The Drive & Control Company

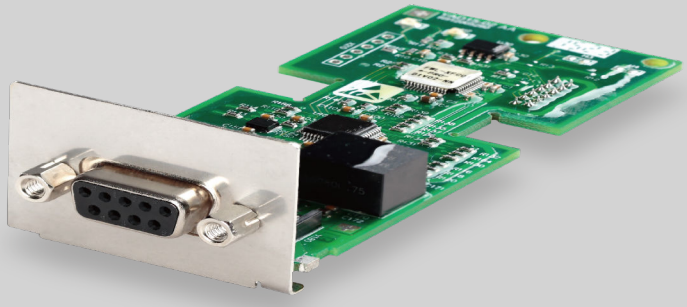
Rexroth
Bosch Group

Frequency Converter

CANopen Card

Instruction Manual
R912006713

Edition 01



Record of Revision

Edition	Release Date	Notes
DOK-RCON0*-XFCX610*CAN-IT01-EN-P	2016.05	First release

Reference

For documentations available in other type or language, please consult your local sales partner or check www.boschrexroth.com.

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1 General Introduction

CANopen is a high-level communication protocol which is based on CAN (Controller Area Network) bus. As one of fieldbus commonly used in the industrial control field, CANopen can realize the interconnection of multiple industrial devices.

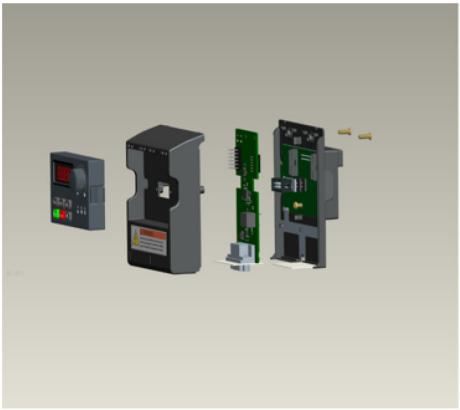
CANopen adopts Open Systems Interconnection (OSI) model and implements media access control and physical signal transmission on basis of CAN technology. Its design is based on three sub-protocols, i.e. DS102 CAN physical layer for industrial applications, DS 301 CANopen communication profile for industrial systems and DSP 402 device profile for drives and motion control.

CANopen operates in master-slave structure or distributed control structure which is based on peer-to-peer communication. Up to 127 slave nodes can be supported. CANopen card of the slave node is powered from frequency converter, and all slave nodes are connected to the same bus.

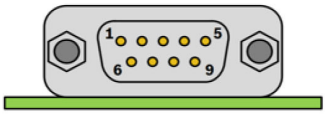
CANopen defines corresponding configuration files for devices in specific classes. For other devices, a specific class must be defined to ensure the compatibility with CANopen system.

2 Installation Introduction

2.1 Interface Introduction



Pins of the DB9 connectors



Connector Pin Description

Pin #	Signal	Description
1	---	Reserved
2	CAN_L	CAN_L Bus line (dominant low)
3	CAN_V-	External bus power GND
4	---	Reserved
5	Earth	CAN cable shield
6	CAN_V-	External bus power GND
7	CAN_H	CAN_H Bus line (dominant high)
8	---	Reserved
9	---	Reserved
10	Earth	CAN cable shield

Fig. 2-1: Interface data

2.2 Cable and Connection

Please select CANopen cable type in accordance with the following instructions.

Baudrate	Max. cable length	Resistance [mΩ/m]	Cable cross section [mm²/AWG]	Termination resistor
1,000 kbps	25m	<70	0.25...0.34 / AWG23...AWG22	120 Ω
500 kbps	100 m	< 60	0.34...0.6 / AWG22...AWG20	
250 kbps	250 m	< 40	0.5...0.6 / AWG20	
125 kbps	500 m			
50 kbps	1,000 m	< 26	0.75...0.8 / AWG18	
20 kbps	1,000 m			
10 kbps	1,000 m			

Tab. 2-1: Cable data

It is not suitable to connect frequency converter with “flat cable” and other unscreened cable types. With regards to the connection of the cable screen, it is recommended to connect to the ground at both ends of the cable at every CANopen slave node. Low impedance ground connection of high frequency screen is very important. This can be achieved by connecting to the ground with a cable clamp or a conductive cable device, such as converter shielding kit.

3 LED Status Introduction

The CiA-303-3 provides a standardized way for state indication of a CANopen device. There is an error LED and a run LED. The run LED is green and indicates the CANopen state. The error LED is red and shows errors of the physical layer.

LED	State	Color	Description
ERROR LED	No error	Off	The device is in working condition.
	Warning limit reached	Single flash	At least one of the error counters of the CAN controller has reached or exceeded the warning limit. (CAN Passive Error)
	Error control event	Double flash	A guard event (NMT slave or NMT master) or a Heartbeat event has occurred.
	Bus off	Red light on	The CAN controller is bus-off.
RUN LED	OFF	Off	The CANopen controller is in “OFF” state.
	NMT stopped	Single flash	The device is in NMT STOPPED state.
	NMT pre-operational	Blinking green	The device is in NMT PRE-OPERATIONAL state.
	NMT operational	Green light on	The device is in NMT OPERATIONAL state.

Tab. 3-1: Description of various LED states

4 Converter Configuration

4.1 Overview

Communication with the frequency converter in CANopen is achieved via Service Data Objects (SDOs), Process Data Objects (PDOs) and Network Management (NMT).

Users can download the EDS file through the following steps:

1. Click on http://www.boschrexroth.com/dcc.
2. Choose “Frequency converter -> EFC 3610 (or EFC 5610)” from the navigation bar on left side of the operation interface.
3. Choose “Download area” tab from right side of the interface.
4. Click on “EDS_XFCX610.ZIP” to download the EDS file.

4.2 COB-Identifiers

Each communication object has a unique identity (COB-ID) comprising the function code and the node ID (node address) shown as follows.

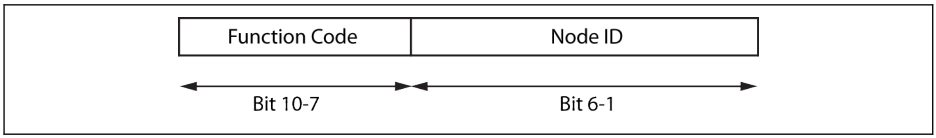


Fig. 4-1: COB-ID

4.3 Object Dictionary

The object dictionary is essentially a grouping of objects accessible via the network in an ordered predefined fashion. Each object within the object dictionary is addressed using a 16-bit index and an 8-bit sub-index. The object dictionary contains collection of all the data items which have an influence on the behaviour of the application objects, the communication objects and the state machine used on this device.

Index range (Hex)	Object group
1000h...1FFFh	Communication profile
2000h...5FFFh	Vendor specific objects
6000h...9FFFh	Standard device profiles

Tab. 4-1: CANopen object groups

The table below gives an overview of the objects prescribed for CANopen:

Object	Index	Name
General objects	1000h	Device type
	1001h	Error register
	1002h	Manufacturer status register
	1008h	Manufacturer device name
	1009h	Manufacturer hardware version
	100Ah	Manufacturer software version
	1010h	Store parameter field
	1011h	Restore default parameters
	1018h	Identity object
Error control protocol	100Ch	Guard time
	100Dh	Life time factor
	1014h	COB-ID EMCY
	1015h	Inhibit time emergency
	1016h	Heartbeat consumer entries
	1017h	Producer heartbeat time
	1029h	Error behaviour
SDO	1200h	Server SDO parameter 1

Object	Index	Name
PDO objects	1400h	Receive PDO communication parameter 1
	1401h	Receive PDO communication parameter 2
	1402h	Receive PDO communication parameter 3
	1403h	Receive PDO communication parameter 4
	1600h	Receive PDO mapping parameter 1
	1601h	Receive PDO mapping parameter 2
	1602h	Receive PDO mapping parameter 3
	1603h	Receive PDO mapping parameter 4
	1800h	Transmit PDO communication parameter 1
	1801h	Transmit PDO communication parameter 2
	1802h	Transmit PDO communication parameter 3
	1803h	Transmit PDO communication parameter 4
	1A00h	Transmit PDO mapping parameter 1
	1A01h	Transmit PDO mapping parameter 2
	1A02h	Transmit PDO mapping parameter 3
	1A03h	Transmit PDO mapping parameter 4
Manufacturer specific objects	2000h...3000h	Function code mapping
	4000h...5FFFh	Reserved for future enhancements
Device profiles	6000h...9FFFh	Used for CANopen drive profile CiA-402

Tab. 4-2: Object dictionary

For CANopen drive profile CiA-402 velocity mode, the following objects are supported:

Device profile segment	603Fh	Error code
	6040h	Control word
	6041h	Status word
	6042h	Target velocity
	6043h	Velocity demand
	6044h	Velocity actual value
	6046h	Velocity min max amount
	6048h	Velocity acceleration
	6049h	Velocity deceleration
	604Dh	Pole number (needed for conversion velocity vs. output frequency)
	6060h	Modes of operation
	6061h	Modes of operation display

Tab. 4-3: CANopen drive profile CiA-402 velocity mode objects

Let H.L be the High and Low byte, respectively of the numerical representation of a function code, where H is the simple decimal interpretation of the hexadecimal encoding of the function class.

Example: Frequency converter class “d” is encoded by 0x10. The simple decimal interpretation of “0x10” then is “10”. (Hint: this simple trick closes the unused gap in frequency converter class encoding between 0x0A and 0x0F in order to get all frequency converters mapped into CANopen index manufacturer parameters ranged between 0x2000 and 0x5FFF.)

Then the index of the corresponding “Manufacturer specific objects” is: I = 0x2000 + H x 100 + L.

Function code Yx.z, where Y ϵ {b,d,C,E,U,F,H}, x ϵ {0...9}, z ϵ {0...99}

That means:

Function code → H.L range (DEC) → FC index (DEC) → CAN index (HEX)

bx.z → {00...09}.{0...99} → {0000...0999} → {0x2000...0x23E7}

dx.z → {10...19}.{0...99} → {1000...1999} → {0x23E8...0x27CF}

Cx.z → {20...29}.{0...99} → {2000...2999} → {0x27D0...0x2BB7}

Ex.z → {30...39}.{0...99} → {3000...3999} → {0x2BB8...0x2F9F}

Ux.z → {40...49}.{0...99} → {4000...4999} → {0x2FA0...0x3387}

Fx.z → {50...59}.{0...99} → {5000...5999} → {0x3388...0x376F}

Hx.z → {60...69}.{0...99} → {6000...6999} → {0x3770...0x3B57}

Manufacturer specific objects (2000h...3FFFh)

All function codes (16 bit) can be reached through the manufacturer specific objects. The structure of the manufacturer specific objects is as follows:

Sub-index	Description
1	Access to data (parameter set 0)
2...8	Reserved (parameter set 1...7)
9	Reserved (parameter set 1...7)
10	Index of the list pointer
11	List element to which the element 10 points (only in case of parameters in the list)
12...18	Reserved (for parameter sets)
21	Parameter name
22...28	Reserved (for parameter sets)
31	Parameter attribute
32...38	Reserved (for parameter sets)
41	Parameter unit
41...48	Reserved (for parameter sets)
51	Minimum value of the parameter

Sub-index	Description
52...58	Reserved (for parameter sets)
61	Maximum value of the parameter
62...68	Reserved (for parameter sets)
71	Maximum length of the parameters in the list
72...78	Reserved (for parameter sets)
81	Actual length of the parameter in the list
82...88	Reserved (for parameter sets)

Tab. 4-4: Manufacturer specific objects

As evident from the table, with the help of the sub-index, besides the date (sub-index 1), even other information (minimum value, maximum value ...) of the function codes can be read out.

List access

The complete list of a list parameter can be read or written via the access to the operating date of the parameter.

To access individual elements in the list, there is an option to set a list index (sub-index 10), and then to access the respective list element of the list index via sub-index 11 (up to sub-index 18). For every access via sub-index 11 (up to sub-index 18), the list index is incremented by one element. With this, in case of multiple access to sub-index 11 (up to sub-index 18), a related section of a list is processed.

The list index is reset to the first element if one of the actions listed below occurs:

- Change in the parameter
- Abort of the connection

Therefore the list index should be set for each list element access which does not start from the first element.

If the length of the list has to be changed, this can be corrected by changing the actual length of the list parameter (sub-indices 81...88). The maximum list length can be read out using the sub-indices 71...78.

The parameter value is stored if writing to the last element occurs.

In case of failure of the control voltage, the changes are discarded.

4.4 Process Data Objects (PDO)

PDOs represent real-time process data with high priority. It is only possible if node is in “operational” state.

The CANopen option card features four sets of predefined PDOs:

- The first set of PDOs is automatically enabled when CiA-402 drive profile is active and it is fixed (static) mapping:
  - One received PDO (RPDO1), is used to control (Control word) the drive.
  - One transmitted PDO (TPDO1), is used to monitor (Status word) the drive.

- The TPDO1 with transmission type of 255 shall only be triggered when the mapped drive status word is changing (event), other mapped objects shall not cause a PDO transmission.
- The TPDO1 with transmission type of 0 shall be transmitted after the occurrence of the SYNC but acyclic (not periodically), i.e. only if the drive status word is changed (event) before the occurrence of SYNC.

- The second set of PDOs (PDO2 for CiA-402 drive profile) includes: The second set of PDOs is initially disabled and the user has to enable it. The default mapping configuration is for supporting CiA-402 velocity mode.
  - One received PDO (RPDO2), is used to control the drive (Control word and velocity reference). In addition, it can be configured to include two additional objects/parameters. Control word and velocity reference can also be replaced with any two other objects which have write access rights via PDO.
  - One transmitted PDO (TPDO2), is used to monitor the drive (Status word and velocity actual value). In addition, it can be configured to include two additional objects which have read access via PDO. Status word and velocity actual value can also be replaced with any two other objects which have read access rights via PDO.
- The third set of PDOs (PDO3 for Rexroth drive profile) includes: The default mapping configuration enables the drive to be commanded by frequency input and Rexroth drive control word.
  - One received PDO (RPDO3), is used to control the drive (Control word and frequency command). In addition, it can be configured to include two additional objects/parameters. Control word and frequency command can also be replaced with any two other objects which have write access rights via PDO.
  - One transmitted PDO (TPDO3), is used to monitor the drive (Status word and actual output frequency). In addition, it can be configured to include two additional objects which have read access via PDO. Status word and actual output frequency can also be replaced with any two other objects which have read access rights via PDO.

- The fourth set of PDOs are initially disabled and no default mapping configuration is done. And the PDO information is freely deployed by the user.

- For TPDO2 with transmission type of 255 no internal profile specific event is defined for triggering PDO transmission. So for this transmission type of 255/254 (asynchronous) only event timer will trigger PDO transmission.
- PDO2 does not support transmission type of 0 (synchronous acyclic).

4.5 Process Data Objects (PDO) Configuration

The following configuration shall be executed.

- PDO1 mapping is static and hence it cannot be changed.
- The default PDO mapping configuration is shown as below for Rexroth drive profile.

RPDO No.	Mapping object index	Mapping object name	Comment
1	0x6040	Control word	Controls the CiA-402 state machine
2	0x6040 0x6042	Control word Target velocity (vl)	Controls the state machine and the nominal speed (vl)
3	0x3770 0x377A	Drive control word Frequency command	Controls the drive system state machine and setting frequency
4	0x0000	-	-
TPDO No.	**Mapping object index**	**Mapping object name**	**Comment**
1	0x6041	Status word	Shows the drive status
2	0x6041 0x6044	Status word vl control effort	Shows status and the current speed (vl)
3	0x3771 0x23EA	Drive status word Output frequency	Shows the drive status and the current output frequency
4	0x0000	-	-

Tab. 4-5: PDO communication parameter structure for CiA-402 profile

Index	Sub	Name	Default value
0x1400	0	Number of entries	5
	1	COB-ID used by PDO	0x80000200 + Node-ID**
	2	Transmission type	255
	3	Inhibit time (not implemented)	0
	4	Reserved	-
	5	Event timer	0
0x1600	0	Number of mapped objects	1
	1	Control word	0x60400010

Tab. 4-6: RPDO1

**: When CiA-402 is enabled, the RPDO1 is enabled, so COB-ID gets changed to 0x80000200 + Node-ID. RPDO1 is disabled in Rexroth Profile. If enabled then it's erroneous.

Index	Sub	Name	Default value
0x1401	0	Number of entries	5
	1	COB-ID used by PDO	0x80000300 + Node-ID
	2	Transmission type	255
	3	Inhibit time (not implemented)	0
	4	Reserved	-
	5	Event timer	0
0x1601	0	Number of mapped objects	2
	1	Control word	0x60400010
	2	Target velocity (vl)	0x60420010

Tab. 4-7: RPDO2

Index	Sub	Name	Default value
0x1402	0	Number of entries	5
	1	COB-ID used by PDO	0x00000400 + Node-ID
	2	Transmission type	255
	3	Inhibit time (not implemented)	0
	4	Reserved	-
	5	Event timer	0
0x1602	0	Number of mapped objects	2
	1	Drive control word	0x37700010
	2	Frequency command	0x377A0010

Tab. 4-8: RPDO3

Index	Sub	Name	Default value
0x1404	0	Number of entries	5
	1	COB-ID used by PDO	0x80000500 + Node-ID
	2	Transmission type	255
	3	Inhibit time (not implemented)	0
	4	Reserved	-
	5	Event timer	0
0x1604	0	Number of mapped objects	0
	1...4	-	0x00000000

Tab. 4-9: RPDO4

Index	Sub	Name	Default value
0x1800	0	Number of entries	5
	1	COB-ID used by PDO	0x00000180 + Node-ID**
	2	Transmission type	255
	3	Inhibit time	50 (100us)
	4	Reserved	-
	5	Event timer	100 (1ms)
0x1A00	0	Number of mapped objects	1
	1	Status word	0x60400010

Tab. 4-10: TPDO1

**: When CiA-402 is enabled, the TPDO1 is enabled, so COB-ID gets changed to 0x00000180 + Node-ID. TPDO1 is disabled in Rexroth Profile. If enabled then it's erroneous.

Index	Sub	Name	Default value
0x1801	0	Number of entries	5
	1	COB-ID used by PDO	0x80000280 + Node-ID
	2	Transmission type	255
	3	Inhibit time	50 (100us)
	4	Reserved	-
	5	Event timer	100 (1ms)
0x1A01	0	Number of mapped objects	2
	1	Status word	0x60410010
	2	vl control effort	0x60440010

Tab. 4-11: TPDO2

Index	Sub	Name	Default value
0x1802	0	Number of entries	5
	1	COB-ID used by PDO	0x00000380 + Node-ID
	2	Transmission type	255
	3	Inhibit time	50 (100us)
	4	Reserved	-
	5	Event timer	100 (1ms)
0x1A02	0	Number of mapped objects	2
	1	Drive status word	0x37710010
	2	Output frequency	0x23EA0010

Tab. 4-12: TPDO3

Index	Sub	Name	Default value
0x1805	0	Number of entries	5
	1	COB-ID used by PDO	0x80000480 + Node-ID
	2	Transmission type	255
	3	Inhibit time	50 (100us)
	4	Reserved	-
	5	Event timer	100 (1ms)
0x1A05	0	Number of mapped objects	0
	1...4	-	0x00000000

Tab. 4-13: TPDO4

1. PDO mapping configuration is not supported in NMT operational state. PDO mapping has to be done in NMT pre-operation state only. If PDO configuration is done in operational state, then CANopen option card automatically enters into pre-operation state.
2. [b8.61]: Field bus option card producer list defines all those parameters which can be mapped to TPDO.
3. [b8.62]: Field bus option card consumer list defines all those parameters which can be mapped to RPDO.

4.6 Service Data Objects (SDO)

SDO telegrams are used for configuration and setup.

The SDO services listed below are supported:

- **Initiate SDO Download** for writing maximum 4 byte data in the VFC/EFC x610, also for initiating the writing of more than 4 byte data in the VFC/EFC x610 (the data length is determined during "Initiate" process).
- **Download SDO Segment** for transmitting a fragment with data in the VFC/EFC x610 Initiate SDO.
- **Upload** for transmitting maximum 4 byte data from VFC/EFC x610 to the master, also for initiating the transmission of more than 4 byte data from VFC/EFC x610 to the master (VFC/EFC x610 informs master the length of the response data).
- **Upload SDO Segment** for transmitting a fragment with data from the VFC/EFC x610 to the master.
- **Abort SDO Transfer** for reporting errors and to abort SDO accesses.

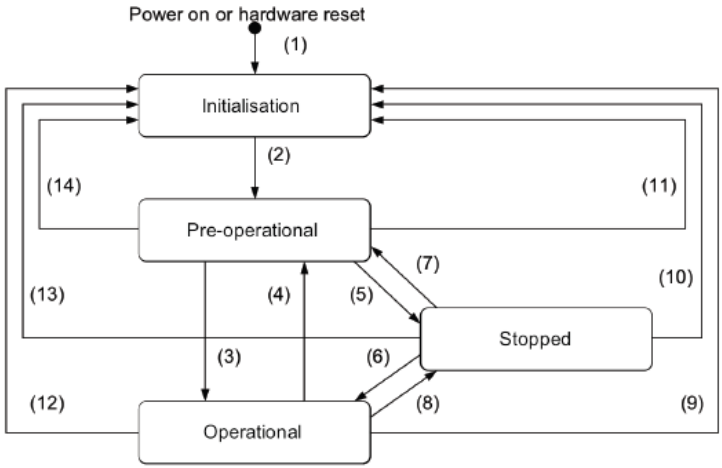
SDO abort code	Description
05040000h	SDO protocol timed out
05040001h	Client/server command specifier not valid or unknown
05040005h	Out of memory
06010001h	Attempt to read a write only object
06010002h	Attempt to write a read only object
06020000h	Object does not exist in the object dictionary
06040041h	Object cannot be mapped to the PDO
06040042h	The number and length of the objects to be mapped would exceed PDO length
06040043h	General parameter incompatibility reason
06060000h	Access failed due to an hardware error
06070010h	Data type does not match, length of service parameter does not match
06090011h	Sub-index does not exist
06090030h	Value range of parameter exceeded (only for write access)
06090031h	Value of parameter written too high
06090032h	Value of parameter written too low
060A0023h	No resources available
08000000h	General error
08000020h	Data cannot be transferred or stored to the application
08000022h	Data cannot be transferred or stored to the application because of the present device state
08000024h	No data available

Tab. 4-14: SDO abort codes

4.7 Network Management Objects (NMT)

NMT functions monitor the network stability and include synchronization, detection of faults and emergency message transmission.

The NMT state machine determines the behaviour of the communication function.



(1)	At Power on the NMT state initialisation is entered autonomously
(2)	NMT state Initialisation finished - enter NMT state Pre-operational automatically
(3)	NMT service start remote node indication or by local control
(4),(7)	NMT service enter pre-operational indication
(5),(8)	NMT service stop remote node indication
(6)	NMT service start remote node indication
(9),(10),(11)	NMT service reset node indication
(12),(13),(14)	NMT service reset communication indication

Fig. 4-2: NMT state diagram of CANopen device

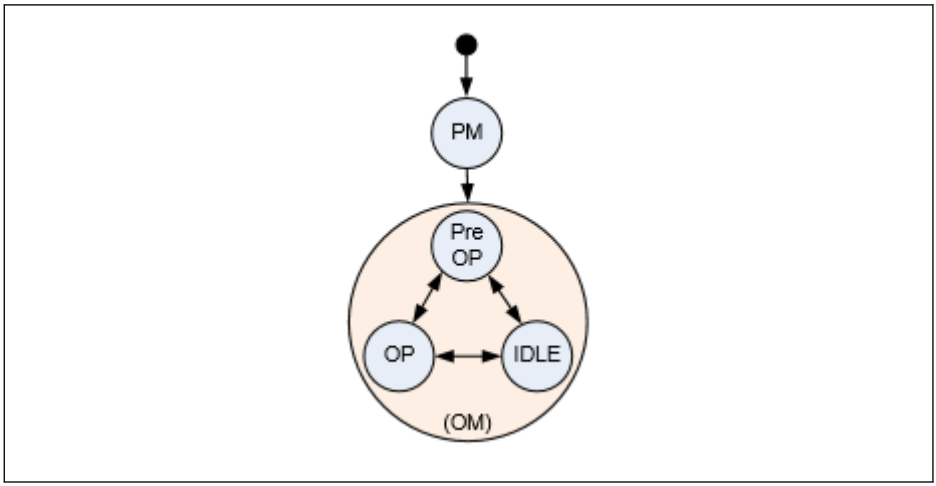


Fig. 4-3: Option card communication states and transitions

State	Description
PM	Parameterization mode (no exchange of process data)
Pre-OP	Pre-operation mode, however, no exchange of process data
OP	Operation mode, exchange of process data, process data is valid
IDLE	Operation mode, exchange of process data, process data is invalid

Tab. 4-15: Option card communication states description

- The communication status between option card and host system is transferred cyclically.
- The coupling between option card and NMT state machine is defined in the table below.

NMT – state	Option card state
Pre-OP / STOPPED	Pre-OP
OP	OP / IDLE IDLE state is entered on two cases: 1. Field-bus Data is Invalid (CAN is in ERROR PASSIVE, BUS OFF or INIT state and NMT is in OP state). 2. IDLE state is entered whenever the PDO configuration is invalid.

Tab. 4-16: Option card communication states description

4.8 Emergency Service (EMCY)

When an error occurs or is cleared, an EMCY telegram is transmitted. The EMCY telegram transports 8-byte data.

0	1	2	3	4	5	6	7
Error code		Error register	Manufacturer specific bytes				
Object: 0x603F This object provides the error code of the last error occurred in the drive device.		Object: 0x1001 The error register is a field of 8 bits, each for a certain error type. If an error occurs the bit has to be set.	[b6.91] Least 2 significant bytes		[b6.91] Least 3 significant bytes		
Error code = 0xFF00 (for all manufacturer specific) Error code -> CiA 301/402 specific error codes		Bit meaning 0: Generic error 1: Current 2: Voltage 3: Temperature 4: Communication error (overrun, error state) 5: Device profile specific 6: Reserved 7: Manufacturer specific	E.g. If [b6.91] = 0xF5001 Man_fact[3] = 0x01 Man_fact[4]= 0x50		Man_fact[5] = 0x01 Man_fact[6] = 0x50 Man_fact[7] = 0x0F		

Tab. 4-17: Error telegram

- Emergency telegram is triggered whenever a critical error is detected in either option card or error condition occurs in Host.
- EMCY Frame with error code 0x8120 is sent when CAN is in error passive state.
- EMCY Frame with error code 0x8140 is sent after CAN recovers from BUS-OFF error condition.
- Supported CiA-301 and CiA-402 error codes:

No Error	0x0000
Generic error	0x1000
Generic communication error	0x8100
CAN overrun	0x8110
CAN in passive error	0x8120
Heart beat or node guarding error	0x8130
Protocol error	0x8200
CAN recovered from bus-off	0x8140
Continuous over current (device output side)	0x2310

Continuous over current no.1	0x2311
2312h continuous over current no.2	0x2312
Continuous over current no.3	0x2313
DC link over-voltage	0x3210
Over-voltage no. 1	0x3211
Over-voltage no. 2	0x3212
DC link under-voltage	0x3220
Over-voltage no. 1	0x3211
Over-voltage no. 2	0x3212
DC link under-voltage	0x3220
Short circuit (device internal)	0x2250
Phase failure	0x3130
Load error	0x3230
Excess temperature drive	0x4310
Too low temperature drive	0x4320
Parameter error	0x6320
Any other manufacturer specific error	0xFF00
Any other manufacturer specific warning	0xFF01

Tab. 4-18: CiA-301 and CiA-402 error codes

0	1	2	3	4	5	6	7
Error code		Error register	Manufacturer Specific Bytes (last occurred error diagnostic code)				
0x0000		Object: 0x1001	[b6.91] Least 2 significant bytes		[b6.91] Least 3 significant bytes		

Tab. 4-19: Error-cleared telegram

4.9 Synchronisation Service (SYNC)

4.9.1 Overview

SYNC object is used to provide synchronous modes of communication of the CANopen slaves.

- PDO1 supports synchronous cyclic and synchronous acyclic modes.
- PDO2, PDO3 and PDO4 support only synchronous cyclic modes.

4.9.2 Error Control Services

The error control services are used to detect failures within a CAN-based network.

The CANopen option card supports the following error control protocols:

1. Heartbeat object
2. Node guarding object

- Either one of the error control protocol i.e. heartbeat or node guarding can be enabled at a time.
- Whenever failures are detected an error “FnC-” (Network Setup Error) is set and an EMCY telegram is sent.

4.9.3 Non-Volatile Storage

The following objects are implemented:

1. 0x1010: Store Parameter Field
2. 0x1011: Restore Default Parameter

- Saving the contents of object (parameter) data value happens whenever it is written and the already saved data value is different. Saving of objects in EEPROM is handled.
- Only communication and device profile objects of CANopen option card parameters are restored to default values upon command to object 0x1011.
- Manufacturer specific parameter/objects are not restored to default values upon command to object 0x1011.
- The following CANopen option card parameters are not restored to default values upon command to object 0x1011:
  - [H2.00] – Node Address
  - [H2.01] – CAN Baudrate
  - [H2.02] – CANopen Device Profile Selection
  - [H2.98] – CANopen Termination Resistor Switch

4.10 Device Profile

4.10.1 Overview

1. Communication profile:

   The communication profile of xFC01 CANopen option card is based on:

   - Physical layer is as per CAN 2.0A standards.
   - The CANopen® specification CiA-301(Version: 4.2.0).

2. Function profile:

   The functional profile of xFC01 CANopen option card complies with:

   - "Device profile for drives and motion control" (DSP-402 V2.0, velocity mode).
   - Bosch Rexroth VFC/EFC x610 drive profile.

Profile Selection Option: For controlling the drive two profiles are provided. The parameter [H2.02] is defined for profile selection. The two profiles are:

0. Rexroth Drive Profile

1. CiA-402 Drive Profile

4.10.2 Rexroth Drive Profile

Rexroth Drive Profile: Set the parameter [H2.02] to 0 and activate Rexroth profile; the CANopen option card automatically disables RPDO1 and TPDO1.

Bit	Value	Description
15...8	-	Reserved
7	1	Active
	0	Control word inactive
6	1	Stop acceleration/deceleration active (stop the internal acc/dec ramp generator)
	0	Inactive
5	1	Fault reset active
	0	Inactive
4	1	E-stop active
	0	Inactive
3	1	Stop according to parameter setting
	0	Inactive
2	1	Reverse
	0	Forward
1	1	Jog active (jogging direction determined by bit 2)
	0	Inactive
0	1	Run command active
	0	Inactive

Tab. 4-20: VFC/EFC x610 drive control word

Bit	Value	Description
15...8	-	Fault code (equal to [E9.05])
7	1	Fault
	0	No fault
6	1	Stall over current
	0	Normal
5	1	Stall over voltage
	0	Normal
4	1	Decelerating
	0	Not in deceleration
3	1	Accelerating
	0	Not in acceleration

Bit	Value	Description
2	1	Jogging
	0	Not in jog
1	1	Running
	0	Stop
0	1	Reverse
	0	Forward

Tab. 4-21: VFC/EFC x610 drive status word

4.10.3 CiA-402 Drive Profile

Set the parameter [H2.02] to 1 and activate CiA-402 Drive Profile; the CANopen option card automatically enables RPDO1 and TPDO1.

After device profile selection option is changed to CiA-402 the CANopen master should send NMT reset application command.

Device control:

The device control function block controls all functions of the drive (drive function and power section). It is divided into:

- Device control of the state machine.
- Operation mode function.

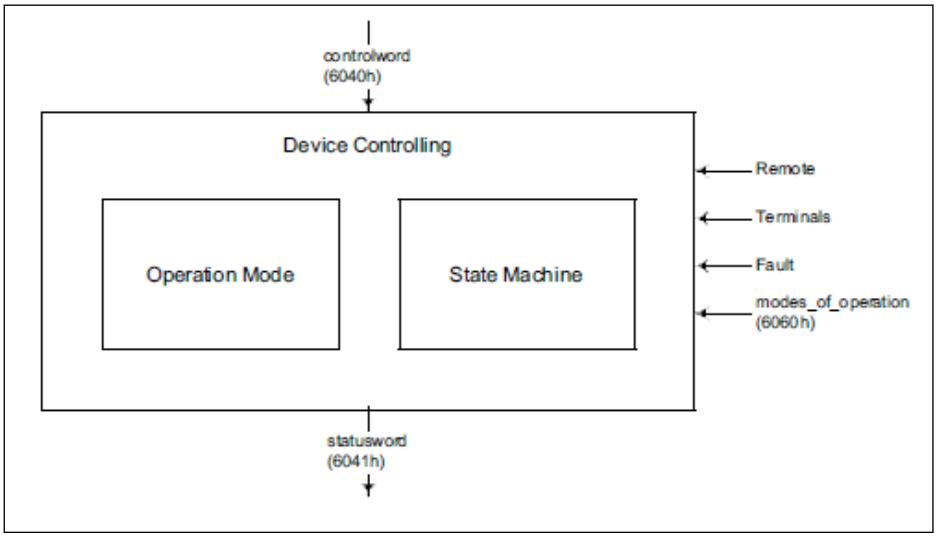


Fig. 4-4: Device control

The state of the drive can be controlled by the control word.

The state of the drive is shown in the status word.

Remote mode:

In remote mode the device is controlled directly from the CANopen network by PDO and SDO.

The state machine is controlled externally by the control word and external signals.

The write access to the control word is controlled by the optional hardware signal "Remote".

The state machine is also controlled by internal signals like faults and modes of operation.

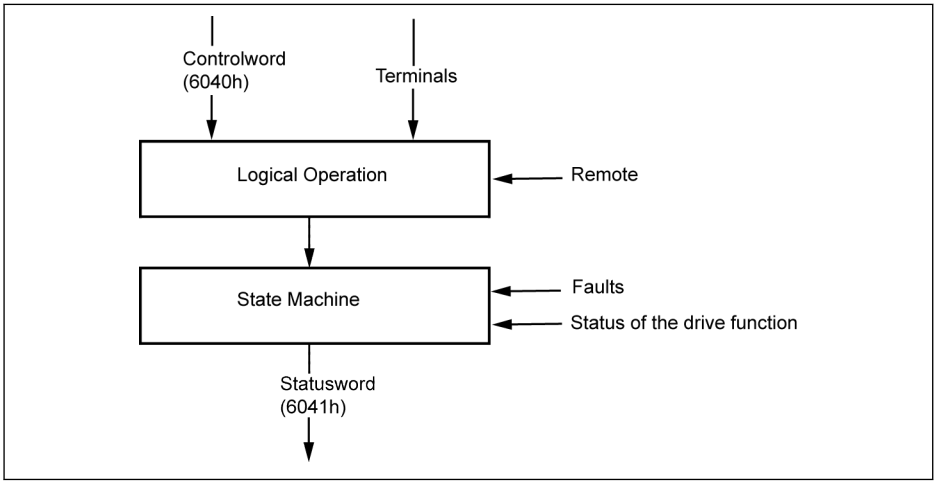


Fig. 4-5: Remote mode

From VFC/EFC x610 drive's perspective, when the Run command source is from communication and the communication protocol is CANopen then remote mode is enabled. This remote mode is reflected in the status word: Remote Bit (set when active).

[E0.01]: First run command source

[E0.02]: Second run command source

[E8.00]: Communication protocol

CiA-402 State Machine:

The state machine describes the device status and the possible control sequence of the drive. A single state represents a special internal or external behaviour. The state of the drive also determines which commands are accepted. States may be changed using the control word and/or according to internal events. The current state can be read using the status word. The state machine describes the state machine of the device with respect to control of the power electronics as a result of user commands and internal drive faults.

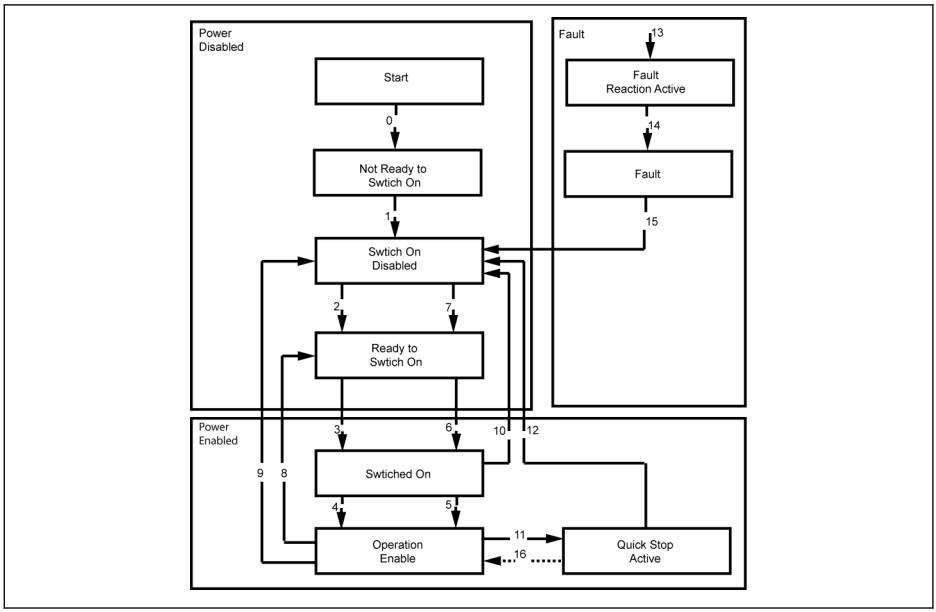


Fig. 4-6: CiA-402 state machine

Note:

- Some of the CiA-402 states cannot be directly mapped to drive's internal system state machine. More-over direct control of the drive's power section by option card is not feasible. The states defined in the CiA-402 state machine are simplified and mapped as follows.

CiA-402 state	Drive status
Not ready to switch on	Initialization phase
Switch on disabled / Ready to switch on / Switched on	Stop
Operation enable	Run
Quick stop active	Run -> Stop transition
Fault reaction active / Fault	When error is set

Tab. 4-22: The state mapping of CiA-402 state machine

- Quick stop object option code (0x605A) is not implemented.
- Transition 16 is not supported.
- Upon reception of Quick stop command the drive automatically transits (12) to "Switch On Disabled" state when the drive stops.
- Illegal state transition request is handled as follows:

  In order to control the drive, the state transitions have to be done in a proper sequence. If the requested state transition is not appropriate (as defined in the state chart) then it is termed as "Illegal transition".

When this occurs, suitable handling or indication will be given to the user/ master.

Examples:

-> Trying to directly move to “Operation Enabled” from “Switch On Disabled”.

-> Giving fault reset command in “Operation Enabled” state.

SDO Access:

If SDO is used to control the drive, then on occurrence of an illegal transition, the control word is rejected with abort code 0609 0030, “Invalid value for parameter”. The drive state is not affected.

PDO Access:

If RPDO is used to control the drive, then on occurrence of an illegal transition the drive state is not affected, but the following indication is given:

1. Warning is set and this is indicated on panel by displaying “ISt” (Invalid State Transition) and also in the CiA-Statusword warning bit (7) is set.
2. Emergency telegram is sent with error code 0x8200(protocol error).
3. The warning will be cleared only when the CANopen master gives a new valid state transition command(CiA-Controlword) either via SDO or PDO.

0	1	2	3	4	5	6	7
Error code Object: 0x603F		Error register Object: 0x1001	Manufacturer Specific Bytes				
0x8200 (Protocol error)		0x21	[b6.91] 0x5900		[b6.91] 0xE5900		

Tab. 4-23: CiA-Statusword warning bit

CiA-402 Controlword:

Object 6040h: Control word

The control word consists of bits for:

- The controlling of the state
- The controlling of operating modes
- Manufacturer specific options

Bit No.	Functionality	Description
0	Switch on	Active
1	Enable voltage	Active
2	Quick stop	Active
3	Enable operation	Active
4	Operation mode specific	Inactive (No need to consider on bit)
5	Operation mode specific	Inactive (No need to consider on bit)

Bit No.	Functionality	Description
6	Operation mode specific	Inactive (No need to consider on bit)
7	Fault reset	Active on Rising edge 0->1
8	Halt	Active
9	Reserved	Reserved (No need to consider on bit)
10	Reserved	Reserved (No need to consider on bit)
11	Manufacturer specific	Reserved (No need to consider on bit)
12	Manufacturer specific	Reserved (No need to consider on bit)
13	Manufacturer specific	Reserved (No need to consider on bit)
14	Manufacturer specific	Reserved (No need to consider on bit)
15	Manufacturer specific	Reserved (No need to consider on bit)

Tab. 4-24: Definition of control word bits

Device control commands are triggered by the following bit patterns in the control word:

Command	Bit of the control word					Transitions
	Fault reset	Enable operation	Quick stop	Enable voltage	Switch on	
Shutdown	0	X	1	1	0	2, 6, 8
Switch on	0	0	1	1	1	3*
Switch on	0	1	1	1	1	3**
Disable voltage	0	X	X	X	X	7, 9, 10, 12
Quick stop	0	X	0	1	X	7, 10, 11
Disable operation	0	0	1	1	1	5
Enable operation	0	1	1	1	1	4, 16
Fault reset	↑	X	X	X	X	15

Tab. 4-25: Device control commands

Halt-Bit (8): Drive stops when halt bit is set and enters “Switch on Disabled State”.

CiA-402 Statusword:

Object 6041h: status word

The status word indicates the current state of the drive. No bits are latched. The status word consists of bits for:

- The current state of the drive
- The operating state of the mode
- Manufacturer specific options

Bit No.	Functionality	Description
0	Ready to switch on	Active
1	Switched on	Active
2	Operation enabled	Active
3	Fault	Active
4	Voltage enabled	Active
5	Quick stop	Active
6	Switch on disabled	Active
7	Warning	Active
8	Manufacturer specific	Set to 0
9	Remote	Active
10	Target reached	Defined as drive transient* status
11	Internal limit active	Active
12	Operation mode specific	Set to 0
13	Operation mode specific	Set to 0
14	Manufacturer specific	Set to 0
15	Manufacturer specific	Set to 0

Tab. 4-26: Definition of status word bits

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

Tab. 4-27: Device state bits

Warning Bit (7):

Drive warnings are indicated on CiA-402 status word Bit-7. No emergency telegram is triggered for warning conditions detected from the Host. In case of warnings the Object 0x603F contains the warning code. If the warning is sig-

naled from the Host then the corresponding error code object's (0x603F) data value is 0xFF01.

Target Reached Bit (10):

This bit detects whether drive is in transient* status or not. Target reached bit is set when the target velocity is reached and this is determined by checking the acceleration and deceleration status of the drive. An internal delay of 30ms is taken before validating and setting this bit in the CiA-Statusword. This is required because drive does not accelerate immediately after RUN command is issued. Approximately 8ms delay time is required for enabling the power-section and entering into RUN state.

Simple Velocity Mode:

Velocity mode is composed of the following sub-functions:

- Reference calculation
- Factor function, Reverse factor function
- Percentage function, Reverse percentage function
- Pole number function, Reverse pole number function
- Velocity limit function
- Velocity motor limit function
- Ramp function
- Ramp min function
- Closed open loop control function

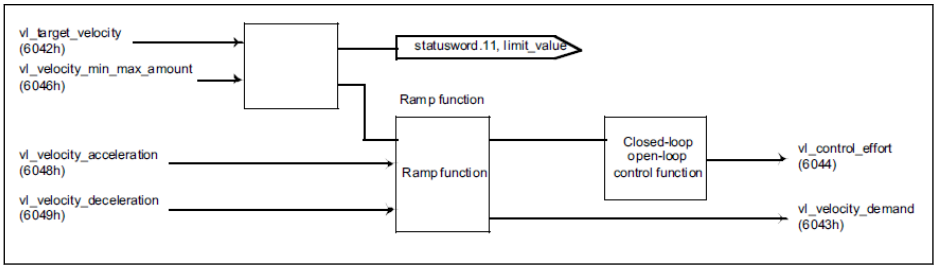


Fig. 4-7: Velocity mode with mandatory objects only

- **Rotation direction** is changed with positive and negative values of object 0x6042:

  Target velocity in RPM. The range of velocity command is from: -32768 RPM to +32767 RPM.

- In velocity mode: Acceleration is defined as: $\frac{\Delta\ Speed}{\Delta\ Time}$

  Whenever Delta speed or time changes, [E0.26] will be calculated and updated in the control board.

  $$[E0.26] = \frac{[E0.08] \times \Delta\ Time \times 120}{\Delta\ Speed \times Poles}$$

  Unit of acceleration is RPM/s.

- In velocity mode: Deceleration is defined as: $\frac{\Delta\ Speed}{\Delta\ Time}$.

  Whenever Delta speed or time changes, [E0.27] will be calculated and updated in the control board.

  $$[E0.27] = \frac{[E0.08] \times \Delta\ Time \times 120}{\Delta\ Speed \times Poles}$$

  [E0.08] -> Maximum output frequency

  Unit of deceleration is RPM/s.

Parameter dependency relation in CiA-402 velocity mode profile:

When CiA-402 drive profile is selected, a watch-list of parameters is prepared in the CANopen option card. So when these watch-list parameters are modified, then the associated dependent parameters are calculated and written back to Host (Control board) by CANopen option card automatically.

Main parameter (Watch list)	Associated dependent parameters and drive profile objects
[C1.11]: Motor Poles	1. [E0.26]: Acceleration Time 2. [E0.27]: Deceleration Time 3. [E0.10]: Output Frequency Low Limit* 4. [E0.09]: Output Frequency High Limit*
[E0.08]: Maximum Frequency	1. [E0.26]: Acceleration Time 2. [E0.27]: Deceleration Time 3. 0x6046: vl Velocity Min Max amount
[E0.09]: Output Frequency High Limit	0x6046-02: vl Velocity Max amount
[E0.10]: Output Frequency Low Limit	0x6046-01: vl Velocity Min amount
[E0.26]: Acceleration Time	Not writable when CiA-402 Profile is Active and NMT is in Operational State
[E0.27]: Deceleration Time	Not writable when CiA-402 Profile is Active and NMT is in Operational State

Tab. 4-28: List of dependent parameters

*: The Low and High limits of frequency are calculated based on the velocity limits as defined in the object 0x6046 : vl Velocity Min Max amount

- When node is in NMT operational state, it is not possible to write parameters [E0.26] and [E0.27] directly by Converter Works/SDO (“Protected by others” error is thrown).
- When node is in NMT pre-operation state, it is possible to write parameters [E0.26] and [E0.27] directly by Converter Works/SDO; but the moment the NMT state transits from pre-operation to operation, the calculated acceleration/deceleration times based on the objects 0x6048 and 0x6049 are written back to [E0.26] and [E0.27].
- If motor poles [C1.11] or maximum frequency [E0.08] parameter is changed when node is in operational state then the dependent parameters are re-calculated and updated automatically.

4.11 Related Communication Parameters

Parameter	Name	Modify	Function	Value
E0.00	First frequency setting source	Stop	Setting frequency selection source	20: Communication
E0.01	First run command source	Stop	Run command selection source	2: Communication
E8.00	Communication protocol	Stop	Field bus protocol selection	0: Modbus* 1: Option card
E8.03	Communication process data loss behaviour	Stop	Selecting the drive behaviour when the CANopen node switches to Pre-Op during RUN	0: Decelerating stop 1: Freewheeling stop 2: Keep running
H0.00	Control word	Run	VFC/EFC x610 drive control word	-
H0.01	Status word	Read	VFC/EFC x610 Drive Status Word	-
H0.10	Frequency command	Run	Setting frequency	0...400 Hz (0...65535) Default: 0
H0.20	Option card 1 type	Read	Shows the option card type in slot 1 detected by frequency converter	0: Inactive* 1: PROFIBUS card 2: CANopen card 3: Multi-Ethernet card 8: I/O card 9: Relay card
H0.21	Option card1 hardware label	Read	-	-
H0.22	Option card1 firmware string	Read	-	-
H0.23	Option card 2 Type	Read	Shows the option card type detected in slot 2 by frequency converter	0: Inactive* 1: PROFIBUS card 2: CANopen card 3: Multi-Ethernet card 8: I/O card 9: Relay card

Parameter	Name	Modify	Function	Value
H0.24	Option card2 hardware label	Read	-	-
H0.25	Option card2 firmware string	Read	-	-

Tab. 4-29: Definition of status word bits

☞ * : Factory default

4.12 CANopen Option Card Parameters

Parameter	Mapped object in MO/CO/DPO	Name	Modify	Function	Value
H2.00	MO: 0x3838	CANopen address	Stop	Selects the address for CANopen Node	1...127 Default: 1
H2.01	MO: 0x3839	CAN baudrate	Stop	Sets the speed of CANopen communication	0...6 Default: 3 0: 10 kbits/s 1: 20 kbits/s 2: 50 kbits/s 3: 125 kbits/s 4: 250 kbits/s 5: 500 kbits/s 6: 1 Mbit/s
H2.02	MO: 0x383A	CANopen device profile selection	Stop	To switch between different drive profiles	0...1 Default: 0-> Rexroth Drive Profile 1-> CiA- 402 Drive Profile
H2.98	MO: 0x389A	CANopen termination resistor switch	Stop	Selects the state of the termination resistor	0:Disabled (Default) 1: Enabled

Tab. 4-30: CANopen option card parameters

MO: Manufacturer Objects

5 Diagnosis

In VFC/EFC x610 CANopen option card, any error/warning messages on field bus status will not be displayed until field bus communication is established.

- If CANopen is in NMT pre-operation (no cyclic field bus communication): No fieldbus communication error or warning is indicated**.
- If CANopen is in NMT operational state (cyclic field bus communication established, but data is invalid). Data can become invalid whenever CAN is in passive or bus-off or if option board is not able to communicate with control board. In that case two scenarios arises:
  - If converter is in RUN state an error “Fdi-” (Field bus data invalid) is set.
  - If converter is in STOP state warning “Fdi” (without minus) is set.

- EMCY telegram is triggered whenever critical error is detected.
- No emergency telegram is triggered for warning condition detected from the Host.
- In VFC/EFC x610 CANopen, the error (Fdi-) can be cleared by user as soon as the converter reaches STOP state. If error condition is still persistent then upon clearing this error by user warning (Fdi) is automatically indicated. This warning disappears automatically, when CAN state switch to error active state and data becomes valid (For. E.g. CAN recovers from error passive state) or pre-operation (field bus offline).
- Resetting fault from CANopen option card: Error can be remotely cleared by drive control word using RPDO (i.e. slave’s NMT should be in operational state).
- If event timer is configured for RPDO, then if within the defined event time an RPDO telegram is missed, then an error(FTL-) is SET if the drive is in RUN state, else a warning(FTL) is indicated if the drive is in STOP state.
- Object 0x1029: Error behaviour is set to 0 by default. So occurrence of the bus-off/heart-beat /node guarding errors causes the NMT state of the slave device to switch autonomously to pre-operation and this behaviour has the following implications on error detection due to heartbeat or node guarding protocol errors.
- If the converter was in RUN state then the error detected on the device is “Fdi-” and not “FnC-”. This is because the control board first detects transition to pre-operation and so the control board first detects the communication disruption so it sets “Fdi-”.
- **Exception: If heart-beat or node-guarding fails then error is SET irrespective of whether drive is in Pre-Op / OP/ RUN / STOP condition.
- On occurrence of CANOVERRUN error is set irrespective of whether drive is in Pre-Op / OP/ RUN / STOP.

- The following diagnostic codes are applicable to CANopen option card.

Diagnostic Code E= Warning F= Error	LED Display	Description	Countermeasures
E5900	ISt	Invalid state transition	This warning is observed when CiA-402 profile is active and it is cleared automatically when user gives proper control word sequence to execute CiA-402 drive state machine.
E5903	FtL	RPDO telegram loss	This warning is generated when RPDO event timer is set and if the converter does not receive the RPDO frame within the pre-defined event time. It gets cleared on arrival of next RPDO - check if CAN message reception is failing. If fail, increase RPDO event time.
E5908	Fdi	Option card process data invalid	Check the communication link - CAN physical layer (CAN wires) are short or CAN connector is disconnected from the slave device when it is in NMT operational. CAN errors- Passive or Bus-off condition occurred.
F5901	FCd-	Host communication timed out	Communication with the control board is lost. Clear the error by press STOP. If error persists, restart the system.
F5902	FPC-	Fieldbus process data configuration erroneous	Re-confirm PDO settings at master and slave (Especially PDO message length)
F5903	FtL-	RPDO telegram loss	Similar as E5903 – But will appear when converter is in run state
F5904	FIn-	Communication platform initialization failed	Try default loading of parameters.
F5905	FnC-	Fieldbus network configuration invalid	Heartbeat or node-guarding protocol failure, check the nodes and communication link.
F5906	FCE-	Communication platform critical error	Check if any invalid parameters are listed in b7.93. If not, review the network settings node guard intervals, PDO's & SDO's (because excessive amount of received/ sending data are related, such as heartbeat, node guard, SDO, NMT, and SYNC.)

Tab. 5-1: Diagnostic codes applicable to CANopen option card

Notes

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