Direction of Rotation	**0**: To run the motor in a direction opposed to the speed reference. **1**: To run the motor in the direction indicated by the speed reference.
Bit 3 JOG	**0**: It disables the JOG function. **1**: It enables the JOG function.
Bit 4 LOC/REM	**0**: The inverter goes to the LOCAL situation. **1**: The inverter goes to the REMOTE situation.
Bit 5 Second Ramp Use	0: The inverter uses as acceleration and deceleration ramp for the motor, the first ramp times, programmed at the parameters P0100 and P0101. 1: The inverter uses as acceleration and deceleration ramp for the motor, the second ramp times, programmed at the parameters P0102 and P0103.
Bit 6 Quick Stop	0: Quick Stop command not activated. 1: Quick Stop command activated. Note: when the control modes V/f or VVW are selected, the use of this function is not recommended.
Bit 7 Fault reset	**0**: No function. **1**: If in a fault condition, then it executes the inverter reset.
Bits 8 to 15	Reserved

P0685 – CANopen/DeviceNet Speed Reference

Range: -32768 … +32767 **Default:** 0

Proprieties: CAN

Access groups via HMI:

01 PARAMETER GROUPS
∟ 49 Communication
∟ 111 Status/Commands

Description:
It allows the programming of the speed reference for the inverter via CANopen/DeviceNet interface. This parameter can only be changed via CAN interface (CANopen or DeviceNet protocols). For the other sources (HMI, USB, Serial, etc.) it behaves like a read-only parameter.

In order that the reference written in this parameter be used, it is necessary that the inverter be programmed for using the speed reference via CANopen/DeviceNet. This programming is done by means of parameters P0221 and P0222.

This word uses a 13 bit resolution with sign to represent the motor synchronous speed:

☑ P0685 = 0000h (0 decimal) → speed reference = 0 rpm
☑ P0685 = 2000h (8192 decimal) → speed reference = synchronous speed

Intermediate or higher speed reference values can be programmed by using this scale. E.g. for a 4 pole 1800 rpm synchronous speed motor, to obtain a speed reference of 900 rpm one must calculate:

1800 rpm – 8192
900 rpm – 13 bit reference

$$\text{13 bit reference} = \frac{900 \times 8192}{1800}$$

13 bit reference = 4096 (value corresponding to 900 rpm in a 13 bit scale)

This parameter also accepts negative values to revert the motor speed direction. The reference speed direction, however, depends also on the control word bit 2 setting – P0684:

☑ Bit 2 = 1 and P0685 > 0: reference for direct speed rotation
☑ Bit 2 = 1 and P0685 < 0: reference for reverse speed rotation
☑ Bit 2 = 0 and P0685 > 0: reference for reverse speed rotation
☑ Bit 2 = 0 and P0685 < 0: reference for direct speed rotation

P0695 – Digital Output Setting

Range: 0000h – FFFFh **Default:** 0000h

Proprieties: Net

Access groups via HMI:

01 PARAMETER GROUPS.
∟ 49 Communication
∟ 111 Status/Commands

Description:
It allows the control of the digital outputs by means of the network interfaces (Serial, USB, CAN, etc.). This parameter cannot be changed via HMI.

Each bit of this parameter corresponds to the desired value for a digital output. In order to have the correspondent digital output controlled according to this content, it is necessary that its function be programmed for "P0695 Content" at parameters P0275 to P0280.

Bits	15 to 5	4	3	2	1	0
Function	Reserved	Setting for DO5	Setting for DO4	Setting for DO3 (RL3)	Setting for DO2 (RL2)	Setting for DO1 (RL1)

Table 3.4 - P0695 parameter bit functions

Bits	Values
Bit 0 Setting for DO1 (RL1)	0: DO1 output open. 1: DO1 output closed.
Bit 1 Setting for DO2 (RL2)	0: DO2 output open. 1: DO2 output closed.
Bit 2 Setting for DO3 (RL3)	0: DO3 output open. 1: DO3 output closed.
Bit 3 Setting for DO4	0: DO4 output open. 1: DO4 output closed.
Bit 4 Setting for DO5	0: DO5 output open. 1: DO5 output closed.
Bits 5 to 15	Reserved

P0696 – Analog Output Value 1

P0697 – Analog Output Value 2

P0698 – Analog Output Value 3

P0699 – Analog Output Value 4

Range: -32769 … +32767 **Default:** 0

Proprieties: Net

Access groups via HMI:

01 PARAMETER GROUPS.
∟ 49 Communication
∟ 111 Status/Commands

Description:
It allows the control of the analog outputs by means of network interfaces (Serial, USB, CAN, etc.) This parameter cannot be changed via HMI.

The value written in those parameters is used as the analog output value, providing that the function for the desired analog output be programmed for "Content P0696/7/8/9", in the parameters P0251, P0254, P0257 or P0260.

The value must be written in a 15 bit scale (7FFFh = 32767)[4] to represent 100% of the output desired value, i.e.:

☑ P0696 = 0000h (0 decimal) → analog output value = 0 %
☑ P0696 = 7FFFh (32767 decimal) → analog output value = 100 %

The showed example was for P0696, but the same scale is also used for the parameters P0697/8/9. For instance, to control the analog output 1 via the CAN interface, the following programming must be done:

☑ Choose a parameter from P0696 to P0699 to be the value used by the analog output 1. For this example we are going to select P0696.
☑ Program the option "Content P0696" as the function for the analog output 1 in P0254.
☑ Using the CAN interface, write in P0696 the desired value for the analog output 1, between 0 and 100 %, according to the parameter scale.

NOTE!
If the analog output is programmed for working from -10 V to +10 V, negative values must be programmed at the specific parameter, so that -32769 to 32767 represent a variation from -10 V to +10 V at the output.

[4] Refer to the CFW-11 manual for knowing the actual output resolution.

P0700 – CAN Protocol

Range: 1 = CANopen
2 = DeviceNet
Default: 2

Proprieties: CFG, CAN

Access groups via HMI:

01 PARAMETER GROUPS.
∟ 49 Communication
∟ 112 CANopen/DeviceNet

Description:
It allows selecting the desired protocol for the CAN interface. In order to enable the CANopen protocol, it is necessary to program this parameter with the option '1 = CANopen'.

If this parameter is changed, it becomes valid only after cycling power of the inverter.

P0701 – CAN Address

Range: 0 to 127
Default: 63

Proprieties: CFG, CAN

Access groups via HMI:

01 PARAMETER GROUPS.
∟ 49 Communication
∟ 112 CANopen/DeviceNet

Description:
It allows programming the inverter address used for the CAN communication. It is necessary that each element of the network has an address different from the others. The valid addresses for this parameter depend on the protocol programmed in P0700:

☑ P0700 = 1 (CANopen) → valid addresses: 1 to 127.
☑ P0700 = 2 (DeviceNet) → valid addresses: 0 to 63.

If this parameter is changed, it becomes valid only after cycling power of the inverter.

P0702 – CAN Baud Rate

Range: 0 = 1 Mbit/s
1 = 800 Kbit/s
2 = 500 Kbit/s
3 = 250 Kbit/s
4 = 125 Kbit/s
5 = 100 Kbit/s
6 = 50 Kbit/s
7 = 20 Kbit/s
8 = 10 Kbit/s
Default: 0

Proprieties: CFG, CAN

Access groups via HMI:

01 PARAMETER GROUPS
∟ 49 Communication
∟ 112 CANopen/DeviceNet

Description:

It allows programming the desired baud rate for the CAN interface, in bits per second. This rate must be the same for all the devices connected to the network.

P0703 –*Bus Off* Reset

Range: 0 = Manual
1 = Automatic

Default: 1

Proprieties: CFG, CAN

Access groups via HMI:

01 PARAMETER GROUPS
∟ 49 Communication
∟ 112 CANopen/DeviceNet

Description:
It allows programming the inverter behavior when detecting a *bus off* error at the CAN interface:

Table 3.5 - Values for the parameter P0703

Options	Description
0 = Manual Reset	If *bus off* occurs, the alarm A134/F234 will be indicated on the HMI, the action programmed in the parameter P0313 will be executed and the communication will be disabled. It is necessary to cycle power in order that the inverter communicates again through the CAN interface.
1 = Automatic Reset	If *bus off* occurs, the communication will be reinitiated automatically and the error will be ignored. In this case there will be no alarm indication on the HMI and the inverter will not execute the action programmed in P0313.

P0705 – CAN Controller Status

Range: 0 = Disabled
1 = Auto-baud
2 = CAN Enabled
3 = Warning
4 = Error Passive
5 = Bus Off
6 = No Bus Power

Default: -

Proprieties: RO

Access groups via HMI:

01 PARAMETER GROUPS
∟ 49 Communication
∟ 112 CANopen/DeviceNet

Description:
It allows identifying if the CAN interface board is properly installed and if the communication presents errors.

Table 3.6 - Parameter P0705 values

Options	Description
0 = Disabled	Inactive CAN interface. It occurs when the inverter does not have the CAN interface board installed.
1 = Auto-baud	
2 = CAN Enabled	The CAN interface is active and without errors.
3 = *Warning*	The CAN controller reached the *warning*[5] state.
4 = *Error Passive*	The CAN controller reached the *error passive*[5] state.
5 = *Bus Off*	The CAN controller reached the *bus off*[5] state.
6 = No Bus Power	The CAN interface does not have power supply between connector pins 1 and 5.

[5] Refer to the description on item 1.1.4.

P0706 – Received CAN Telegram Counter

Range: 0 to 65535 **Default:** -

Proprieties: RO, CAN

Access groups via HMI:

01 PARAMETER GROUPS
∟ 49 Communication
∟ 112 CANopen/DeviceNet

Description:

This parameter works as a cyclic counter that is incremented every time a CAN telegram is received. It informs the operator if the device is being able to communicate with the network. This counter is set back to zero when the inverter is switched off, a reset is performed or the parameter maximum limit is reached.

P0707 – Transmitted CAN Telegram Counter

Range: 0 to 65535 **Default:** -

Proprieties: RO, CAN

Access groups via HMI:

01 PARAMETER GROUPS
∟ 49 Communication
∟ 112 CANopen/DeviceNet

Description:

This parameter works as a cyclic counter that is incremented every time a CAN telegram is transmitted. It informs the operator if the device is being able to communicate with the network. This counter is set back to zero when the inverter is switched off, a reset is performed or the parameter maximum limit is reached.

P0708 – Bus Off Error Counter

Range: 0 to 65535 **Default:** –

Proprieties: RO, CAN

Access groups via HMI:

01 PARAMETER GROUPS
∟ 49 Communication
∟ 112 CANopen/DeviceNet

Description:
It is a cyclic counter that indicates the number of times the inverter got in the CAN network *bus off* state. This counter is set back to zero when the inverter is switched off, a reset is performed or the parameter maximum limit is reached.

P0709 – Lost CAN Message Counter

Range: 0 to 65535 **Default:** –

Proprieties: RO, CAN

Access groups via HMI:

01 PARAMETER GROUPS
∟ 49 Communication
∟ 112 CANopen/DeviceNet

Description:
It is a cyclic counter that indicates the number of messages received by the CAN interface, but could not be processed by the inverter. If the number of lost messages is frequently incremented, it is recommended to reduce the used CAN network baud rate. This counter is set back to zero when the inverter is switched off, a reset is performed or the parameter maximum limit is reached.

P0721 – CANopen Communication Status

Range: 0 = Disabled **Default:** –
1 = Reserved
2 = Communication Enabled
3 = Error Control Enabled
4 = *Guarding* Error
5 = *Heartbeat* Error

Proprieties: RO, CAN

Access groups via HMI:

01 PARAMETER GROUPS
∟ 49 Communication
∟ 112 CANopen/DeviceNet

Description:
It indicates the board state regarding the CANopen network, informing if the protocol has been enabled and if the error control service is active (*Node Guarding* or *Heartbeat*).

P0722 – CANopen Node Status

Range: 0 = Disabled **Default:** –
1 = Initialization
2 = Stopped
3 = Operational
4 = Preoperational

Proprieties: RO, CAN

Access groups via HMI:

01 PARAMETER GROUPS
∟ 49 Communication
∟ 112 CANopen/DeviceNet

Description:
The CFW-11 inverter operates as a slave of the CANopen network, and as such element it has a state machine that controls its behavior regarding the communication. This parameter indicates in which state the device is.

P0799 – I/O Update Delay

Range: 0.0 to 999.0 **Default:** 0.0

Proprieties: RW

Access groups via HMI:

01 PARAMETER GROUPS.
∟ 49 Communication
∟ 111 Status/Commands

Description:
It allows setting the delay time for the update of the data mapped in the writing words (data received by the equipment) via Profibus DP, Devicenet, CANopen communication networks and Anybus interface. The delay time is activated in the transition of the equipment status in the network from offline to online[6], as in *figure 3.1*.

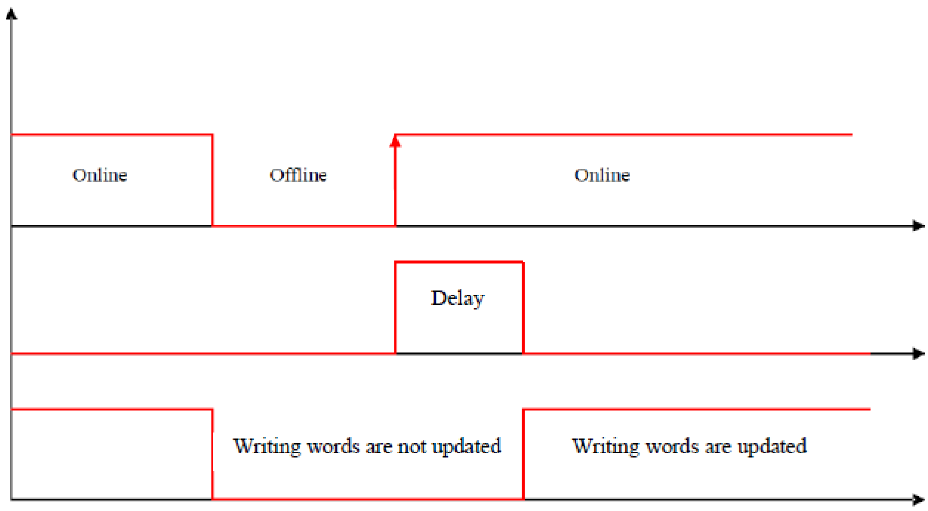


Figure 3.1 Delay in the update of I/O words

6 For this function, online represents the state where the exchange of cyclic I/O data occurs.

4 Object Dictionary

The object dictionary is a list containing several equipment data which can be accessed via CANopen network. An object of this list is identified by means of a 16-bit index, and it is based in that list that all the data exchange between devices is performed.

The CiA DS 301 document defines a set of minimum objects that every CANopen network slave must have. The objects available in that list are grouped according to the type of function they execute. The objects are arranged in the dictionary in the following manner:

Table 4.1 - *Object dictionary groupings*

Index	Objects	Description
0001h – 0360h	Data type definition	Used as reference for the data type supported by the system.
1000h – 1FFFh	Communication objects	They are objects common to all the CANopen devices. They contain general information about the equipment and also data for the communication configuration.
2000h – 5FFFh	Manufacturer specific objects	In this range, each CANopen equipment manufacturer is free to define which data those objects will represent.
6000h – 9FFFh	Standardized device objects	This range is reserved to objects that describe the behavior of similar equipment, regardless of the manufacturer.

The other indexes that are not referred in this list are reserved for future use.

4.1 Dictionary Structure

The general structure of the dictionary has the following format:

Index	Object	Name	Type	Access

- ☑ **Index**: indicates directly the object index in the dictionary.
- ☑ **Object**: describes which information the index stores (simple variable, array, record, etc.).
- ☑ **Name**: contains the name of the object in order to facilitate its identification.
- ☑ **Type**: indicates directly the stored data type. For simple variables, this type may be an integer, a float, etc. For arrays, it indicates the type of data contained in the array. For records, it indicates the record format according to the types described in the first part of the object dictionary (indexes 0001h – 0360h).
- ☑ **Access:** informs if the object in question is accessible only for reading (ro), for reading and writing (rw), or if it is a constant (const).

For objects of the array or record type, a sub-index that is not described in the dictionary structure is also necessary.

4.2 Data Type

The first part of the object dictionary (index 0001h - 0360h) describes the data types that can be accessed at a CANopen network device. They can be basic types, as integers and floats, or compound types formed by a set of entries, as records and arrays.

4.2.1 Basic Types

The following basic data types are supported:

- ☑ **Integer with sign:** There are three types of integers with sign supported by the CFW-11, INTEGER8, INTEGER16 and INTEGER32, which represent respectively integers with 8, 16 and 32 data bits. Integers with sign are calculated using two's complement, and in a CAN telegram the least significant byte is always transmitted first.
- ☑ **Integer without sign:** There are three types of integers without sign supported by the CFW-11, UNSIGNED8, UNSIGNED16 and UNSIGNED32, which represent respectively integers with 8, 16 and 32 data bits. Also the least significant byte is always transmitted first.

4.2.2 Compound Types

It is possible to form new data types by grouping the basic types in lists (*arrays* – formed by one single type of data) and structures (*records* – formed by several types of data). In this case, each item of this type is identified by means of a sub-index. The compound types used by the inverter are listed below.

PDO COMM PARAMETER: this *record* defines the necessary information for configuring a CANopen communication PDO. The content of the field and the manner each one is used are detailed in the section 5.3.

Table 4.2 - Record for PDOs configuration

Sub-index	Entry description	Type
00h	Number of entries supported in this *record*	UNSIGNED8
01h	COB-ID	UNSIGNED32
02h	*Transmission type*	UNSIGNED8
03h	*Inhibit time*	UNSIGNED16
04h	Reserved	UNSIGNED8
05h	*Event timer*	UNSIGNED16

PDO MAPPING: this *record* defines how to map the data that will be transmitted by a PDO during the CANopen communication. The content of the field and the manner each one is used are detailed in the section 5.3.

Table 4.3 - Record for a PDO data mapping

Sub-index	Entry description	Type
00h	Number of objects mapped in the PDO	UNSIGNED8
01h	1st mapped object	UNSIGNED32
02h	2nd mapped object	UNSIGNED32
	...	
	...	
	...	
40h	64th mapped object	UNSIGNED32

SDO PARAMETER: this *record* defines the necessary information for configuring a CANopen communication SDO. The content of the field and the manner each one is used are detailed in the section 5.2.

Table 4.4 - Record for SDOs configuration

Sub-index	Entry description	Type
00h	Number of entries supported in this *record*	UNSIGNED8
01h	client → server COB-ID	UNSIGNED32
02h	server → client COB-ID	UNSIGNED32
03h	client/server Node-ID	UNSIGNED8

IDENTITY: this *record* is used to describe the type of device present in the network.

Table 4.5 - Record for device identification

Sub-index	Entry description	Type
00h	Number of entries supported in this *record*	UNSIGNED8
01h	*Vendor-ID*	UNSIGNED32
02h	*Product Code*	UNSIGNED32
03h	*Revision Number*	UNSIGNED32
04h	*Serial Number*	UNSIGNED32

4.2.3 Extended Types

The CFW-11 does not have extended types.

4.3 *Communication Profile* – Communication Objects

The indexes from 1000h to 1FFFh in the object dictionary correspond to the part responsible for the CANopen network communication configuration. Those objects are common to all the devices, however only a few are obligatory. A list with the objects of this range that are supported by the inverter is presented next.

Table 4.6 - *CFW-11 object list – Communication Profile*

Index	Object	Name	Type	Access
1000h	VAR	device type	UNSIGNED32	Ro
1001h	VAR	error register	UNSIGNED8	Ro
1005h	VAR	COB-ID SYNC	UNSIGNED32	Rw
100Ch	VAR	guard time	UNSIGNED16	Rw
100Dh	VAR	life time factor	UNSIGNED8	Rw
1014h	VAR	COB-ID EMCY	UNSIGNED32	Ro
1016h	ARRAY	Consumer heartbeat time	UNSIGNED32	Rw
1017h	VAR	Producer heartbeat time	UNSIGNED16	Rw
1018h	RECORD	Identity Object	Identity	Ro
Server SDO Parameter				
1200h	RECORD	1st Server SDO parameter	SDO Parameter	Ro
Receive PDO Communication Parameter				
1400h	RECORD	1st receive PDO Parameter	PDO CommPar	Rw
1401h	RECORD	2nd receive PDO Parameter	PDO CommPar	Rw
1402h	RECORD	3rd receive PDO Parameter	PDO CommPar	Rw
1403h	RECORD	4th receive PDO Parameter	PDO CommPar	Rw
Receive PDO Mapping Parameter				
1600h	RECORD	1st receive PDO mapping	PDO Mapping	Rw
1601h	RECORD	2nd receive PDO mapping	PDO Mapping	Rw
1602h	RECORD	3rd receive PDO mapping	PDO Mapping	Rw
1603h	RECORD	4th receive PDO mapping	PDO Mapping	Rw
Transmit PDO Communication Parameter				
1800h	RECORD	1st transmit PDO Parameter	PDO CommPar	Rw
1801h	RECORD	2nd transmit PDO Parameter	PDO CommPar	Rw
1802h	RECORD	3rd transmit PDO Parameter	PDO CommPar	Rw
1803h	RECORD	4th transmit PDO Parameter	PDO CommPar	Rw
Transmit PDO Mapping Parameter				
1A00h	RECORD	1st transmit PDO mapping	PDO Mapping	Rw
1A01h	RECORD	2nd transmit PDO mapping	PDO Mapping	Rw
1A02h	RECORD	3rd transmit PDO mapping	PDO Mapping	Rw
1A03h	RECORD	4th transmit PDO mapping	PDO Mapping	Rw

The other objects not presented in this list are not used by the CFW-11, otherwise they are in reserved ranges of the dictionary.

4.4 *Manufacturer Specific* – CFW-11 Specific Objects

For indexes from 2000h to 5FFFh, each manufacture is free to define which objects will be present, and also the type and function of each one. In the case of the CFW-11, the whole list of parameters was made available in this object range. It is possible to operate the CFW-11 by means of these parameters, carrying out any function that the inverter can execute. The parameters were made available starting from the index 2000h, and by adding their number to this index their position in the dictionary is obtained. The next table illustrates how the parameters are distributed in the object dictionary.

Table 4.7 - *CFW-11 object list – Manufacturer Specific*

Index	Object	Name	Type	Access
2000h	VAR	P0000 – Access parameter	INTEGER16	rw
2001h	VAR	P0001 – Speed reference	INTEGER16	ro
2002h	VAR	P0002 – Motor speed	INTEGER16	ro
2003h	VAR	P0003 – Motor current	INTEGER16	ro
2004h	VAR	P0004 – DC voltage	INTEGER16	ro
...	...	...	...	...
2064h	VAR	P0100 – Acceleration time	INTEGER16	rw
2065h	VAR	P0101 – Deceleration time	INTEGER16	rw
...	...	...	...	...

Refer to the CFW-11 manual for a complete list of the parameters and their detailed description. In order to be able to program the inverter operation correctly via the CANopen network, it is necessary to know its operation through the parameters.

4.5 *Device Profile* – COMMON Objects for Drives

The CANopen documentation also includes suggestions for standardization of certain device types. In the case of the CFW-11, it follows the *CiA DPS 402 – Device Profile Drives and Motion Control* description. This document describes a set of objects that must be common for drives, regardless of the manufacturer. This makes the interaction between devices with the same function easier (as for frequency inverters), because the data, as well as the device behavior, are made available in a standardized manner.

For those objects the indexes from 6000h to 9FFFh were reserved. It is possible to operate the inverter through the CANopen network via the parameters (located from the index 2000h on), as well as by means of these standardized objects. Refer to the section 6 for a detailed description of which objects are available for this range of the object dictionary.

5 Communication Objects Description

In this section each of the objects mentioned in the table 4.6 is fully described, besides also describing the operation of the communication objects (COBs) mentioned in section 1.7. It is necessary to know how these objects are operated in order to be able to use the available functions for the CFW-11 communication.

5.1 Identification Objects

There is a set of objects in the dictionary which are used for equipment identification; however, they do not have influence on their behavior in the CANopen network.

5.1.1 1000h Object – *Device Type*

This object gives a 32-bit code that describes the type of object and its functionality.

Index	1000h
Name	Device type
Object	VAR
Type	UNSIGNED32

Access	ro
Mappable	No
Range	UNSIGNED32
Default value	0001.0192h

This code can be divided into two parts: 16 low-order bits describing the type of profile that the device uses, and 16 high-order bits indicating a specific function according to the specified profile. For the CFW-11 these values are respectively 0192h (it follows the specified by the *CiA 402 - Device Profile Drives and Motion Control* document), and 0001h (it has frequency inverter functionalities).

5.1.2 1001h Object – *Error Register*

This object indicates whether or not an error in the device occurred. The type of error registered for the CFW-11 follows what is described in the table 5.1.

Index	1001h
Name	Error register
Object	VAR
Type	UNSIGNED8

Access	ro
Mappable	Yes
Range	UNSIGNED8
Default value	0

Table 5.1 - Structure of the object Error Register

Bit	Meaning
0	Generic error
1	Current
2	Voltage
3	Temperature
4	Communication
5	Reserved (always 0)
6	Reserved (always 0)
7	Specific of the manufacturer

If the device presents any error, the equivalent bit must be activated. The first bit (generic error) must be activated with any error condition.

5.1.3 1018h Object – *Identity Object*

It brings general information about the device.

Index	1018h
Name	Identity object
Object	Record
Type	Identity

Sub-index	0
Description	Number of the last sub-index
Access	ro
Mappable	No
Range	UNSIGNED8
Default value	4

Sub-index	1
Description	Vendor ID
Access	ro
Mappable	No
Range	UNSIGNED32
Default value	0000.0123h

Sub-index	2
Description	Product code
Access	ro
Mappable	No
Range	UNSIGNED32
Default value	0000.0400h

Sub-index	3
Description	Revision number
Access	ro
Mappable	No
Range	UNSIGNED32
Default value	According to the equipment firmware version

Sub-index	4
Description	Serial number
Access	ro
Mappable	No
Range	UNSIGNED32
Default value	Different for every CFW-11

The vendor ID is the number that identifies the manufacturer at the CiA. The product code is defined by the manufacturer according to the type of product. The revision number represents the equipment firmware version. The sub-index 4 is a unique serial number for each frequency inverter CFW-11 in CANopen network.

5.2 Service Data Objects – SDOS

The SDOs are responsible for the direct access to the object dictionary of a specific device in the network. They are used for the configuration and therefore have low priority, since they do not have to be used for communicating data necessary for the device operation.

There are two types of SDOs: client and server. Basically, the communication initiates with the client (usually the master of the network) making a read (*upload*) or write (*download*) request to a server, and then this server answers the request.

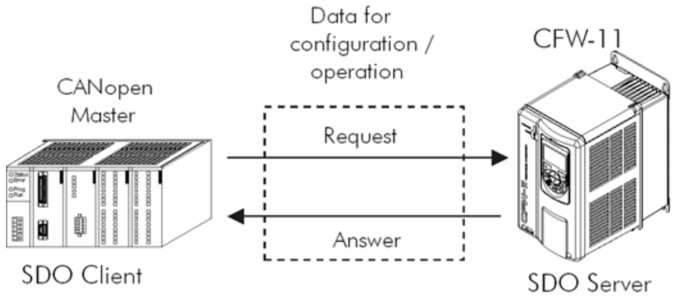


Figure 5-1 - *Communication between SDO client and server*

5.2.1 1200h Object – SDO Server

The CFW-11 has only one SDO of the server type, which makes it possible the access to its entire object dictionary. Through it, an SDO client can configure the communication, the parameters and the inverter operation. Every SDO server has an object, of the SDO_PARAMETER type (refer to section 4.2.2), for its configuration, having the following structure:

Index	1200h
Name	SDO Server Parameter
Object	Record
Type	SDO Parameter

Sub-index	0
Description	Number of the last sub-index
Access	ro
Mappable	No
Range	UNSIGNED8
Default value	2

Sub-index	1
Description	COB-ID Client - Server (rx)
Access	ro
Mappable	No
Range	UNSIGNED32
Default value	600h + Node-ID

Sub-index	2
Description	COB-ID Server - Client (tx)
Access	ro
Mappable	No
Range	UNSIGNED32
Default value	580h + Node-ID

5.2.2 SDOs Operation

A telegram sent by an SDO has an 8 byte size, with the following structure:

Identifier	*8 data bytes*							
	Command	Index		Sub-index	Object data			
11 bits	byte 0	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7

The identifier depends on the transmission direction (rx or tx) and on the address (or Node-ID) of the destination server. For instance, a client that makes a request to a server which Node-ID is 1, must send a message with the identifier 601h. The server will receive this message and answer with a telegram which COB-ID is equal to 581h.

The command code depends on the used function type. For the transmissions from a client to a server, the following commands can be used:

Table 5.2 - Command codes for SDO client

Command	Function	Description	Object data
22h	*Download*	Write object	Not defined
23h	*Download*	Write object	4 bytes
2Bh	*Download*	Write object	2 bytes
2Fh	*Download*	Write object	1 byte
40h	*Upload*	Read object	Not used
60h or 70h	*Upload segment*	Segmented read	Not used

When making a request, the client will indicate through its COB-ID, the address of the slave to which this request is destined. Only a slave (using its respective SDO server) will be able to answer the received telegram to the client. The answer telegram will have also the same structure of the request telegram, the commands however are different:

Table 5.3 - Command codes for SDO server

Command	Function	Description	Object data
60h	*Download*	Response to write object	Not used
43h	*Upload*	Response to read object	4 bytes
4Bh	*Upload*	Response to read object	2 bytes
4Fh	*Upload*	Response to read object	1 byte
41h	*Upload segment*	Initiates segmented response for read	4 bytes
01h ... 0Dh	*Upload segment*	Last data segment for read	8 ... 2 bytes

For readings of up to four data bytes, a single message can be transmitted by the server; for the reading of a bigger quantity of bytes, it is necessary that the client and the server exchange multiple telegrams.

A telegram is only completed after the acknowledgement of the server to the request of the client. If any error is detected during telegram exchanges (for instance, no answer from the server), the client will be able to abort the process by means of a warning message with the command code equal to 80h.

NOTE!
When the SDO is used for writing in objects that represent the CFW-11 parameters (objects starting from the index 2000h), this value is saved in the nonvolatile frequency inverter memory. Therefore, the configured values are not lost after the equipment is switched off or reset. For all the other objects these values are not saved automatically, so that it is necessary to rewrite the desired values.

E.g.: A client SDO requests for a CFW-11 at address 1 the reading of the object identified by the index 2000h, sub-index 0 (zero), which represents an 16-bit integer. The master telegram has the following format:

Identifier	*Command*	*Index*		*Sub-index*	*Data*			
601h	40h	00h	20h	00h	00h	00h	00h	00h

The CFW-11 responds to the request indicating that the value of the referred object is equal to 999[7]:

Identifier	*Command*	*Index*		*Sub-index*	*Data*			
581h	4Bh	00h	20h	00h	E7	03h	00h	00h

5.3 Process Data Objects – PDOS

The PDOs are used to send and receive data used during the device operation, which must often be transmitted in a fast and efficient manner. Therefore, they have a higher priority than the SDOs.

In the PDOs only data are transmitted in the telegram (index and sub-index are omitted), and in this way it is possible to do a more efficient transmission, with larger volume of data in a single telegram. However it is necessary to configure previously what is being transmitted by the PDO, so that even without the indication of the index and sub-index, it is possible to know the content of the telegram.

There are two types of PDOs, the receive PDO and the transmit PDO. The transmit PDOs are responsible for sending data to the network, whereas the receive PDOs remain responsible for receiving and handling these data.

[7] Do not forget that for any integer type of data, the byte transfer order is from the least significant to the most significant.

In this way it is possible to have communication among slaves of the CANopen network, it is only necessary to configure one slave to transmit information and one or more slaves to receive this information.

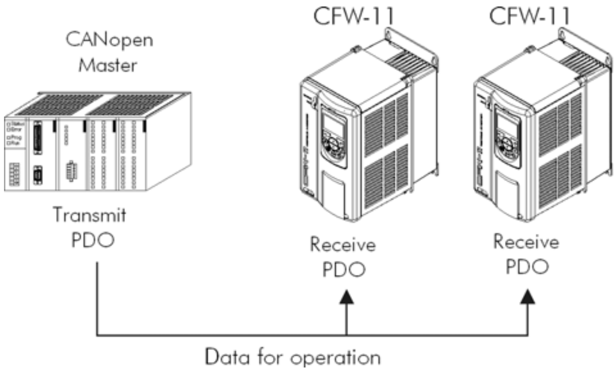


Figure 5-2 - Communication using PDOs

NOTE!
PDOs can only be transmitted or received when the device is in the operational state. The figure 5.5 illustrates the available states for CANopen network node.

5.3.1 Mappable Objects for the PDOs

In order to be able to be transmitted by a PDO, it is necessary that an object be mappable for this PDO content. In the description of communication objects (1000h – 1FFFh), the filed "Mappable" informs this possibility. Usually only information necessary for the operation of the device is mappable, such as enabling commands, device status, reference, etc. Information on the device configuration are not accessible through PDOs, and if it is necessary to access them one must use the SDOs.

For CFW-11 specific objects (2000h – 5FFFh), the next table presents some objects mappable for the PDOs. Read-only parameters (ro) can be used only by transmit PDOs, whereas the other parameters can be used only by receive PDOs. The CFW-11 EDS file brings the list of all the objects available for the inverter, informing whether the object is mappable or not.

Table 5.4 - Examples of mappable parameters for PDOs

Index	Object	Name	Type	Access
2002h	VAR	P0002 – Motor speed	UNSIGNED16	ro
2003h	VAR	P0003 – Motor current	UNSIGNED16	ro
2004h	VAR	P0004 – DC link voltage (Ud)	UNSIGNED16	ro
2005h	VAR	P0005 – Motor frequency	UNSIGNED16	ro
2006h	VAR	P0006 – Inverter status	UNSIGNED16	ro
2007h	VAR	P0007 – Output voltage	UNSIGNED16	ro
2009h	VAR	P0009 – Motor torque	INTEGER16	ro
200Ah	VAR	P0010 – Output power	UNSIGNED16	ro
200Ch	VAR	P0012 – DI1 to DI8 status	UNSIGNED16	ro
200Dh	VAR	P0013 – DO1 to RL3 status	UNSIGNED16	ro
2012h	VAR	P0018 – AI1 value	INTEGER16	ro
2013h	VAR	P0019 – AI2 value	INTEGER16	ro
2014h	VAR	P0020 – AI3 value	INTEGER16	ro
2015h	VAR	P0021 – AI4 value	INTEGER16	ro
2064h	VAR	P0100 – Acceleration time	UNSIGNED16	rw
2065h	VAR	P0101 – Deceleration time	UNSIGNED16	rw
22A8h	VAR	P0680 – Logical status	UNSIGNED16	ro
22A9h	VAR	P0681 – Motor speed in 13 bits	UNSIGNED16	ro
22ACh	VAR	P0684 – Control CANopen/DeviceNet	UNSIGNED16	rw
22ADh	VAR	P0685 – Speed reference CANopen/DeviceNet	UNSIGNED16	rw

5.3.2 Receive PDOs

The receive PDOs, or RPDOs, are responsible for receiving data that other devices send to the CANopen network. The CFW-11 has 4 receive PDOs, each one being able to receive up to 8 bytes. Each RPDO has two parameters for its configuration, a PDO_COMM_PARAMETER and a PDO_MAPPING, as described next.

PDO_COMM_PARAMETER

Index	1400h
Name	Receive PDO communication parameter
Object	Record
Type	PDO COMM PARAMETER

Sub-index	0
Description	Number of the last sub-index
Access	ro
Mappable	No
Range	UNSIGNED8
Default value	2

Sub-index	1
Description	COB-ID used by the PDO
Access	rw
Mappable	No
Range	UNSIGNED32
Default value	1400h: 200h + Node-ID 1401h: 300h + Node-ID 1402h: 400h + Node-ID 1403h: 500h + Node-ID

Sub-index	2
Description	Type of transmission
Access	rw
Mappable	No
Range	UNSIGNED8
Default value	254

The sub-index 1 contains the receive PDO COB-ID. Every time a message is sent to the network, this object will read the COB-ID of that message and, if it is equal to the value of this field, the message will be received by the device. This field is formed by an UNSIGNED32 with the following structure:

Table 5.5 - COB-ID description

Bit	Value	Description
31 (MSB)	0	PDO is enabled
	1	PDO is disabled
30	0	RTR permitted
29	0	Identifier size = 11 bits
28 – 11	0	Not used, always 0
10 – 0 (LSB)	X	11-bit COB-ID

The bit 31 allows enabling or disabling the PDO. The bits 29 and 30 must be kept in 0 (zero), they indicate respectively that the PDO accepts remote frames (RTR frames) and that it uses an 11-bit identifier. Since the CFW-11 frequency inverter does not use 29-bit identifiers, the bits from 28 to 11 must be kept in 0 (zero), whereas the bits from 10 to 0 (zero) are used to configure the COB-ID for the PDO.

The sub-index 2 indicates the transmission type of this object, according to the next table.

Table 5.6 - Description of the type of transmission

Type of transmission	PDOs transmission				
	Cyclic	*Acyclic*	*Synchronous*	*Asynchronous*	*RTR*
0		•	•		
1 – 240	•		•		
241 – 251	Reserved				
252			•		•
253				•	•
254				•	
255				•	

- ☑ **Values 0 – 240:** any RPDO programmed in this range presents the same performance. When detecting a message, it will receive the data; however it won't update the received values until detecting the next SYNC telegram.
- ☑ **Values 252 and 253:** not allowed for receive PDOs.
- ☑ **Values 254 and 255:** they indicated that there is no relationship with the synchronization object. When receiving a message, its values are updated immediately.

PDO_MAPPING

Index	1600h
Name	Receive PDO mapping
Object	Record
Type	PDO MAPPING

Sub-index	0
Description	Number of mapped objects
Access	ro
Mappable	No
Range	0 = disabled 1 ... 4 = number of mapped objects
Default value	1600h: 1 1601h: 2 1602h: 2 1603h: 2

Sub-index	1
Description	1st object mapped in the PDO
Access	rw
Mappable	No
Range	UNSIGNED32
Default value	1600h: 6040.0010h 1601h: 6040.0010h 1602h: 6040.0010h 1603h: 22AC.0010h

Sub-index	2
Description	2nd object mapped in the PDO
Access	rw
Mappable	No
Range	UNSIGNED32
Default value	1600h: 0 1601h: 6060.0008h 1602h: 6042.0010h 1603h: 22AD.0010h

Sub-index	3
Description	3rd object mapped in the PDO
Access	rw
Mappable	No
Range	UNSIGNED32
Default value	1600h: 0 1601h: 0 1602h: 0 1603h: 0

Sub-index	4
Description	4th object mapped in the PDO
Access	rw
Mappable	No
Range	UNSIGNED32
Default value	1600h: 0 1601h: 0 1602h: 0 1603h: 0

This parameter indicates the mapped objects in the CFW-11 receive PDOs. It is possible to map up to four different objects for each RPDO, provided that the total length does not exceed eight bytes. The mapping of an object is done indicating its index, sub-index[8] and size (in bits) in an UNSIGNED32, field with the following format:

UNSIGNED32		
Index (16 bits)	Sub-index (8 bits)	Size of the object (8 bits)

For instance, analyzing the receive PDO standard mapping, we have:

- ☑ **Sub-index 0 = 2:** the RPDO has two mapped objects.
- ☑ **Sub-index 1 = 22AC.0010h:** the first mapped object has an index equal to 22ACh, sub-index 0 (zero), and a size of 16 bits. This object corresponds to the inverter parameter P0684, which represents the CANopen control word.
- ☑ **Sub-index 2 = 22AD.0010h:** the second mapped object has an index equal to 22ADh, sub-index 0 (zero), and a size of 16 bits. This object corresponds to the inverter parameter P0685, which represents the speed reference.

Therefore, every time this PDO receives a telegram, it knows that the telegram must contain four data bytes, with the contents for the CFW-11 control word and speed reference. It is possible to modify this mapping by changing the quantity or the number of mapped objects. Remember that a maximum of 4 objects or 8 bytes can be mapped.

NOTE!

- ☑ In order to change the mapped objects in a PDO, it is first necessary to write the value 0 (zero) in the sub-index 0 (zero). In that way the values of the sub-indexes 1 to 4 can be changed. After the desired mapping has been done, one must write again in the sub-index 0 (zero) the number of objects that have been mapped, enabling again the PDO.
- ☑ In order to speed up the updating of data via PDO, the values received with these objects are not saved in the inverter non-volatile memory. Therefore, after switching off or resetting the equipment the objects modified by an RPDO get back to their default value.
- ☑ Do not forget that PDOs can only be received if the CFW-11 is in the operational state.

5.3.3 Transmit PDOs

The transmit PDOs, or TPDOs, as the name says, are responsible for transmitting data for the CANopen network. The CFW-11 has 4 transmit PDOs, each one being able to transmit up to 8 data bytes. In a manner similar to RPDOs, each TPDO has two parameters for its configuration, a PDO_COMM_PARAMETER and a PDO_MAPPING, AS DESCRIBED NEXT.

PDO_COMM_PARAMETER

Index	1800h
Name	Transmit PDO Parameter
Object	Record
Type	PDO COMM PARAMETER

[8] If the object is of the VAR type and does not have sub-index, the value 0 (zero) must be indicated for the sub-index.

Sub-index	0
Description	Number of the last sub-index
Access	ro
Mappable	No
Range	UNSIGNED8
Default value	5

Sub-index	1
Description	COB-ID used by the PDO
Access	rw
Mappable	No
Range	UNSIGNED32
Default value	1800h: 180h + Node-ID 1801h: 280h + Node-ID 1802h: 380h + Node-ID 1803h: 480h + Node-ID

Sub-index	2
Description	Type of transmission
Access	rw
Mappable	No
Range	UNSIGNED8
Default value	254

Sub-index	3
Description	Time between transmissions
Access	rw
Mappable	No
Range	UNSIGNED16
Default value	-

Sub-index	4
Description	Reserved
Access	rw
Mappable	No
Range	UNSIGNED8
Default value	-

Sub-index	5
Description	Event timer
Access	rw
Mappable	No
Range	0 = disabled UNSIGNED16
Default value	0

The sub-index 1 contains the transmit PDO COB-ID. Every time this PDO sends a message to the network, the identifier of that message will be this COB-ID. The structure of this field is described in table 5.5.

The sub-index 2 indicates the transmission type of this object, which follows the table 5.6 description. Its working is however different for transmit PDOs:

- ☑ Value 0: indicates that the transmission must occur immediately after the reception of a SYNC telegram, but not periodically.
- ☑ Values 1 – 240: the PDO must be transmitted at each detected SYNC telegram (or multiple occurrences of SYNC, according to the number chosen between 1 and 240).
- ☑ Value 252: indicates that the message content must be updated (but not sent) after the reception of a SYNC telegram. The transmission of the message must be done after the reception of a remote frame (RTR frame).
- ☑ Value 253: the PDO must update and send a message as soon as it receives a remote frame.
- ☑ Values 254: The object must be transmitted according to the timer programmed in sub-index 5.
- ☑ Values 255: the object is transmitted automatically when the value of any of the objects mapped in this PDO is changed. It works by changing the state (*Change of State*). This type does also allow that the PDO be transmitted according to the timer programmed in sub-index 5.

In the sub-index 3 it is possible to program a minimum time (in multiples of 100μs) that must elapse after the a telegram has been sent, so that a new one can be sent by this PDO. The value 0 (zero) disables this function.

The sub-index 5 contains a value to enable a timer for the automatic sending of a PDO. Therefore, whenever a PDO is configured as the asynchronous type, it is possible to program the value of this timer (in multiples of 1ms), so that the PDO is transmitted periodically in the programmed time.

NOTE!

☑ The value of this timer must be programmed according to the used transmission rate. Very short times (close to the transmission time of the telegram) are able to monopolize the bus, causing indefinite retransmission of the PDO, and avoiding that other less priority objects transmit their data.

☑ The minimum time allowed for this Function in CFW-11 is 2ms.

☑ It is important to observe the time between transmissions programmed in the sub-index 3, especially when the PDO is programmed with the value 255 in the sub-index 2 (*Change of State*).

☑ Do not forget that PDOs can only be transmitted if the slave is in operational state.

PDO_MAPPING

Index	1A00h
Name	Transmit PDO mapping
Object	Record
Type	PDO MAPPING

Sub-index	0
Description	Number of the last sub-index
Access	ro
Mappable	No
Range	0 = disabled 1 ... 4 = number of mapped objects
Default value	1A00h: 1 1A01h: 2 1A02h: 2 1A03h: 2

Sub-index	1
Description	1st object mapped in the PDO
Access	rw
Mappable	No
Range	UNSIGNED32
Default value	1A00h: 6041.0010h 1A01h: 6041.0010h 1A02h: 6041.0010h 1A03h: 22A8.0010h

Sub-index	2
Description	2nd object mapped in the PDO
Access	rw
Mappable	No
Range	UNSIGNED32
Default value	1A00h: 0 1A01h: 6061.0008h 1A02h: 6044.0010h 1A03h: 22A9.0010h

Sub-index	3
Description	3rd object mapped in the PDO
Access	rw
Mappable	No
Range	UNSIGNED32
Default value	1A00h: 0 1A01h: 0 1A02h: 0 1A03h: 0

Sub-index	4
Description	4th object mapped in the PDO
Access	rw
Mappable	No
Range	UNSIGNED32
Default value	1A00h: 0 1A01h: 0 1A02h: 0 1A03h: 0

The PDO MAPPING for the transmission works in similar way than for the reception, however in this case the data to be transmitted by the PDO are defined. Each mapped object must be put in the list according to the description showed next:

UNSIGNED32		
Index (16 bits)	Sub-index (8 bits)	Size of the object (8 bits)

For instance, analyzing the standard mapping of the fourth transmit PDO, we have:

☑ **Sub-index 0 = 2:** This PDO has two mapped objects.
☑ **Sub-index 1 = 22A8.0010h:** the first mapped object has an index equal to 22A8h, sub-index 0 (zero), and a size of 16 bits. This object corresponds to the inverter parameter P0680, which represents the inverter logical status.
☑ **Sub-index 2 = 22A9.0010h:** the second mapped object has an index equal to 22A9h, sub-index 0 (zero), and a size of 16 bits. This object corresponds to the inverter parameter P0681, which represents the motor speed.

Therefore, every time this PDO transmits its data, it elaborates its telegram containing four data bytes, with the values of the parameters P0680 and P0681. It is possible to modify this mapping by changing the quantity or the number of mapped objects. Remember that a maximum of 4 objects or 8 bytes can be mapped.

NOTE!
In order to change the mapped objects in a PDO, it is first necessary to write the value 0 (zero) in the sub-index 0 (zero). In that way the values of the sub-indexes 1 to 4 can be changed. After the desired mapping has been done, one must write again in the sub-index 0 (zero) the number of objects that have been mapped, enabling again the PDO.

5.4 Emergency Object – EMCY

The emergency object (EMCY) is used to signalize the occurrence of an error in the device. Every time that an error occurs in the CFW-11 (short-circuit, overvoltage, communication failure, etc.), this object will send an emergency message to the network. This message can be interpreted by an EMCY consumer (usually the network master), which will be able to take an action according to the programmed for the application, such as performing an error reset or disabling the other devices in the network.

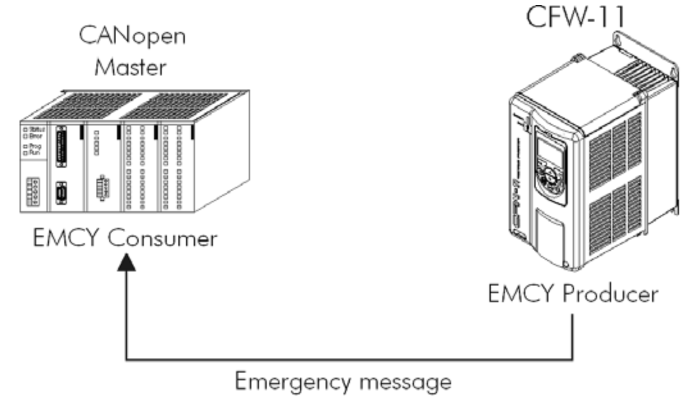


Figure 5-3 - *EMCY*

When transmitting a message, three pieces of information are sent with the eight data bytes: the CiA error code, the object 1001h (*error register*) and the CFW-11 fault code. The telegram has then the following structure:

byte 0	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7
CIA error code		Object 1001h Error Register	CFW-11 error code	Reserved			

This object is always active in the CFW-11 and therefore it will always report the occurrence of inverter errors to the network. There is a single parameter that allows reading the object COB-ID, i.e. which identifier for the sent error message telegrams.

Index	1014h
Name	COB-ID emergency message
Object	VAR
Type	UNSIGNED32

Access	ro
Mappable	No
Range	UNSIGNED32
Default value	80h + Node-ID

5.5 Synchronization Object – SYNC

This object is transmitted with the purpose of allowing the synchronization of events among the CANopen network devices. It is transmitted by a SYNC producer, and the devices that detect its transmission are named SYNC consumers

The CFW-11 has the function of a SYNC consumer and, therefore, it can program its PDOs to be synchronous. As described in table 5.6, synchronous PDOs are those related to the synchronization object, thus they can be programmed to be transmitted or updated based in this object.

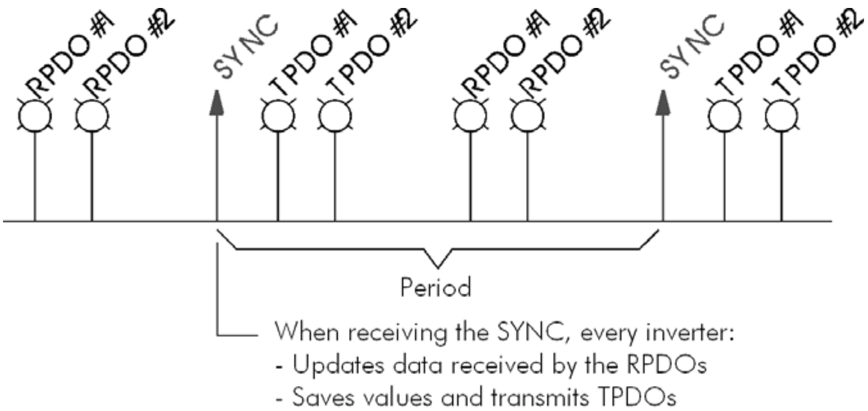


Figure 5-4 - *SYNC*

The SYNC message transmitted by the producer does not have any data in its data field, because its purpose is to provide a time base for the other objects. There is an object in the CFW-11 for the configuration of the COB-ID of the SYNC consumer.

Index	1015h
Name	COB-ID SYNC
Object	VAR
Type	UNSIGNED32

Access	rw
Mappable	No
Range	UNSIGNED32
Default value	80h

NOTE!
The period of the SYNC telegrams must be programmed in the producer according to the transmission rate and the number of synchronous PDOs to be transmitted. There must be enough time for the transmission of these objects, and it is also recommended that there is a tolerance to make it possible the transmission of asynchronous messages, such as EMCY, asynchronous PDOs and SDOs.

5.6 Network Management – NMT

The network management object is responsible for a series of services that control the communication of the device in a CANopen network. For the CFW-11 the services of node control and error control are available (using *Node Guarding* or *Heartbeat*).

5.6.1 Slave State Control

With respect to the communication, a CANopen network device can be described by the following state machine:

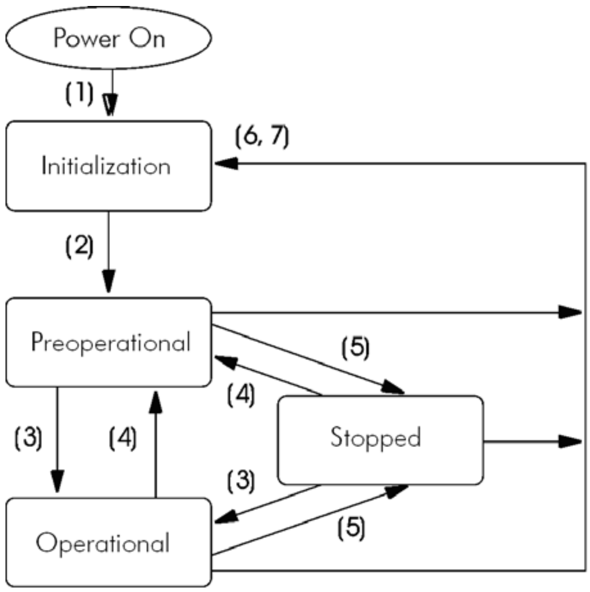


Figure 5-5 - CANopen node state diagram

Table 5.7 - Transitions Description

Transition	Description
1	The device is switched on and initiates the initialization (automatic).
2	Initialization concluded, it goes to the preoperational state (automatic).
3	It receives the Start Node command for entering the operational state.
4	It receives the Enter Pre-Operational command, and goes to the preoperational state.
5	It receives the Stop Node command for entering the stopped state.
6	It receives the Reset Node command, when it executes the device complete reset.
7	It receives the Reset Communication command, when it reinitializes the object values and the CANopen device communication.

During the initialization the Node-ID is defined, the objects are created and the interface with the CAN network is configured. Communication with the device is not possible during this stage, which is concluded automatically. At the end of this stage the slave sends to the network a telegram of the Boot-up Object, used only to indicate that the initialization has been concluded and that the slave has entered the preoperational state. This telegram has the identifier 700h + Node-ID, and only one data byte with value equal to 0 (zero).

In the preoperational state it is already possible to communicate with the slave, but its PDOs are not yet available for operation. In the operational state all the objects are available, whereas in the stopped state only the NMT object can receive or transmit telegrams to the network. The next table shows the objects available for each state.

Table 5.8 - Objects accessible in each state

	Initialization	Preoperational	Operational	Stopped
PDO			•	
SDO		•	•	
SYNC		•	•	
EMCY		•	•	
Boot-up	•			
NMT		•	•	•

This state machine is controlled by the network master, which sends to each slave the commands so that the desired state change be executed. These telegrams do not have confirmation, what means that the slave does only receive the telegram without returning an answer to the master. The received telegrams have the following structure:

Identifier	*byte 1*	*byte 2*
00h	Command code	Destination Node-ID

Table 5.9 - Commands for the state transition

Command code	Destination Node-ID
1 = *START node* (transition 3) 2 = *STOP node* (transition 4) 128 = *Enter pre-operational* (transition 5) 129 = *Reset node* (transition 6) 130 = *Reset communication* (transition 7)	0 = All the slaves 1 ... 127 = Specific slave

The transitions indicated in the command code correspond to the state transitions executed by the node after receiving the command (according to the Figure 5-5). The *Reset node* command makes the CFW-11 execute a complete reset of the device, while the *Reset communication* command causes the device to reinitialize only the objects pertinent to the CANopen communication.

5.6.2 Error Control – *Node Guarding*

This service is used to make it possible the monitoring of the communication with the CANopen network, both by the master and the slave as well. In this type of service the master sends periodical telegrams to the slave, which responds to the received telegram. If some error that interrupts the communication occurs, it will be possible to identify this error, because the master as well as the slave will be notified by the *Timeout* in the execution of this service. The error events are called *Node Guarding* for the master and *Life Guarding* for the slave.

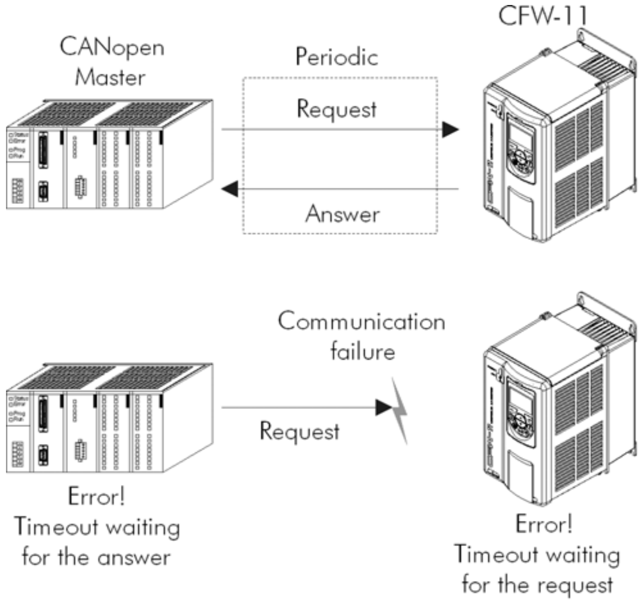


Figure 5-6 - *Error control service – Node Guarding*

There are two objects of the dictionary for the configuration of the error detection times for the *Node Guarding* service:

Index	100Ch
Name	Guard Time
Object	VAR
Type	UNSIGNED16

Access	rw
Mappable	No
Range	UNSIGNED16
Default value	0

Index	100Dh
Name	Life Time Factor
Object	VAR
Type	UNSIGNED8

Access	rw
Mappable	No
Range	UNSIGNED8
Default value	0

The 100Ch object allows programming the time necessary (in milliseconds) for a fault occurrence being detected, in case the CFW-11 does not receive any telegram from the master. The 100Dh object indicates how many faults in sequence are necessary until it be considered that there was really a communication error. Therefore, the multiplication of these two values will result in the total necessary time for the communication error detection using this object. The value 0 (zero) disables this function.

Once configured, the CFW-11 starts counting these times starting from the first *Node Guarding* telegram received from the network master. The master telegram is of the remote type, not having data bytes. The identifier is equal to 700h + Node-ID of the destination slave. However the slave response telegram has 1 data byte with the following structure:

Identifier	*byte 1*	
	bit 7	bit 6 … bit 0
700h + Node-ID	Toggle	Slave state

This telegram has one single data byte. This byte contains, in the seven least significant bits, a value to indicate the slave state (4 = stopped, 5 = operational and 127 = preoperational), and in the eighth bit, a value that must be changed at every telegram sent by the slave (*toggle bit*).

If the CFW-11 detects an error using this mechanism, it will turn automatically to the preoperational state and indicate alarm A135 on its HMI. The occurrence of this error can also be observed through the parameter P0721. It is also possible to program the inverter for taking an action when this error occurs, by means of the parameter P0313. Refer to the item 3 of the detailed description of the parameters.

NOTE!
- ☑ This object is active even in the stopped state (see table 5.8).
- ☑ The value 0 (zero) in any of these two objects will disable this function.
- ☑ If after the error detection the service is enabled again, then the error indication will be removed from the HMI.
- ☑ The minimum value accepted by the CFW-11 is 2ms, but considering the transmission rate and the number of nodes in the network, the times programmed for this function must be consistent, so that there is enough time for the transmission of the telegrams and also that the rest of the communication be able to be processed.
- ☑ For any every slave only one of the two services - *Heartbeat* or *Node Guarding* – can be enabled.

5.6.3 Error Control – *Heartbeat*

The error detection through the *Heartbeat* mechanism is done using two types of objects: the *Heartbeat* producer and the *Heartbeat* consumer. The producer is responsible for sending periodic telegrams to the network, simulating a heartbeat, indicating that the communication is active and without errors. One or more consumers can monitor these periodic telegrams, and if they cease occurring, it means that any communication problem occurred.

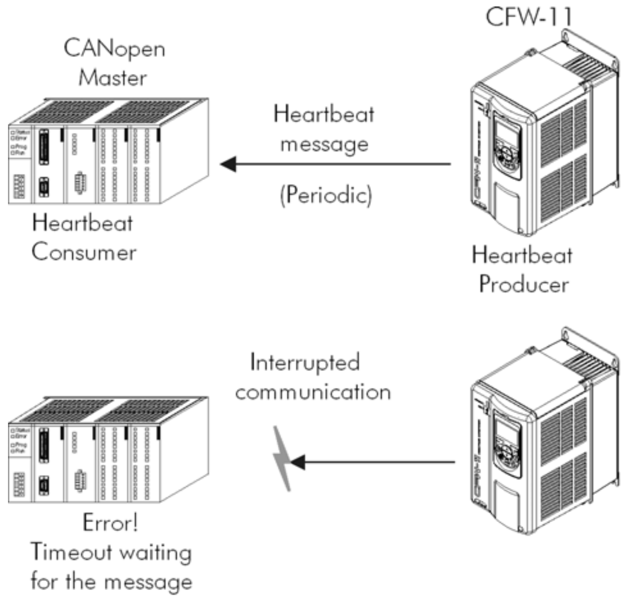


Figure 5-7 - Error control service – Heartbeat

One device of the network can be both producer and consumer of *heartbeat* messages. For example, the network master can consume messages sent by a slave, making it possible to detect communication problems with the master, and simultaneously the slave can consume *heartbeat* messages sent by the master, also making it possible to the slave detect communication fault with the master..

The CFW-11 has the producer and consumer of *heartbeat* services. As a consumer, it is possible to program up to 4 different producers to be monitored by the inverter.

Index	1016h
Name	Consumer Heartbeat Time
Object	ARRAY
Type	UNSIGNED32

Sub-index	0
Description	Number of the last sub-index
Access	ro
Mappable	No
Range	-
Default value	4

Sub-indexs	1 – 4
Description	Consumer Heartbeat Time 1 – 4
Access	rw
Mappable	No
Range	UNSIGNED32
Default value	0

At sub-indexes 1 to 4, it is possible to program the consumer by writing a value with the following format:

UNSIGNED32		
Reserved (8 bits)	Node-ID (8 bits)	Heartbeat time (16 bits)

☑ **Node-ID**: it allows programming the Node_ID for the *heartbeat* producer to be monitored.
☑ ***Heartbeat time***: it allows programming the time, in 1 millisecond multiples, until the error detection if no message of the producer is received. The value 0 (zero) in this field disables the consumer.

Once configured, the *heartbeat* consumer initiates the monitoring after the reception of the first telegram sent by the producer. In case that an error is detected because the consumer stopped receiving messages from the *heartbeat* producer, the inverter will turn automatically to the preoperational state and indicate alarm A135 on its HMI. The occurrence of this error can also be observed through the parameter P0721.

As a producer, the CFW-11 has an object for the configuration of that service:

Index	1017h
Name	Producer Heartbeat Time
Object	VAR
Type	UNSIGNED16

Access	rw
Mappable	No
Range	UNSIGNED8
Default value	0

The 1017h object allows programming the time in milliseconds during which the producer has to send a *heartbeat* telegram to the network. Once programmed, the inverter initiates the transmission of messages with the following format:

Identifier	*byte 1*	
	bit 7	bit 6 ... bit 0
700h + Node-ID	Always 0	Slave state

NOTE!
☑ This object is active even in the stopped state (see table 5.8).
☑ The value 0 (zero) in the object will disable this function.
☑ If after the error detection the service is enabled again, then the error indication will be removed from the HMI.
☑ The time value programmed for the consumer must be higher than the programmed for the respective producer. Actually, it is recommended to program the consumer with a multiple of the value used for the producer.
☑ For any every slave only one of the two services - *Heartbeat* or *Node Guarding* – can be enabled.

5.7 Initialization Procedure

Once the operation of the objects available for the frequency inverter CFW-11 is known, then it becomes necessary to program the different objects to operate combined in the network. In a general manner, the procedure for the initialization of the objects in a CANopen network follows the description of the next flowchart:

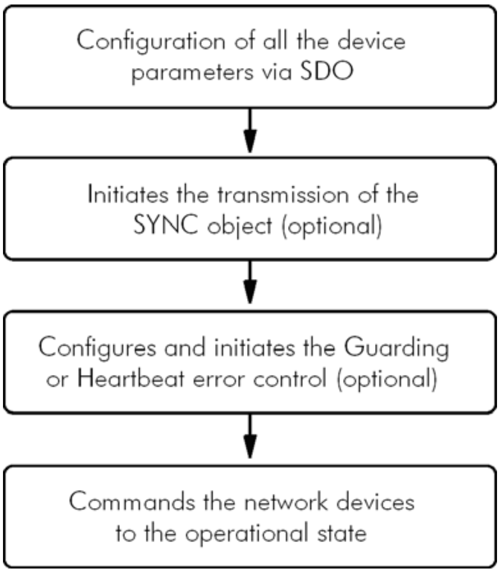


Figure 5-8 - Initialization process flowchart

It is necessary to observe that the CFW-11 communication objects (1000h to 1FFFh) are not stored in the nonvolatile memory. Therefore, every time the equipment is reset or switched off, it is necessary to redo the communication objects parameter setting. The manufacturer specific objects (starting from 2000h that represents the parameters), they are stored in the nonvolatile memory and, thus, could be set just once.

6 Description of the Objects for Drives

The objects that are common for drives, defined by the CANopen specification in the CiA DSP 402 document, are described in this section. Regardless of the drive manufacturer, the objects mentioned here have a similar description and operation. This makes it easier the interaction and the interchangeability between different devices.

The figure 6.1 shows a diagram with the logic architecture and the operation of a drive through the CANopen network, with the different operation modes defined in this specification. Each operation mode has a set of objects that allows the configuration and operation of the drive in the network.

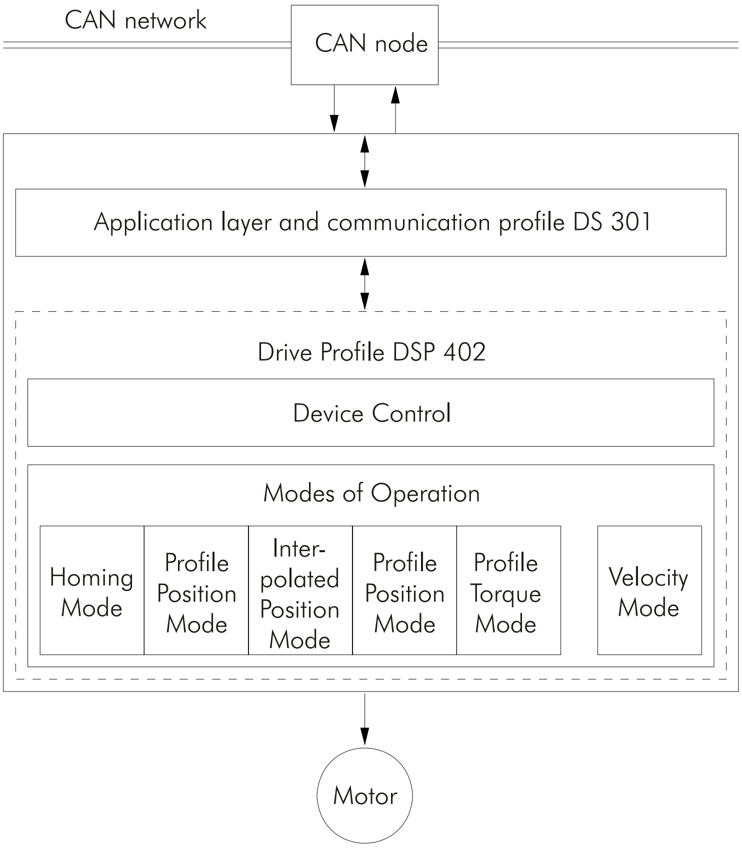


Figure 6-1 - Communication architecture for a drive in the CANopen network

For the CFW-11, only the *Velocity Mode* is supported. The table 6.1 presents the list of the available objects for the CFW-11, divided according to the different operation modes of the inverter.

Table 6.1 - CFW-11 object list – Drive Profile

Index	Object	Name	Type	Access	Mappable
Device Control					
6040h	VAR	Controlword	UNSIGNED16	rw	Yes
6041h	VAR	Statusword	UNSIGNED16	ro	Yes
6060h	VAR	Modes of Operation	INTEGER8	rw	Yes
6061h	VAR	Modes of Operation Display	INTEGER8	ro	Yes
Velocity Mode					
6042h	VAR	vl target velocity	INTEGER16	rw	Yes
6043h	VAR	vl velocity demand	INTEGER16	ro	Yes
6044h	VAR	vl control effort	INTEGER16	ro	Yes
6046h	ARRAY	vl velocity min max amount	UNSIGNED32	rw	Yes
6048h	RECORD	vl velocity acceleration	vl vel. accel. decl. record	rw	Yes
6049h	RECORD	vl velocity deceleration	vl vel. accel. decl. record	rw	Yes
Position Control Function					
6063h	VAR	Position actual value*	INTEGER32	Ro	Yes

Every time an object of that list is read or written, the CFW-11 will map its functions in the inverter parameters. Thus, by operating the system through these objects, the value of the parameters can be changed according to the used function. In the next items a detailed description of each of these objects is presented, where the inverter parameters used to execute these object functions are indicated.

6.1 *Device Control* – Objects for Controlling the Drive

Every drive operating in a CANopen network following the DSP 402 must be in accordance with the description of the following state machine:

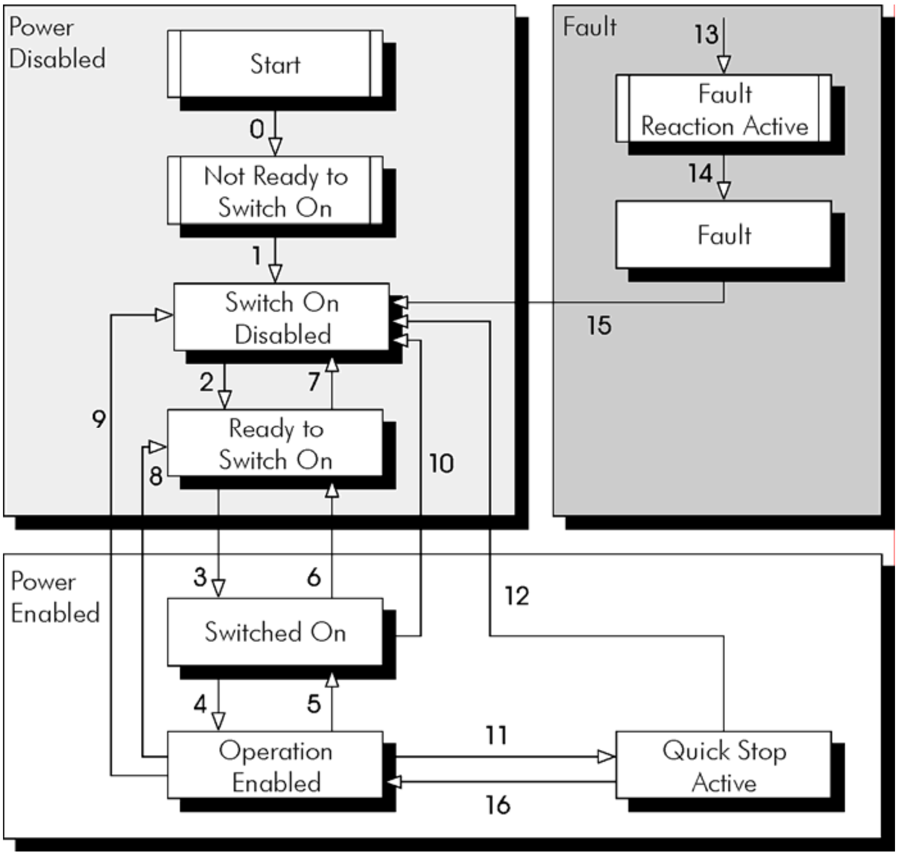


Figure 6-2 - State machine for drives

Estate descriptions:

- ☑ *Not ready to switch on:* The inverter is initializing, it cannot be commanded.
- ☑ *Switch on disabled:* Initialization complete, the inverter is able to receive commands.
- ☑ *Ready to switch on:* Command to allow powering up the drive has been received.
- ☑ *Switched on:* Command for powering up the drive has been received.
- ☑ *Operation enabled***:** The drive is enabled, being controlled according to the programmed operation mode. Power is being applied to the motor.
- ☑ *Quick stop active***:** During the operation, the *quick stop* command was received. Power is being applied to the motor.
- ☑ *Fault reaction active:* A fault has occurred and the drive is performing the action related to the type of fault.
- ☑ *Fault:* Drive with fault. Disabled function, without power being applied to the motor.

NOTE!
The frequency inverter CFW-11 does not have a switch for disabling / enabling the power section supply of the equipment. Therefore, the states described in the *Power disabled* group were implemented for a matter of compatibility with the described state machine; however the power section supply remains active even in these states.

Description of the transitions:

☑ Transition 0: The drive is switched on and the initialization procedure starts. The power section supply of the drive is active.
☑ Transition 1: Initialization completed (automatic).
☑ Transition 2: The *Shutdown* command has been received. The state transition is performed, but no action is taken by the CFW-11.
☑ Transition 3: The *Switch on* command has been received. The state transition is performed, but no action is taken by the CFW-11.
☑ Transition 4: The *Enable operation* command has been received. The drive is enabled. It corresponds to activate the bit 1 of the control word of the inverter via CAN – P0684.
☑ Transition 5: The *Disable operation* command has been received. The drive is disabled. It corresponds to reset the bit 1 of the control word of the inverter via CAN – P0684.
☑ Transition 6: The *Shutdown* command has been received. The state transition is performed, but no action is taken by the CFW-11.
☑ Transition 7: The *Quick stop* and *Disable voltage* commands have been received. The state transition is performed, but no action is taken by the CFW-11.
☑ Transition 8: The *Shutdown* command has been received. During the operation of the drive it is disabled, blocking the supply for the motor. It corresponds to reset the bit 1 of the control word of the inverter via CAN – P0684.
☑ Transition 9: The *Shutdown* command has been received. During the operation of the drive it is disabled, blocking the supply for the motor. It corresponds to reset the bit 1 of the control word of the inverter via CAN – P0684.
☑ Transition 10: The *Quick stop* or *Disable voltage* command has been received. The state transition is performed, but no action is taken by the CFW-11.
☑ Transition 11: The *Quick stop* command has been received. The inverter performs the stopping via ramp function. It corresponds to reset the bit 0 of the control word of the inverter via CAN – P0684.
☑ Transition 12: The *Disable voltage* command has been received. The drive is disabled. It corresponds to reset the bit 1 of the control word of the inverter via CAN – P0684.
☑ Transition 13: A fault is detected and the drive is disabled.
☑ Transition 14: After disabling the drive, it goes to the fault state (automatic).
☑ Transition 15: The *Fault reset* command has been received. The inverter performs the fault reset and returns to the disabled and without fault state.
☑ Transition 16: The *Enable operation* command has been received. The inverter performs the start via ramp function. It corresponds to activate the bit 0 of the control word of the inverter via CAN – P0684.

This state machine is controlled by the 6040h object, and the other states can be monitored by the 6041h object. Both objects are described next.

6.1.1 6040h Object– Controlword

It controls the inverter state

Index	6040h
Name	Controlword
Object	VAR
Type	UNSIGNED16
Used parameters	P0684

Access	rw
Mappable	Yes
Range	UNSIGNED16
Default value	-

The bits of this word have the following functions:

15 – 9	8	7	6 – 4	3	2	1	0
Reserved	Halt	Fault reset	Operation mode specific	Enable operation	Quick stop	Enable voltage	Switch on

The bits 0, 1, 2, 3 and 7 allow controlling the drive state machine. The commands for state transitions are given by means of the bit combinations indicated in the table 6.2. The bits marked with "x" are irrelevant for the command execution.

Table 6.2 - Control word Commands

Command	Control word bits					Transitions
	Fault reset	Enable operation	Quick stop	Enable voltage	Switch on	
Shutdown	0	×	1	1	0	2, 6, 8
Switch on	0	0	1	1	1	3
Disable voltage	0	×	×	0	×	7, 9, 10, 12
Quick stop	0	×	0	1	×	7, 10, 11
Disable operation	0	0	1	1	1	5
Enable operation	0	1	1	1	1	4, 16
Fault reset	0 → 1	×	×	×	×	15

The bits 4, 5, 6 and 8 have different functions according to the used operation mode. The detailed description of the functions of these bits for the velocity mode is presented on the section 6.2.1.

6.1.2 6041h Object– Statusword

It indicates the CFW-11 present state.

Index	6041h
Name	Statusword
Object	VAR
Type	UNSIGNED16
Used parameters	P0680

Access	ro
Mappable	Yes
Range	UNSIGNED16
Default value	-

The bits of this word have the following functions:

Table 6.3 - Statusword bit functions

Bit	Description
0	Ready to switch on
1	Switched on
2	Operation enabled
3	Fault
4	Voltage enabled
5	Quick stop
6	Switch on disabled
7	Warning
8	Reserved
9	Remote
10	Target reached
11	Internal limit active
12 – 13	Operation mode specific
14 – 15	Reserved

In this word the bits 0, 1, 2, 3, 5 and 6 indicate the state of the device according to the state machine described in the figure 6.2. The table 6.4 describes the combinations of these bits for the state indications. The bits marked with "x" are irrelevant for the state indication.

Table 6.4 - Drive states indicated through the Statusword

Value (binary)	State
xxxx xxxx x0xx 0000	Not ready to switch on
xxxx xxxx x1xx 0000	Switch on disabled
xxxx xxxx x01x 0001	Ready to switch on
xxxx xxxx x01x 0011	Switched on
xxxx xxxx x01x 0111	Operation enabled
xxxx xxxx x00x 0111	Quick stop active
xxxx xxxx x0xx 1111	Fault reaction active
xxxx xxxx x0xx 1000	Fault

The other bits indicate a specific condition for the drive.

- ☑ **Bit 4 – *Voltage enabled***: indicates that the drive power section is being fed.
- ☑ **Bit 7 – *Warning***: It is not used for the CFW-11.
- ☑ **Bit 9 – *Remote***: indicates when the drive is in the remote mode and accepts commands via the CANopen[9] network. It represents the Statusword bit 4 value – P0680.
- ☑ **Bit 10 – *Target reached***: indicates when the drive is operating at the reference value, which depends on the used operation mode. It is also set to 1 when the functions *Quick stop* or *Halt* are activated.
- ☑ **Bit 11 – *Internal limit active***: indicates when the drive is operating at an internal limit value, as current limit for instance.
- ☑ **Bits 12 e 13 – *Operation mode specific***: they depend on the drive operation mode.

6.1.3 6060h Object– Modes of Operation

It allows programming the CFW-11 operation mode.

Index	6060h
Name	Modes of operation
Object	VAR
Type	INTEGER8
Used parameters	-

Access	rw
Mappable	Yes
Range	INTEGER8
Default value	-

The only mode supported by the CFW-11 inverter is the *Velocity Mode*, represented by the value 2.

6.1.4 6061h Object– Modes of Operation Display

It indicates the CFW-11 operation mode.

Index	6061h
Name	Modes of operation display
Object	VAR
Type	INTEGER8
Used parameters	-

Access	rw
Mappable	Yes
Range	INTEGER8
Default value	-

The only mode supported by the CFW-11 inverter is the *Velocity Mode*, represented by the value 2.

[9] It depends on the inverter programming.

6.2 *Velocity Mode* – Objects for Controlling the Drive

This operation mode allows the control of the inverter in a simple manner, making available functions of the following type:

- ☑ Reference value calculation.
- ☑ Capture and monitoring of the speed.
- ☑ Speed limitation.
- ☑ Speed ramps, among other functions.

These functions are executed based on a set of objects for the configuration of that operation mode.

6.2.1 Control and State Bits

The bits 4, 5, 6 and 8 of the control word (6040h object – Control word) have the following functions in the velocity mode:

Bit	Name	Value	Description
4	*rfg enable* (ramp enabling)	0	Ramp disabling – bit 0 of P0684 = 0
		1	Ramp enabling – bit 0 of P0684 = 1
5	Reserved		
6	Reserved		
8	*Halt*	0	Ramp enabling – bit 0 of P0684 = 1
		1	Ramp disabling – bit 0 of P0684 = 0

In order that the motor runs according to the acceleration ramp, it is necessary that the bit 4 be activated.

For the Statusword, the bits specified in the operation mode (bits 12 and 13) are reserved for future use.

6.2.2 6042h Object– *vl target velocity*

It allows programming the speed reference for the inverter, in rpm:

Index	6042h
Name	vl target velocity
Object	VAR
Type	INTEGER16
Used parameters	P0684, P0685

Access	rw
Mappable	Yes
Range	INTEGER16
Default value	0

The object *vl target velocity* allows the writing of negative speed reference values in order to run the motor in the reverse speed direction. This change in the speed direction is performed through the writing of the bit 2 in the CAN control word - P0684.

6.2.3 6043h Object– *vl velocity demand*

It indicates the value of the speed reference after the ramp, in rpm:

Index	6043h
Name	vl velocity demand
Object	VAR
Type	INTEGER16
Used parameters	-

Access	ro
Mappable	Yes
Range	INTEGER16
Default value	-

6.2.4 6044h Object– *vl control effort*

It indicates the speed value according to the measured at the motor, in rpm. For the control modes without feedback, this object has the same value as the object 6043h.

Index	6044h
Name	vl control effort
Object	VAR
Type	INTEGER16
Used parameters	P0681

Access	ro
Mappable	Yes
Range	INTEGER16
Default value	-

6.2.5 6046h Object– *vl velocity min max amount*

It allows programming the value of the minimum and the maximum speed for the inverter. Only positive values are accepted, however the programmed values are also valid for the reverse speed direction. The values are written in rpm.

Index	6046h
Name	vl velocity min max amount
Object	ARRAY
Type	UNSIGNED32
Used parameters	P0133, P0134

Sub-index	0
Description	Number of the last sub-index
Access	ro
Mappable	No
Range	2
Default value	2

Sub-index	1
Description	vl velocity min amount
Access	rw
Mappable	Yes
Range	UNSIGNED32
Default value	-

Sub-index	2
Description	vl velocity max amount
Access	rw
Mappable	Yes
Range	UNSIGNED32
Default value	-

6.2.6 6048h Object– *vl velocity acceleration*

It allows programming the inverter acceleration ramp.

Index	6048h
Name	vl velocity acceleration
Object	RECORD
Type	Vl velocity acceleration deceleration record
Used parameters	P0100

Sub-index	0
Description	Number of the last sub-index
Access	ro
Mappable	No
Range	2
Default value	2

Sub-index	1
Description	Delta speed
Access	rw
Mappable	Yes
Range	UNSIGNED32
Default value	-

Sub-index	2
Description	Delta time
Access	rw
Mappable	Yes
Range	UNSIGNED32
Default value	-

The acceleration value is calculated dividing the speed programmed at the sub-index 1 by the time programmed at the sub-index 2. The programmed values must respect the parameter P0100 allowed value range.

6.2.7 6049h Object– *vl velocity deceleration*

It allows programming the inverter deceleration ramp.

Index	6049h
Name	vl velocity deceleration
Object	RECORD
Type	Vl velocity acceleration deceleration record
Used parameters	P0101

Sub-index	0
Description	Number of the last sub-index
Access	ro
Mappable	No
Range	2
Default value	2

Sub-index	1
Description	Delta speed
Access	rw
Mappable	Yes
Range	UNSIGNED32
Default value	-

Sub-index	2
Description	Delta time
Access	rw
Mappable	Yes
Range	UNSIGNED32
Default value	-

The deceleration value is calculated dividing the speed programmed at the sub-index 1 by the time programmed at the sub-index 2. The programmed values must respect the parameter P0101 allowed value range.

Position control function – Objects for position control

Despite not supporting the position control operation mode, the objects related to this function were made available in the CFW-11 inverter.

6063h Object– *Position actual value**

It informs the encoder pulse counter value. This counter is valid only if the inverter has the accessory for the interface with the encoder. This object value is increased until reaching the encoder number of pulses, being reset when reaching this value.

Index	6063h
Name	Actual position value
Object	VAR
Type	INTEGER32
Used parameters	P0681

Access	ro
Mappable	Yes
Range	0 up to the encoder number of pulses minus 1
Default value	-

In order to get more information on this function operation, refer to the parameters P0039, P0191 and P0405 in the CFW-11 programming manual.

7 Faults and Alarms Related to the CANopen Communication

A133/F233 – CAN Interface Without Power Supply

Description:
It indicates that the CAN interface does not have power supply between the connector pins 1 and 5.

Operation:
IN order that it be possible to send and receive telegrams through the CAN interface, it is necessary to provide an external supply for the interface circuit.

If the absence of power supply at the CAN interface is detected, the alarm A133 or the fault F233, depending on the P0313 programming, will be signalized through the HMI. If the circuit power supply is reestablished, the CAN communication will be reinitiated. In case of alarms, the alarm indication will also be removed from the HMI.

Possible Causes/Correction:
- ☑ Measure the voltage between the pins 1 and 5 of the CAN interface connector, as indicated in the table 2.2.
- ☑ Make sure that the supply cables are not inverted or changed.
- ☑ Inspect the cable and the CAN interface connector looking for contact problems.

A134/F234 – *Bus Off*

Description:
The *Bus off* error was detected at the CAN interface.

Operation:
If the number of transmission or reception errors detected by the CAN interface is very high[10], the CAN controller can be taken to the *bus off* state, and thus interrupting the communication and disabling the CAN interface.

In this case the alarm A134 or the fault F234, depending on the P0313 programming, will be signalized through the HMI. In order that the communication be reestablished, it will be necessary to cycle the power of the inverter, or remove the power supply from the CAN interface and apply it again, so that the communication be reinitiated.

Possible Causes/Correction:
- ☑ Verify if there is any short-circuit between the CAN circuit transmission cables.
- ☑ Make sure that the cables are not inverted or changed.
- ☑ Verify if all the network devices use the same baud rate.
- ☑ Verify if termination resistors with the correct values were installed only at the extremes of the main bus.
- ☑ Verify if the CAN network installation was carried out in proper manner.

A135/F235 – CANopen Communication Error

Description:
The CANopen communication error control detected a communication error by using the *guarding* mechanism.

Operation:
By using the error control mechanisms – *Node Guarding or Heartbeat* – the master and the slave can exchange periodic telegrams, with a predetermined period. If the communication is interrupted by some reason, the master, as well as the slave, will be able to detect communication error through the timeout in the exchange of those messages.

In this case the alarm A135 or the fault F235, depending on the P0313 programming, will be signalized through the HMI. In case of alarms, the alarm indication will be removed from the HMI if this error control is enabled again.

[10] For more information on the error detection, refer to the CAN specification.

Possible Causes/Correction:

- ☑ Verify the times programmed in both master and slave, for the message exchanging. In order to avoid problems due to transmission delays and differences in the time counting, it is recommended that the values programmed for message exchanging in the master be a little bit shorter than the times programmed for the error detection by the slave.
- ☑ Verify if the master is sending the *guarding* telegrams in the programmed time.
- ☑ Verify communication problems that can cause telegram losses or transmission delays.