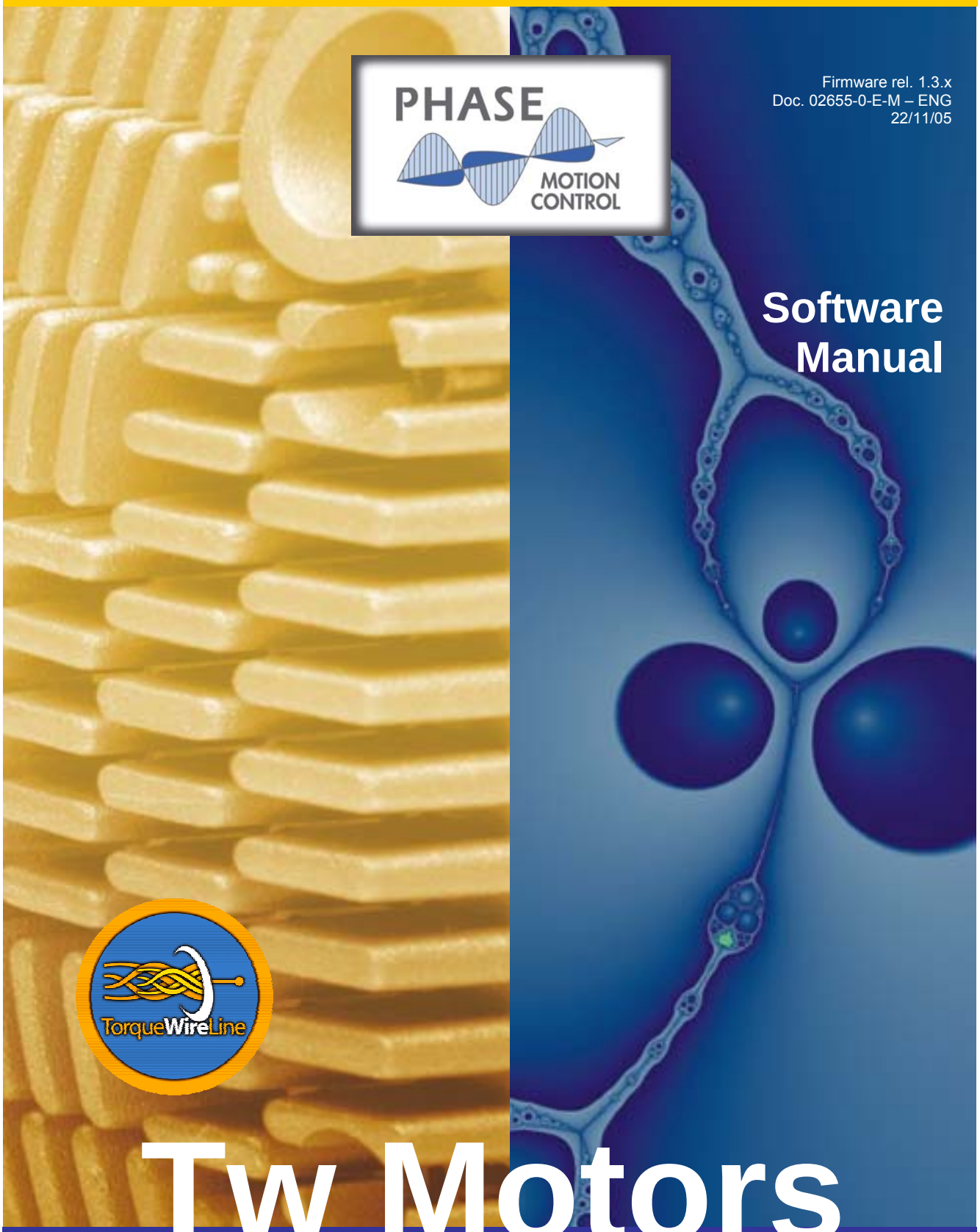


Firmware rel. 1.3.x
Doc. 02655-0-E-M – ENG
22/11/05

Software Manual

Tw Motors

With Integrated Servodrive

http://www.phase.it

Summary

References

/ 1: CiA DS301 V4.02
/ 2: CiA DSP305 V1.1
/ 3: CiA DSP402 V2.0
/ 4: Phase Motion Control Tw Motors User manual
/ 5: Phase Motion Control CANPC-S1 User manual
/ 6: Phase Motion Control Cockpit II manual

Figures

Tables

History

Rev. B — Document modified for the firmware release V1.0.x:

- Notation chapter added (§1.1)
- Asynchronous PDO timing clarification (§2.6)
- Aux input triggered PDO added (§4.6 and object 530Ah.0h)
- Synchronisation Object timing clarification (§2.7)
- SYNC statistics added (§2.7 and objects 5110h.0h, 5111h.0h, 5112h.0h and 530Bh.0h)
- Error codes added and more details for some error codes in the Table 6
- Factor group approximation clarification (§3.7)
- Position error calculation clarification (§4.1)
- Torque mode chapter added (§4.3)
- Speed loop control chapter added (§4.5)
- Digital filters chapter added (§4.7)
- New led behaviour added (§4.8)
- Target position initial value clarification (object 607Ah.0h)
- Home offset enhancement (object 607Ch.0h)
- Hardware configuration object added (5311h.0h)
- User configuration version object added (5312h.0h)
- Objects 5102h.0h, 607Dh, 5380h.0h, 5012h.0h, 5013h.0h added
- Objects added to Velocity control parameters (object 60F9h)
- Adaptation to the new functions of the second application example (§6.2 and §6.3)
- Adaptation to the new functions of speed loop control schema (Appendix A)
- **Cockpit configuration tool** chapter removed

Rev. C — Document modified for the firmware release V1.1.x:

- LSS Switch modes clarification (§2.4)
- Error code object added (603Fh.0h)
- SYNC PDO overtime error code added in the Table 6
- CAN SW overrun / CAN HW overrun / PDO length error codes now trigger an Abort connection event
- More details on approximation of factor group (§3.7)
- More details on current and speed loops (§4.2 and §4.5)
- More details and wrong equations fixed in the digital filter (§4.7)
- Filtered velocity demand value object 5103h.0h added
- Disable software position limits flag added on object 5380h.0h
- More details on object 1011h

Rev. D — Document modified for the firmware release V1.2.x:

- New behaviour of the SYNC Controller alarm generation (§2.8)
- Enable rotary axis flag added on object 5380h.0h
- Enable signed position flag added on object 5380h.0h
- Homing mode chapter added (§3.6)
- Rotary table control chapter added (§4.4)
- New functionality added to auxiliary digital input (§4.6)
- Bits added to statusword (object 6041h.0h)
- New encoder type added (§4.1)
- COB-ID value range clarification
- Objects 6098h.0h, 6099h, 609Ah.0h, 5320h, 5321h.0h, 5322h.0h, 5323.0h added

Rev. E Document modified for the firmware release V1.3.x:

- Application zero position in homing mode added (§3.6)
- Control loop performance measurements parameters added (§4.5)
- More details on rotary axis enabled bit (§4.1)
- More details on default values for the hardware configuration dependant objects (Appendix C)
- Objects 5120h.0h, 5121h.0h, 5122h.0h, 5123h.0h, 5124h.0h, 5330h.0h added

Please read also the **changelog.txt** file included in the firmware package for more information

1. Introduction

The Tw drives use a subset of the standard CANopen protocol to provide access to whole drive parameters. Several standard CANopen functions codes are supported as described in the CiA DS301.

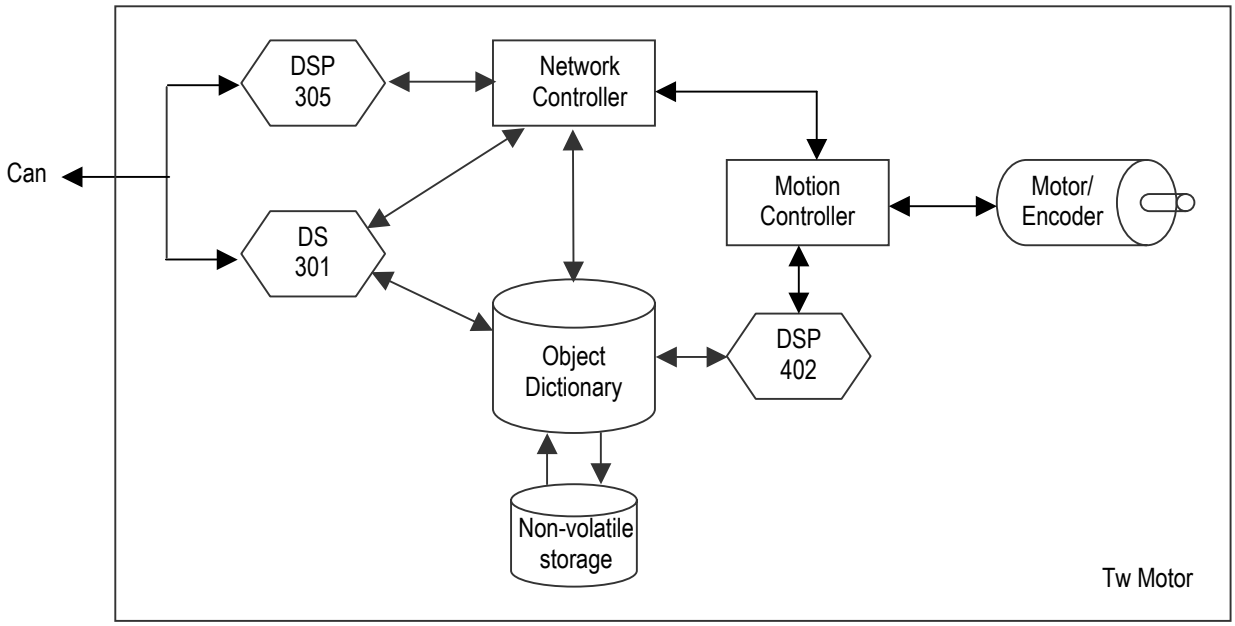


Figure 1: Relation between basic objects in the Tw Motor

The field bus that is used here is defined in ISO 11898 (Controller Area Network CAN for high-speed communication). The Layer-1/2 protocol (Physical Layer/Data Link Layer) that is implemented in all CAN modules provides, amongst other things, the requirements for data. Data transport or data request is made by means of a data telegram (Data Frame) with up to 8 bytes of user data, or by a data request telegram (Remote Frame or RTR). Communication Objects (COB) are labeled by an 11-bit Identifier (ID) that also determines the priority of Objects. A Layer-7 protocol (Application Layer) was developed, to decouple the application from the communication. The service elements that are provided by the Application Layer make it possible to implement an application that is spread across the network. These service elements are described in the CiA DS301.

The Tw drives are slave systems and then they need a CANopen master system (master CANopen, PC with **Cockpit** (refer to / 6), PC with CANopen configuration tool, PLC, etc.) to be configured via the CAN bus.

The Tw Motor uses also a subset of the CiA DSP402, which standardizes the objects necessary for the digital motion controller.

1.1. Notation

In this manual all references from CiA standards are adapted to the specific Tw drives. These does not includes features not implemented on the Tw drives.
All COBs are expressed in a structured table, including the COB-ID, where the length of the COB depends on how many bytes (Bx) are represented.
All objects are articulated is in the form **index.sub-index**, e.g. 1018h.2h means index 1018h sub-index 2h. If only **index** is specified then it means reference to the complete RECORD or ARRAY object, refer to §2.2.
All numerical data expressed inside a COB are always reordered starting from the least significant octet, refer to §2.3.

2. CANopen protocol – DS301

The CANopen protocol is one of the most common CAN protocols. Since 1995 the CANopen specification is handed over to CAN in Automation (CiA) international users and manufacturers group. The European standardization authorities

have accepted the CANopen Device Specification version 4.01 as EN 50325-4. The main concept of CANopen is based on use of an object dictionary (basically device's variables, parameters, etc.). This dictionary gathers data related to the communication and the application. To access to these objects two methods are used: SDO & PDO.

SDO mean Service Data Object and is a confirmed way to exchange data of the object dictionary between master and slave. Usually a slave device is an SDO server, this mean that it could answer to a query originated by an SDO client, typically the master device of the network. Usually this protocol is used to configure the internal parameters of the device; in the Tw Motor it is used also to upgrade the firmware wherever necessary. The confirmed nature of this protocol generate a large amount of traffic on the CAN bus making it unsuitable for high-speed real-time communication.

The PDO (Process Data Object) is an unconfirmed way and extremely configurable protocol to exchange high-speed real-time data, maximizing advantages of the CAN architecture. The transfer of PDOs is performed with no protocol overhead. The PDOs correspond to entries in the device Object Dictionary and provide the interface to the application objects. Data type and mapping of application objects into a PDO is determined by a corresponding PDO mapping structure within the Device Object Dictionary. Basically a PDO could be asynchronous (means that the transmission is triggered on a specific event or is remotely requested) or synchronous (means that the transmission is synchronized with the Synchronization Object).

The SYNC producer, typically the master, broadcasts the Synchronization Object periodically. This SYNC provides the basic network clock. There can be a time jitter in transmission by the SYNC producer corresponding approximately to the latency due to some other COB being transmitted just before the SYNC. In order to guarantee timely access to the CAN bus the SYNC is given a very high priority identifier.

Emergency objects are triggered by the occurrence of a device internal error situation and are transmitted from an emergency producer (typically the slave) on the device. Emergency objects are suitable for interrupt type error alerts.

The Network Management (NMT) is node oriented and follows a master-slave structure. NMT objects are used for executing NMT services. Through NMT services, nodes are initialized, started, monitored, reset or stopped. All nodes are regarded as NMT slaves. An NMT Slave is uniquely identified in the network by its node-ID, a value in the range of [1..127]. NMT requires that one device in the network fulfils the function of the NMT Master.

LSS (Layer Setting Service) offers the possibility to inquire and change the settings of certain parameters of the local layers on a CANopen module with LSS Slave capabilities by a CANopen module with LSS Master capabilities via the CAN bus. The following parameters can be inquired and/or changed by the use of LSS:

- Node-ID of the CANopen Slave
- Bit timing parameters of the physical layer (baud rate)
- LSS address (Identity Object, 1018h)

By using LSS a LSS Slave can be configured for a CANopen network without using any devices like DIP-switches for setting the parameters. Then the configuration can be stored on a non-volatile memory.

2.1. CANopen Protocol Parameters

Standard features that are implemented in Tw Motor are:

NMT:	Slave only
Baud rate / node-ID:	1000 / 800 / 500 / 250 / 125 / 100 / 50 kbps; node 1 ÷ 127
Server SDO:	1
Tx PDO:	8
Rx PDO:	8
PDO Mapping:	User programmable (only in pre-operational state)
PDO Modes:	All types supported
Emergency object:	Yes
Sync object:	Yes
Time object:	No
Error control protocols:	Boot-up / Node Guarding / Heartbeat

Table 1: Tw Motor CANopen features

2.2. Object Dictionary

The most important part of a device profile is the Object Dictionary description. The Object Dictionary is essentially a grouping of objects accessible via the network in an ordered pre-defined fashion. The overall layout of the standard Object Dictionary is shown below. This layout closely conforms to other industrial serial bus system concepts:

Index	*Object*
0000h-0FFFh	data definition / reserved
1000h-1FFFh	communication profile area (DS301)
2000h-5FFFh	manufacturer specific area (Tw Motor specific)
6000h-9FFFh	standardized device profile area (DSP402)
A000h-FFFFh	other profiles / reserved

Table 2: Object dictionary layout

A 16-bit index is used to address all entries within the Object Dictionary. In case of a simple variable (**VAR**) the index directly references the value. In case of records (**RECORD**) and arrays (**ARRAY**) however, the index addresses the whole data structure. To allow individual elements of structures of data to be accessed via the network a sub-index is defined. For single Object Dictionary entries such as an UNSIGNED8, INTEGER32 etc. the value for the sub-index is always zero. For complex Object Dictionary entries such as arrays or records with multiple data fields the sub-index references fields within a data-structure pointed to by the main index. The fields accessed by the sub-index can be composed of different data types.

All objects accessible in the Tw Motor are described in §5.

2.3. Data Type Encoding

Basic data types used for accessing the object dictionary are:

- **INTEGER8** (8 bit signed integer)
- **INTEGER16** (16 bit signed integer)
- **INTEGER32** (32 bit signed integer)
- **UNSIGNED8** (8 bit unsigned integer)
- **UNSIGNED16** (16 bit unsigned integer)
- **UNSIGNED32** (32 bit unsigned integer)

For transmission across a CAN bus a bit sequence is reordered into a sequence of octets, starting from the least significant octet.

Examples:
Unsigned16 value: 18911 = 49DFh

B0	B1
49DFh	

⇒

B0	B1
DFh	49h

Unsigned32 value: 98827716 = 05E3 FDC4h

B0	B1	B2	B3
05E3 FDC4h			

⇒

B0	B1	B2	B3
C4h	FDh	E3h	05h

2.4. LSS – DSP305

Since in the LSS Protocol all LSS Slaves use the same COB to send information to the LSS Master, there must be only one LSS Slave at a time that communicates with the LSS Master. For all protocols the LSS Master takes the initiative, a LSS Slave is only allowed to transmit within a confirmed service after it has been uniquely switched into configuration mode. Since there can be almost one confirmed LSS service outstanding at a time, the synchronization is established.

The factory default setting for the Tw Motor is node-ID equal to 1 and baud rate equal to 125kbps.

Master could switch the slave to configuration mode with the **switch mode global** command:

Request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E5h	04h	01h	Reserved					

The Tw Motor support also the **switch mode selective** (see / 2).

A non-standard command that find appliance only on Tw Motor is the **switch mode selective with serial number**. This command let a network with all powered-on and connected Tw Motor to switch to configuration mode one selected drive, providing only his serial number.

Request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E5h	80h	serial number				Reserved		

The response came only if desired slave exist and has switched to configuration mode.

Response (Slave → Master)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E4h	44h	reserved						

After a slave has switched to configuration mode the master could modify the node-ID with the following command:

Request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E5h	11h	node-ID	reserved					

node-ID: *01h to 7Fh*

Response (Slave → Master)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E4h	11h	error code	spec. error	reserved				

error code: *0 means successful executing*

This command alter all COB-ID that by default are in the form xxxh+node-ID (COB-ID of PDOs and of EMCY), but only if they have still the default value.

To configure the baud rate the following command is to be used:

Request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E5h	13h	00h	Speed idx	reserved				

speed idx: *see Table 3*

Response (Slave → Master)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E4h	13h	error code	spec. error	reserved				

error code: *0 means successful executing*

Baud Rate	*Speed idx*
1000 kbps	0
800 kbps	1
500 kbps	2
250 kbps	3
125 kbps	4
100 kbps	5
50 kbps	6

Table 3: Baud rates

Then master can activate the new speed immediately with the following optional command:

Request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E5h	15h	switch delay		reserved				

switch delay: *the duration of the two periods of time to wait until the bit timing parameters switch is done (first period) and before transmitting any COB with the new bit timing parameters after performing the switch (second period). The time unit of switch delay is 1 ms.*

Master now should store the new configuration in the internal non-volatile storage:

Request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E5h	17h	reserved						

Response (Slave → Master)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E4h	17h	error code	spec. error	reserved				

error code: *0 means successful executing*

Finally, master should switch back the slave to the normal operation mode:

Request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E5h	04h	00h	reserved					

For further details and examples please refer to / 2 and §6.1.

2.5. SDO

With Service Data Objects (SDO) the access to entries of a device Object Dictionary is provided. As these entries may contain data of arbitrary size and data type, SDOs can be used to transfer multiple data sets (each containing an arbitrary large block of data) from a client to a server (**download** or write) and vice versa (**upload** or read). The client can control via a multiplexor (16 bit index and 8 bit sub-index of the Object Dictionary) which data set is to be transferred. The contents of the data set are defined within the Object Dictionary.

Basically a SDO is transferred as a **sequence of segments**. Prior to transferring the segments there is an initialization phase where client and server prepare themselves for transferring the segments.

This is the sequence of the object **download**:

Initialization download request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
600h+node-ID	21h	index		subidx	data size			

data size: *this is the overall size (in bytes) of the object to be downloaded*

If the transfer could be done the server acknowledge the initialization phase:

Initialization download response (Slave → Master)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
580h+node-ID	60h	index		subidx	reserved			

Then the object download begin with a series of a segments:

Segment download request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
600h+node-ID	client cmd	segment data						

client cmd:
bit 7-5: segment download request, equal to 0
bit 4: toggle bit: this bit must alternate for each subsequent segment that is downloaded. The first segment will have the toggle bit set to 0. The toggle bit will be equal for the request and the response COB
*bit 3-1: indicates the number of bytes in **segment data** that do not contain data. Bytes [8-n, 7] do not contain data*
bit 0: indicates whether there are still more segments to be downloaded: 0 means more segment to be downloaded, 1 means no more segments (this is the last segment)

Segment download response (Slave → Master)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
580h+node-ID	server cmd	reserved						

server cmd:
bit 7-5: segment download response, equal to 1
bit 4: toggle bit: this bit must alternate for each subsequent segment that is downloaded. The first segment will have the toggle bit set to 0. The toggle bit will be equal for the request and the response COB
bit 3-0: reserved, always 0

This is the sequence of the object **upload**:

Initialization upload request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
600h+node-ID	40h	index		subidx	reserved			

If the transfer could be done the server acknowledge the initialization phase:

Initialization upload response (Slave → Master)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
580h+node-ID	41h	index		subidx	data size			

Data size: *this is the overall size (in bytes) of the object to be uploaded*

Then the object upload begin with a series of a segments:

Segment upload request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
600h+node-ID	client cmd	reserved						

client cmd:
bit 7-5: segment upload request, equal to 3
bit 4: toggle bit: this bit must alternate for each subsequent segment that is uploaded. The first segment will have the toggle bit set to 0. The toggle bit will be equal for the request and the response COB
bit 3-0: reserved, always 0

Segment upload response (Slave → Master)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
580h+node-ID	server cmd	segment data						

server cmd:
bit 7-5: segment upload response, equal to 0
bit 4: toggle bit: this bit must alternate for each subsequent segment that is uploaded. The first segment will have the toggle bit set to 0. The toggle bit will be equal for the request and the response COB
*bit 3-1: indicates the number of bytes in **segment data** that do not contain data. Bytes [8-n, 7] do not contain data*
bit 0: indicates whether there are still more segments to be uploaded: 0 means more segment to be uploaded, 1 means no more segments (this is the last segment)

It is also possible to transfer a data set of up to four bytes during the initialization phase. This mechanism is called an **expedited transfer**:

Expedited request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
600h+node-ID	client cmd	index		subidx	data (optional)			

client cmd:
2Fh: expedited download of 8 bit data
2Bh: expedited download of 16 bit data
23h: expedited download of 32 bit data
40h: expedited upload

Expedited response (Slave → Master)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
580h+node-ID	server cmd	index		subidx	data (optional)			

server cmd:
60h: expedited download successful
4Fh: expedited upload of 8 bit data successful
4Bh: expedited upload of 16 bit data successful
43h: expedited upload of 32 bit data successful

If transfer would fail for some reason, both master and slave could send the **abort transfer** COB (it could be sent in any download/upload segment):

Abort transfer (Master → Slave or Slave → Master)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
600h+node-ID or 580h+node-ID	80h	index		subidx	abort code			

The **abort code** could be one of the following:

Abort code	*Description*
0503 0000h	SDO toggle bit not alternated during segmented transfer.
0504 0000h	SDO protocol timed out.
0504 0001h	SDO client/server command specifier not valid or unknown.
0504 0005h	Out of dynamic allocated memory.
0601 0001h	Attempt to read a write only object.
0601 0002h	Attempt to write a read only object.

Abort code	*Description*
0602 0000h	Object does not exist in the object dictionary.
0604 0041h	Object cannot be mapped to the PDO.
0604 0042h	The number and length of the objects to be mapped would exceed PDO length.
0604 0047h	SDO wrong COB length
0606 0000h	Access failed due to an hardware error of the internal non-volatile storage
0607 0010h	Data type does not match, length of service parameter does not match
0607 0012h	Data type does not match, length of service parameter too high
0607 0013h	Data type does not match, length of service parameter too low
0609 0011h	Sub-index does not exist.
0609 0030h	Value range of parameter exceeded (only for write access).
0609 0031h	Value of parameter written too high.
0609 0032h	Value of parameter written too low.
0609 0036h	Maximum value is less than minimum value.
0800 0020h	Data cannot be saved or restored from the internal non-volatile storage, wrong signature.
0800 0021h	Data cannot be saved or restored from the internal non-volatile storage because the power output is enabled
0800 0022h	Data cannot be transferred or stored to the application because of the present device state, depending on the object accessed either NMT state is operational or power output enabled, see description of the **Write override** attribute in §5.

Table 4: Abort codes

Examples:

Master download (via expedited transfer) to a slave the 16 bit value 1AC7h to the object 6066h.0h:

Request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
600h+node-ID	2Bh	6066h		00h	1AC7h		0	

Response (Slave → Master)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
580h+node-ID	60h	6066h		00h	0			

Master upload (via expedited transfer) from a slave the object 1018h.4h (that is a 32 bit value equal to 0098 9CABh):

Request (Master → Slave)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
600h+node-ID	40h	1018h		04h	0			

Response (Slave → Master)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
580h+node-ID	43h	1018h		04h	0098 9CABh			

For further details please refer to / 1.

2.6. PDO

Process Data Objects are used to transmit any process data for the process control. The PDOs are transmitted in broadcast and without any confirmation back to the transmitting device. There are two kinds of use for PDOs. The first is data transmission and the second data reception. It is distinguished in Transmit-PDOs (**TPDOs**, from slave to master) and Receive-PDOs (**RPDOs**, from master to slave).
Synchronous PDOs are transmitted on SYNC event and could be cyclic (means that the transmission is every n SYNC, with n between 1 and 240), acyclic (means that the transmission is triggered on event and then synchronized with SYNC event) or RTR-Only (only for TPDOs, means that master request the transmission by sending an RTR COB with same

COB-ID of the specific TPDO). The received RPDOs data is internally processed on the SYNC event, not immediately after receiving RPDO itself. The transmitted TPDOs data is sampled on the SYNC event, not at the time of transmission. TPDOs are dispatched immediately after the SYNC event, while RPDOs normally are dispatched from the master after all TPDOs and just before next SYNC event.
Asynchronous TPDOs could be triggered on event (means on changing data) or RTR-Only (means that master request the transmission by sending an RTR COB with same COB-ID of the specific TPDO). It is not guaranteed that the time on which data change and the time the TPDO are transmitted are the same. The received data of the asynchronous RPDOs are internally dispatched as soon as possible.
TPDOs could also have enabled the RTR allowed attribute, this means that, disregarding the transmission type, the master has the possibility to force the transmission by RTR COB.

Examples:

Predefined RPDO #3, with control word (16 bit) and target position (32 bit):

COB-ID	B0	B1	B2	B3	B4	B5
400h+node-ID	6040h.0h		607Ah.0h			

Predefined TPDO #2, with status word (16 bit) and mode of operation display (8 bit):

COB-ID	B0	B1	B2
280h+node-ID	6041h.0h		6061h.0h

In the Tw Motor it is possible to change the COB-ID (independently from the node-ID), the data mapping (for all PDOs) and specify an **inhibit time** (valid only for asynchronous TPDOs), that defines the minimum time that has to elapse between two consecutive invocations of a transmission service for that TPDO. In addition the Tw Motor provide an aux input triggered TPDO, refer to §4.6.

For all PDOs configuration there are specific entries in the object dictionary: 1400h and 1600h for RPDOs, 1800h and 1A00h for TPDOs. Refer to §6.2 for examples on how to fully configure PDOs.

For further details please refer to / 1.

2.7. SYNC

The **Synchronization Object** does not carry any data and is unconfirmed service.

Sync COB (broadcast)

COB-ID
080h

This object trigger the internal parameters exchange to and from all synchronous PDO buffers.

Tw Motor also use the SYNC object to synchronize his internal machine cycle with that of the Synchronization Object producer, but only if the SYNC cycle time is multiple of 250μs; also the time tolerance should be below ±5μs; the maximum recommended cycle time is 25ms. In addition it is suggested that the master start generating the SYNC object at least 100ms before **Start** remote node command and/or before enabling output power, to let drive synchronization. This feature (enabled by default) could be disabled if the user experience troubles with tolerance greater than specified.

The Tw Motor also monitor continuously the time period of the SYNC object, giving the user the ability to have a feedback on the quality of the SYNC object; this is given in the form of three parameters, the minimum cycle time, the maximum cycle time and the average cycle time. Those parameters are updated every user-specified amount of time (default 2 seconds), giving back the cycle time quality of the past period and letting the user never miss any intermittently discontinuity of the SYNC (e.g. missing transmission of SYNC objects). The statistics are not cumulative, at the end of every update time period the drive reset the internal counters. Please note that in the Tw Motor all the EMCY, NMT and SDO objects are not internally synchronized with the SYNC object, then they could be dispatched at any time.

The SYNC related objects are: 1005h.0h, 60C2h, 60C3h, 5110h.0h, 5111h.0h, 5112h.0h, 530Bh.0h and 5380h.0h bit 2.

For further details please refer to / 1.

2.8. EMCY

Tw Motor support the emergency object, both for hardware and software faults. An emergency object is transmitted only once per 'error event'.

Emergency COB (broadcast)

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
080h+node-ID	error code		error register	Tw Motor error register				reserved

error code: *standard CiA error code (object 603Fh.0h)*
error register: *standard CiA error register (object 1001h.0h)*
Tw Motor error reg.: *mapped in the manufacturer status register (object 1002h.0h)*

Every bit in the **error register** refer to a category of faults, more than one bit at time could be set to 1, meaning that more than one fault is active. Bit 0 is set to 1 if one or more faults are active, is reset to 0 if all faults are cleared.

Every bit in the **Tw Motor error register** refer to a specific faults of the motion controller and the OS but the communication module; more than one bit at time could be set to 1, meaning that more than one fault is active.

Bit	*Meaning*
0	generic error
1	current
2	voltage
3	temperature
4	communication error (overrun, error state)
5	device profile specific
7	manufacturer specific

Table 5: Error register reference

After the fault is cleared the slave transmit and EMCY object with **error code** equal to 0h, meaning that one fault is cleared. The other fields report remaining active faults; if none, all fields will be 0h.

Except when specified, the behaviour of non-fatal faults are described in the Fault Reaction option code (object 605Eh.0h).

Error code	*Error register bit*	*Tw Motor error register bit*	*Fatal fault*	*Description*	*Remedy / Cause*
2110h	1	0	Yes	Overcurrent / power short-circuit / power module fail	Overcurrent; if the fault is persistent please contact technical service
3210h	2	1	Yes	DC-link overvoltage	Check the functionality of the external clamp device, refer to / 4
4210h	3	2	No	Device overtemperature	Environment too warm, refer to / 4
4310h	3	3	No	Power section overtemperature	Heavy working cycle, refer to / 4
6100h	N/A	4	Yes	Internal software	Contact technical service
7121h	7	5	Yes	Motor blocked / following error overlimit	Check that output shaft is free of rotating / check the VS PID parameters, refer to object 60F9h / check that the difference between two set-point in Interpolated mode is coherent with maximum admitted speed, refer to §3.5 / check the motor blocked threshold, refer to object 5305h.0h
7300h	7	6	Yes	Encoder	Position encoder disalignment; if the fault is persistent please contact technical service
8700h	4	7	No‡	Sync controller	The timing of the SYNC object is not accurate, refer to §2.7. It is generated only when bit 2 of the object 5380h.0h is enabled.
6320h	N/A	8	-	Parameter error on object 6060h.0h	Check data consistency of written object 6060h.0h

Error code	*Error register bit*	*Tw Motor error register bit*	*Fatal fault*	*Description*	*Remedy / Cause*
6321h	N/A	9	-	Parameter error on object 6086h.0h	Check data consistency of written object 6086h.0h
9001h	7	10	No*	Loss of external auxiliary input voltage	The voltage on the auxiliary input has switched off or is detached
3211h	2	11	Yes†	DC-link rising too fast	Check overall external DC-link capacitor, refer to / 4
4211h	3	12	No	Motor overtemperature	Heavy working cycle, refer to / 4
6200h	N/A	13	Yes	SYNC PDO processing overtime	The time slot assigned to the sinchronous PDOs is not enough to process all user defined PDOs, reduce the number of PDO or the number of objects inside them
8A01h	N/A	16	No	Abort connection	Sent only if the object 6007h.0h state a specific action, none by default
5530h	N/A	17	-	Flash parameters error	The non volatile parameters memory is corrupted, the drive has booted with default configuration; issue a store parameters command (object 1010h); if the fault Is persistent please contact technical service
8401h	N/A	18	Yes	Overspeed	The shaft has reached the maximum tolerated mechanical speed, ~3500 rpm
8110h	4	N/A	No‡	CAN HW overrun	Reduce network load for the slave
8111h	4	N/A	No‡	CAN SW overrun	The node has received a new instance of one RPDO before processing the old one, refer to §2.6
8120h	4	N/A	No‡	CAN controller entered error passive mode	Noisy network environment or incorrect bus termination, refer to / 4
8140h	4	N/A	No‡	Recover from CAN controller bus-off	Extremely noisy network environment
8130h	4	N/A	No‡	Life guard error	Master has not polled the node within the life time, refer to §2.9
8220h	4	N/A	No‡	PDO length error	The length of RPDO does not match with the internally calculated length, refer to §2.6
8230h	4	N/A	-	PDO out of memory	Due to internal handling of PDOs, reduce the number of PDO or the number of objects inside them or the order of these objects; all PDOs are not created, thus unavailable
8231h	4	N/A	-	Aux input triggered PDO parameter error	The transmission type of this PDO is invalid, refer to §4.6; all PDOs are not created, thus unavailable

Table 6: Tw Motor emergency codes reference

The error register is mapped to the object 1001h.0h and the Tw Motor error register is mapped to the object 1002h.0h, while the last error code is mapped in the object 603Fh.0h. For further information on faults behaviour refer to §3.2.

2.9. NMT

The Network Management (NMT) divides in two categories, as follow.

2.9.1. Module Control Services

Through Module Control Services, the NMT master controls the state of the NMT slaves. The state attribute is one of the values {STOPPED, PRE-OPERATIONAL, OPERATIONAL, INITIALISING}. The Module Control Services can be performed with a certain node or with all nodes simultaneously.

* This emergency code trigger an Auxiliary Input event, which the behaviour is defined by the object 5300h.0h
† This event trigger a special fault reaction: the three power output lines are shorted together, acting both as brake for the motor and as a brake resistor to reduce DC-link voltage
‡ This emergency code trigger an Abort Connection event, which the behaviour is defined by the object 6007h.0h

NMT COB

COB-ID	B0	B1
000h	CS	node-ID

CS: *01h: **start** remote node*
*02h: **stop** remote node*
*80h: enter **pre-operational** remote node*
*81h: **reset** remote node*
*82h: **reset communication** of remote node*

Node-ID: *Node-ID of the remote node or 00h for broadcast to all nodes*

Immediately after power-on the node enter in the PRE-OPERATIONAL state; then master could follow these steps to set-up the nodes before enabling them to the OPERATIONAL state:

- Configuration of all device parameters, including communication parameters (via Default SDO)
- start transmission of SYNC, wait for synchronization of all devices
- Start of Node Guarding

All of those operations are optional as Tw Motor support full parameters saving to internal non-volatile storage and the requirement of SYNC depend from the specific application.

The state transition (except the PRE-OPERATIONAL to OPERATIONAL transition) could trigger an Abort Connection event, which the behaviour is defined by the object 6007h.0h. State transitions are caused by reception of an NMT COB used for module control services or an hardware reset.

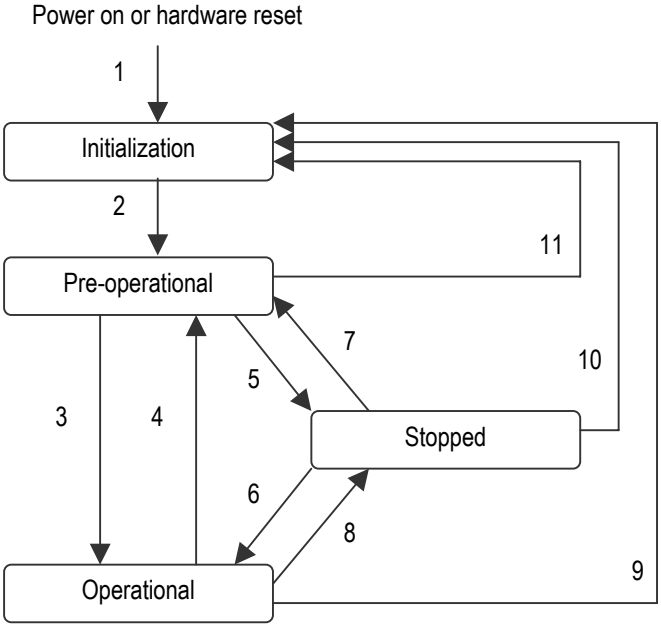


Figure 2: State diagram of a device

1	At Power on the initialization state is entered autonomously
2	Initialization finished - enter **pre-operational** automatically
3,6	**Start** remote node
4,7	Enter **pre-operational** remote node
5,8	**Stop** remote node
9,10,11	**Reset** remote node / **Reset communication** of remote node

Table 7: Trigger for state transition

	INITIALISING	*PRE-OPERATIONAL*	*OPERATIONAL*	*STOPPED*
PDO			X	
SDO		X	X	
SYNC		X	X	
EMCY		X	X	
Boot-Up Object	X			
Network Management Objects		X	X	X

Table 8: NMT states and defined communication objects

2.9.2. Error Control Protocols

Through Error control services the NMT detects failures in the network. Local faults in a node may lead to a reset or change of state. Error Control services are achieved principally through periodically transmitting of COBs by a device. There exist two possibilities to perform Error Control. The **guarding** is achieved through transmitting guarding requests (Node guarding protocol) by the NMT Master. If a NMT Slave has not responded within a defined span of time (node life time) or if the NMT Slave's communication status has changed, the NMT Master informs its NMT Master Application about that event. The slave uses the guard time and lifetime factor from its Object Dictionary to determine the node life time. If the NMT Slave is not guarded within its life time, the NMT Slave informs its local Application about that event. If guard time and life time factor are 0 (default values), the NMT Slave does not guard the NMT Master. Guarding starts for the slave when the first remote-transmit-request for its guarding identifier is received. This may be during the boot-up phase or later. A slave establishes the **heartbeat** mechanism for a device through cyclically transmitting a message. One or more devices in the network are aware of this heartbeat message. If the heartbeat cycle fails for the slave the local application on the master will be informed about that event. It is not allowed for a slave to use both protocol; in case both are activated the heartbeat protocol will be used.

- **Node Guarding Protocol**: The NMT Master polls (with an RTR COB with same COB-ID of the Error Control COB) each NMT Slave at regular time intervals. This time-interval is called the guard time and may be different for each NMT Slave. The response of the NMT Slave contains the state of that NMT Slave. The node life time is given by the guard time (object 100Ch.0h) multiplied by the life time factor (object 100Dh.0h). The node life time can be different for each NMT Slave. If the NMT Slave has not been polled during its life time, it issues an EMCY object with error code 8130h (see §2.8) and then the action indicated in the Abort Connection (object 6007h.0h) is issued. The error is cleared either restarting polling slave or by a reset node / reset communication command.
- **Heartbeat Protocol**: It defines an Error Control Service without need for remote frames. The slave transmits a Heartbeat message cyclically. The master receives the indication. The master guards the reception of the Heartbeat within the Producer Heartbeat Time (object 1017h.0h).
- **Bootup Protocol***:* It is used to signal that a NMT slave has entered the node state PRE-OPERATIONAL after the state INITIALISING.

Error Control COB

COB-ID	B0	
700h+node-ID	7 t	6..0 s

t: *used only with the **Node Guarding Protocol**, it toggle between 0 and 1 every time the COB is sent (the first time after boot-up or reset node / reset communication command is 0); other ways is 0*

s: *00h: Bootup*
04h: Stopped
05h: Operational
7Fh: Pre-Operational

3. CANopen for digital motion controller – DSP402

The purpose of this profile is to give drives an understandable and unique behavior on the CAN bus. The purpose of drive units is to connect axle controllers or other motion control products to the CAN bus. At run time, data can be obtained from the drive unit via CAN bus by either polling or event driven (interrupt). The motion control products have a process data object mapping for real time operation. This communication channel is used to interchange real-time data like set-points or present values like a position actual value e.g.
The two principal advantages of the profile approach for device specification are in the areas of system integration and device standardization.
If two independent device manufacturers design products that have to communicate, then both manufacturers must be provided with a device specification from the other one. These specifications will widely differ in formal and terminological

aspects from one company to another. The concept of device profiling provides a standard for producing such specifications. By adopting this approach, all manufacturers will specify their devices in a similar fashion, what greatly reduces the effort involved in system integration.
The other obvious advantage of the profile approach for device specification is, that it can be used to guide manufacturers into producing standardized devices. The advantages of standardized devices are numerous. Perhaps most important is the idea, that a standardized device decouples a system integrator from a specific supplier. If one supplier cannot meet special application demands, a system designer can use devices from another supplier with reduced effort. On the other hand the device manufacturers are not forced any more to implement private protocols for each customer.
A device profile defines a 'standard' device. This standard device represents really basic functionality, every device within this device class must support. This mandatory functionality is necessary to ensure, that at least simple non-manufacturer-specific operation of a device is possible. For example the standard drive unit provides a **Quick stop** function to stop a drive. This function is defined as mandatory, such that any drive unit supporting the CANopen Device Profile for Drives and Motion Control, can be halted using the same message.

3.1. Architecture of the drive

The basic architecture is composed of two main modules:

- **Device Control**: the state machine executes the starting and stopping of the drive and several mode specific commands.
- **Modes of Operation**: The operation mode defines the behavior of the drive. The following modes are defined in this profile:
    1. **Profile position mode**: The positioning of the drive is defined in this mode. Speed, position and acceleration can be limited and profiled moves using a Trajectory Generator are possible as well.
    2. **Profile velocity mode**: The Profile Velocity Mode is used to control the velocity of the drive with no special regard of the position. It supplies Trajectory Generation.
    3. **Interpolated position mode**: This mode allow the time interpolation of single axes and the spatial interpolation of coordinated axes.
    4. **Torque mode**: The user could drive the motor feeding torque reference (current reference); please note that this is not the same as the standard **Profile torque mode**, but Tw Motor specific.
    5. **Homing mode**: This is the method by which a drive seeks the home position (also called, the datum, reference point or zero point).
    6. **Rotary table control**: The user could select a position on a rotary table by an index (up to 126 positions); the drive will select the best route choosing the rotation direction.

The Tw Motor support switching between the various modes of operation, also when the axes is moving.

3.2. Device Control

The device control function block controls all functions of the drive (drive function and power section). The state of the drive can be controlled by the controlword (object 6040h.0h) and is shown in the statusword (object 6041h.0h). The state machine is controlled externally by the controlword. The state machine is also controlled by internal signals like faults.

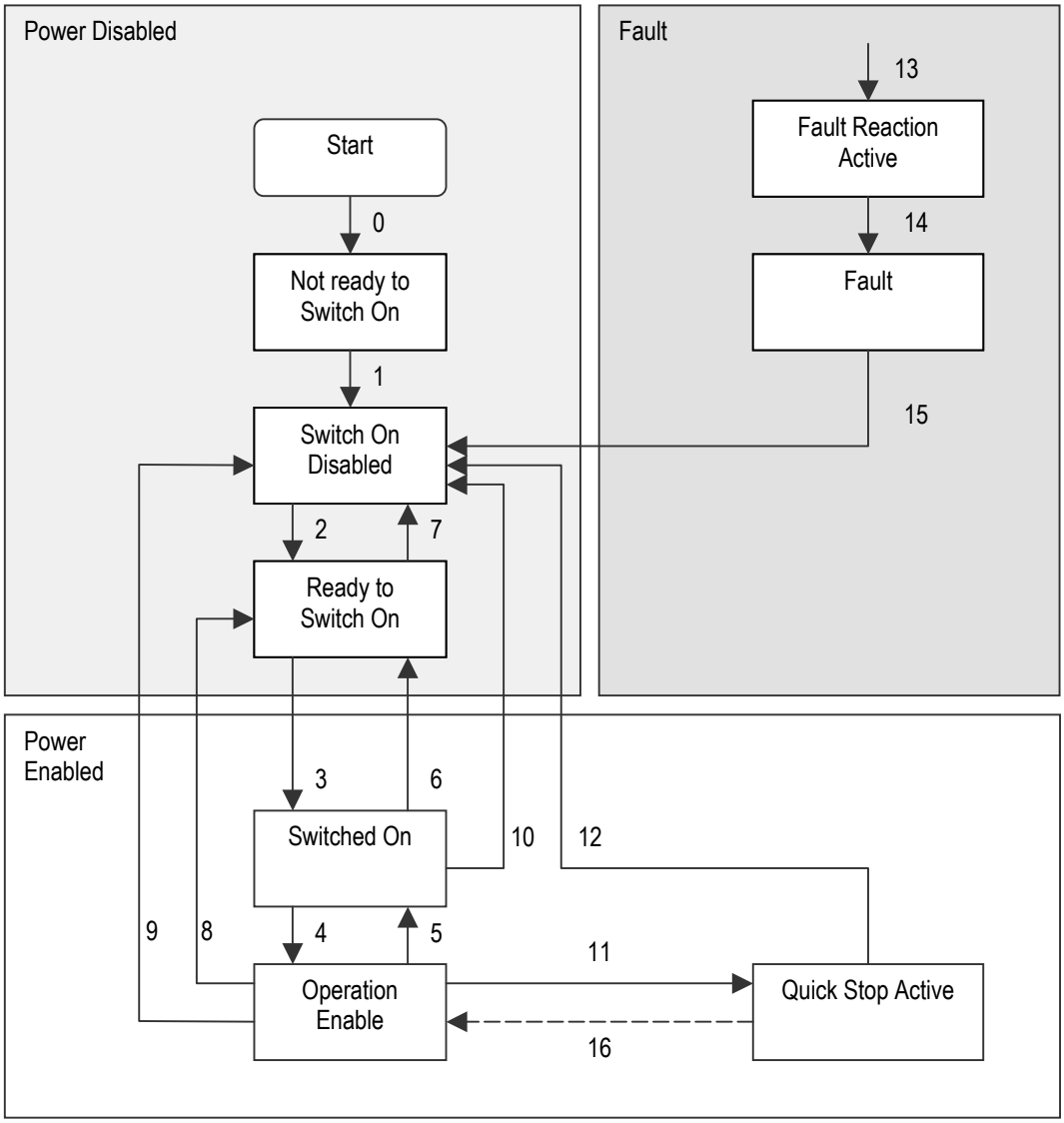


Figure 3: Device Control State Machine

When power output is enabled high voltage switching is applied to the motor phases, torque could be applied or could be null.

State	*Statusword*	*Description*
Not Ready to Switch On	xxxx xxxx x0xx 0000	The Tw Motor is being initialized, then is not ready to accept command and the power output is disabled
Switch On Disabled	xxxx xxxx x1xx 0000	Tw Motor initialization is complete, then is ready to accept command, the power output and the drive functions are disabled
Ready To Switch On	xxxx xxxx x01x 0001	The drive functions are disabled, the drive is ready to enable power output
Switched On	xxxx xxxx x01x 0011	The drive functions are disabled, the drive has power output enabled, the motor shaft has no torque
Operation Enable	xxxx xxxx x01x 0111	The drive functions and power output are enabled, the torque could be applied on the motor shaft, no faults detected, specific selected Mode Of Operation is

State	*Statusword*	*Description*
		executed
Quick Stop Active	xxxx xxxx x00x 0111	The drive functions and power output are enabled, the quick stop function is being executed or finished and the motor stopped (depending from object 605Ah.0h)
Fault Reaction Active	xxxx xxxx x0xx 1111	The drive functions and power output are enabled, the fault recovering is being executed (defined by the object 605Eh.0h and if not a fatal fault, see Table 6)
Fault	xxxx xxxx x0xx 1000	A fault is occurred in the device, the drive functions and power output are disabled

For complete reference look at statusword (object 6041h.0h)

Table 9: Drive states

Transition	*Event*	*Action*
0	Reset	Tw Motor internal self-initialization
1	Tw Motor has finished self-initialization	Activate communication
2	**Shutdown** command	None
3	**Switch On** command	Enable power output
4	**Enable Operation** command	The drive functions are enabled and torque could be applied
5	**Disable Operation** command	The drive functions are disabled, the behaviour of the motor depend from the object 605Ch.0h
6	**Shutdown** command	Disable power output
7	**Quick Stop** or **Disable Voltage** command	None
8	**Shutdown** command	The drive functions and power output are disabled, the behaviour of the motor depend from the object 605Bh.0h
9	**Disable Voltage** command	The drive functions and power output are disabled, the motor is free to rotate
10	**Disable Voltage** or **Quick Stop** command	The drive functions and power output are disabled, the motor is free to rotate
11	**Quick Stop** command	The quick stop function is executed, (see object 605Ah.0h)
12	**Quick Stop** function executed or **Disable Voltage** command	The drive functions and power output are disabled, the motor is free to rotate
13	A fault is occurred	Execute the appropriate fault reaction (see object 605Eh.0h) if non-fatal fault, see Table 6
14	The fault reaction is completed	The drive functions and power output are disabled, the motor is free to rotate
15	**Fault Reset** command	Reset of the fault condition; after leaving the state Fault, the bit Fault Reset in the command word has to be cleared by the host
16	**Enable Operation** command	The drive functions are enabled; the transition is possible according to the object 605Ah.0h

Table 10: State transition

Command	*Controlword*	*Transitions*
Shutdown	xxxx xxxx xxxx x110	2,6,8
Switch On	xxxx xxxx xxxx x111	3
Disable Voltage	xxxx xxxx xxxx xx0x	7,9,10,12
Quick Stop	xxxx xxxx xxxx x01x	7,10,11
Disable Operation	xxxx xxxx xxxx 0111	5
Enable Operation	xxxx xxxx xxxx 1111	4,16
Fault Reset	xxxx xxxx 1xxx xxxx	15

For complete reference look at controlword (object 6040h.0h)

Table 11: Commands in the controlword

The drive functions depend from the selected mode of operation (object 6060h.0h), that could be checked reading the mode of operation display (object 6061h.0h); this selection also modifies the behaviour of some bits of the controlword and the statusword. The specific drive function is executed only when the drive status is **Operation Enabled**.

Refer to §6.2 and to §6.3 for examples on how to use the controlword.

6040h.0h: Controlword
6041h.0h: Statusword
605Bh.0h: Shutdown option code
605Ch.0h: Disable operation option code
605Ah.0h: Quick stop option code
605Eh.0h: Fault reaction option code

6060h.0h: Modes of operation
6061h.0h: Modes of operation display
6085h.0h: Quick stop deceleration

Table 12: Device Control related objects

3.3. Profile Position Mode

A target position (object 607Ah.0h) is applied to the trajectory generator; it generates a position demand value (object 6062h.0h) that is feed as reference position to the internal speed loop. These two function blocks are controlled by individual parameter set.

The trajectory generator support only linear ramp (trapezoidal profile), with separate parameters for acceleration (object 6083h.0h) and deceleration (object 6084h.0h), velocity profile (object 6081h.0h) and optional non-zero end velocity (the speed the motor has on reaching target position, object 6082h.0h). All those parameters could also be changed during positioning: the trajectory generator will always follows the new rules; for example, if you change velocity profile parameter, the drive will reach the new speed using the profile acceleration or deceleration.

This mode is driven by specific bits of the controlword and the statusword, as follow:

Command	*Controlword*	*Description*
New Set Point	xxxx xxxx xxx1 xxxx	Assume new target position
Change Set Immediately	xxxx xxxx xx1x xxxx	If 0 the new positioning is started after finish of the current positioning, if 1 the new positioning interrupt the current positioning
Abs / rel	xxxx xxxx x1xx xxxx	If 0 the target position is an absolute value, if 1 is a relative value (incremental)
Halt	xxxx xxx1 xxxx xxxx	Stop the motor with the profile deceleration (depend from the object 605Dh.0h); on reset resume the interrupted positioning

For complete reference look at controlword (object 6040h.0h)

Table 13: Profile position commands

State	*Statusword*	*Description*
Target Reached	xxxx x1xx xxxx xxxx	The target position is reached (see object 6067h.0h and object 6068h.0h) or, if an halt command is issued, the velocity of the motor is zero
Set Point Acknowledge	xxx1 xxxx xxxx xxxx	Trajectory generator has assumed the new target position
Following Error	xx1x xxxx xxxx xxxx	Following error, the thresholds are defined in the objects 6065h.0h and 6066h.0h

For complete reference look at statusword (object 6041h.0h)

Table 14: Profile position status

First of all the target position have to be loaded with the desired value, then the **New Set Point** bit has to be set; the drive signal the acquisition (and then the execution of the movement) of the target position setting the **Set Point Acknowledge** bit. Resetting the **New Set Point** also reset the **Set Point Acknowledge**, this operation does not affect the current positioning. Now a new target position could be loaded and signaled via **New Set Point** to the drive: if the previous targeting is not completed the drive will keep **Set Point Acknowledge** low until target is reached (signaled in the statusword), then it go high and the drive start the new positioning. If **Change Set Immediately** is set together with the **New Set Point**, then the new positioning is started immediately, still respecting the trajectory generator parameters.

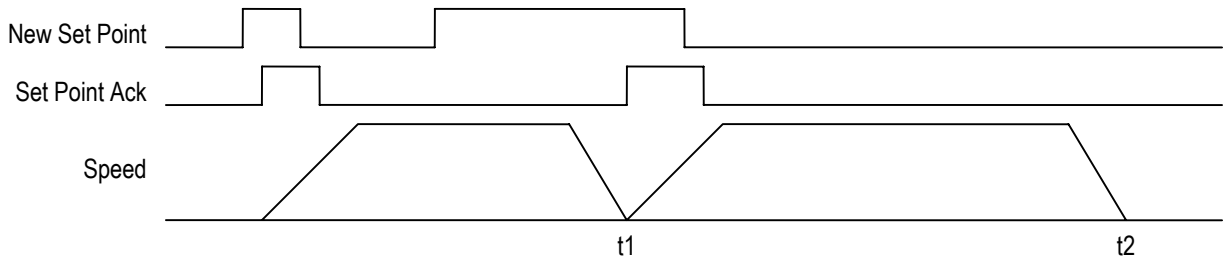


Figure 4: Single set point

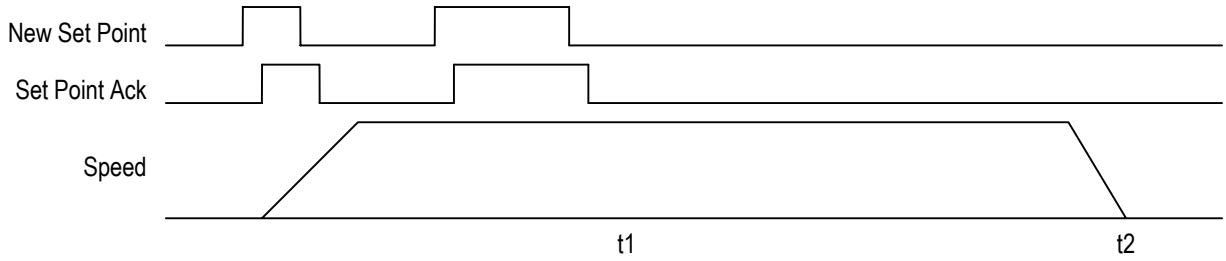


Figure 5: Change set immediately set point

If **Abs / rel** is set together with **New Set Point** then the target position is treated as an signed increment of the present target position.

Symmetrically around the target position a window (object 6067h.0h) is defined for the accepted position range, that is *target position±position window*. If a drive is situated (object 6064h.0h) in the accepted position range over the time position window time (object 6068h.0h) the **Target Reached** bit is set.

A following error window (object 6065h.0h) is defined for the accepted following error tolerance. If the modulus of the following error actual value (object 60F4h.0h) is greater than the following error window for more than following error time out time (object 6066h.0h) then the **Following Error** bit is set.

Refer to §6.2 and to §6.3 for examples on profile position mode.

6040h.0h: Controlword
6041h.0h: Statusword
605Dh.0h: Halt option code
607Ah.0h: Target position
607Dh: Software position limit
6081h.0h: Profile velocity
6082h.0h: End velocity
6083h.0h: Profile acceleration
6084h.0h: Profile deceleration
6086h.0h: Motion profile type
6062h.0h: Position demand value
6064h.0h: Position actual value
6065h.0h: Following error window
6066h.0h: Following error time out
6067h.0h: Position window
6068h.0h: Position window time
60F4h.0h: Following error actual value

Table 15: Profile Position Mode related objects

3.4. Profile Velocity Mode

A target velocity (object 60FFh.0h) is applied to the trajectory generator; it generates a velocity demand value (object 606Bh.0h) that is feed as reference speed to the internal speed loop. These two function blocks are controlled by individual parameter set.

The trajectory generator support only linear ramp (trapezoidal profile), with separate parameters for acceleration (object 6083h.0h) and deceleration (object 6084h.0h).

This mode is driven by specific bits of the controlword and the statusword, as follow:

Command	*Controlword*	*Description*
Halt	xxxx xxx1 xxxx xxxx	Stop the motor with the profile deceleration (depend from the object 605Dh.0h)

For complete reference look at controlword (object 6040h.0h)

Table 16: Profile velocity commands

State	*Statusword*	*Description*
Target Reached	xxxx x1xx xxxx xxxx	The target velocity is reached (see object 606Dh.0h and object 606Eh.0h) or, if an halt command is issued, the velocity of the motor is zero
Speed	xxx1 xxxx xxxx xxxx	The speed is equal to zero (see object 606Fh.0h and object 6070h.0h)

For complete reference look at statusword (object 6041h.0h)

Table 17: Profile velocity status

The **Target Reached** bit is set when the modulus difference between the velocity demand value and the velocity actual value (object 606Ch.0h) is within the velocity window (object 606Dh.0h) longer than the velocity window time (object 606Eh.0h).

The **Speed** bit is reset as soon as the velocity actual value exceeds the velocity threshold (object 606Fh.0h) longer than the velocity threshold time (object 6070h.0h). Below this threshold the bit is set and indicates that the axle is stationary.

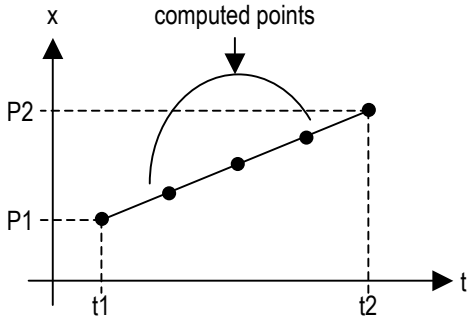
Refer to §6.2 and to §6.3 for examples on profile velocity mode.

6040h.0h: Controlword
6041h.0h: Statusword
605Dh.0h: Halt option code
6083h.0h: Profile acceleration
6084h.0h: Profile deceleration
6069h.0h: Velocity sensor actual value
606Bh.0h: Velocity demand value
606Ch.0h: Velocity actual value
606Dh.0h: Velocity window
606Eh.0h: Velocity window time
606Fh.0h: Velocity threshold
6070h.0h: Velocity threshold time
60FFh.0h: Target velocity

Table 18: Profile Velocity Mode related objects

3.5. Interpolated position Mode

The interpolated position mode is used to control multiple coordinated axes or a single axle with the need for time-interpolation of set-point data. The interpolated position mode uses the SYNC (see §2.7) as the time synchronization mechanism for a time coordination of the related drive units.



The interpolation data record contains the interpolation data; the Tw Motor supports only synchronous operation and linear interpolation, thus the data record has only one field, the position set-point (object 60C1h); the interpolation time period (object 60C2h) is referred to the ip sync period. The ip sync is the event that triggers the execution of the set-point data, the SYNC is the physically COB on the network and trigger the sync PDO; the relation between two is called sync definition (object 60C3h): it specifies how many SYNC should be received to trigger one ip sync.

To ensure proper operations, the interpolation data should be supplied continuously in real time via PDO (see §2.6), one set-point per ip sync for the calculation of the next demand value. For each interpolation cycle, the drive will calculate a position demand value (at every internal cycle time that is 250μs) by interpolating positions over a period of time. The position demand value is feed directly as input of the speed loop, bypassing the trajectory generator and thus neglecting all velocity and acceleration limitations.
Optionally the set-points could be iterated across a 2nd order digital filter (see §4.7).

WARNING: when the **Enable rotary axis** flag (object 5380h.0h) is enabled, the position set-point (object 60C1h) must always falls between the boundary. User has to take care about wrapping this object. For further information refer to §4.1.

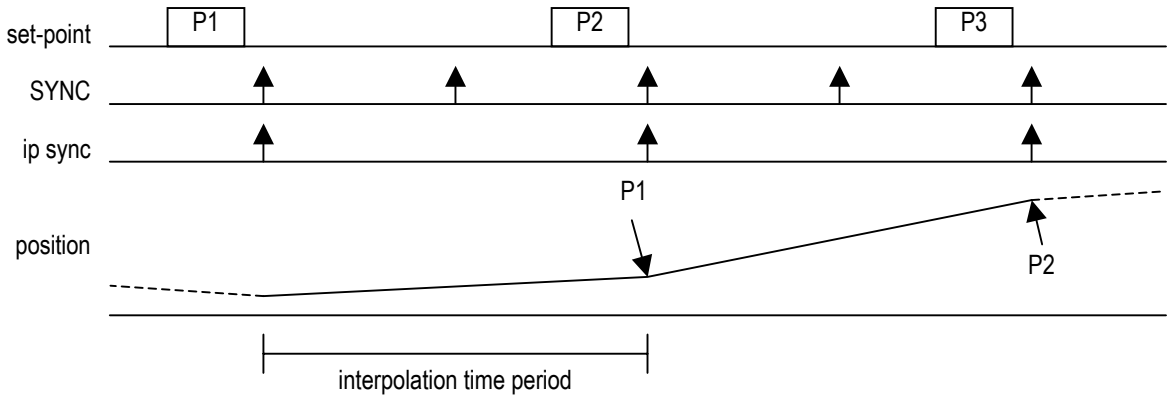


Figure 6: Interpolation with ip sync every 2 SYNC

This mode is driven by specific bits of the controlword and the statusword, as follow:

Command	*Controlword*	*Description*
Enable ip mode	xxxx xxxx xxx1 xxxx	Enable movement of the axes
Halt	xxxx xxx1 xxxx xxxx	Stop the motor with the profile deceleration (depend from the object 605Dh.0h)

For complete reference look at controlword (object 6040h.0h)

Table 19: Interpolated position commands

State	*Statusword*	*Description*
Target Reached	xxxx x1xx xxxx xxxx	The target position is reached or, if an halt command is issued, the velocity of the motor is zero
Ip mode active	xxx1 xxxx xxxx xxxx	Axes movement active

For complete reference look at statusword (object 6041h.0h)

Table 20: Interpolated position status

To have an accurate start-up condition, it is suggested to map the controlword (object 6040h.0h) in one sync PDO and then use it to give the drive the **Enable ip mode**; in this way only the following SYNC will start triggering the ip sync, apart when drive has began receiving the SYNC.

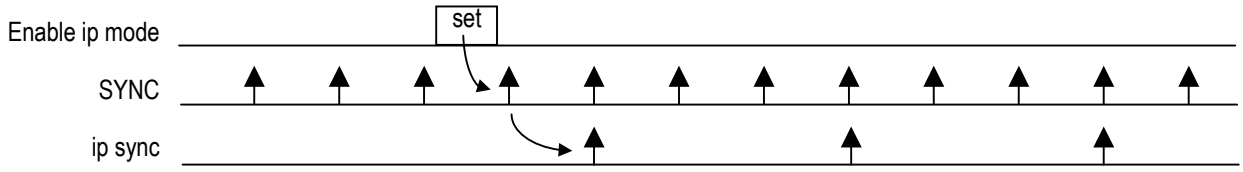


Figure 7: Interpolation start-up synchronization (ip sync every 3 SYNC)

6040h.0h: Controlword
6041h.0h: Statusword
605Dh.0h: Halt option code
607Dh: Software position limit
60C1h: Interpolation data record
60C2h: Interpolation time period
60C3h: Interpolation sync definition
6062h.0h: Position demand value
6064h.0h: Position actual value

60F4h.0h: Following error actual value
5309h: Position set-point filter constants

Table 21: Interpolated Position Mode related objects

3.6. Homing Mode

This is the method by which a drive seeks the home position (also called, the datum, reference point or zero point). There are various methods of achieving this, all of them use a home switch (zero point switch) in mid-travel. The home switch have to be connected to the auxiliary digital input (see §4.6), no additional configuration for this input has to be done. The user could specify an homing speed, an homing acceleration and an homing method, that will be used throughout all the procedure. At the end of the seeking, the drive will set-up the home offset (object 607Ch.0h) with the right value to zero all the position objects on the home position; the previous value of the home offset is ignored. If the needing is for a value other than zero, preset the desired position value in the application zero position (object 5330h.0h). The successfully completed procedure will be signalled by the **Homing done** bit in the statusword (object 6041h.0h).

In order to start seeking of home position, the **Home operation start** bit has to be set. If the selected method is not supported, the **Homing error** bit will be activated; otherwise the **Homing attained** bit activation will signal the successfully end of homing procedure and the zero speed of the motor. Now **Home operation start** bit could be reset.

WARNING: if **Enable rotary axis** flag (bit 8 of the object 5380h.0h) is set, at the end of the homing procedure wait until the **Rotary axis enabled** bit in the statusword (object 6041h.0h) is set before using position objects, as the drive could need some time to update his internal status (see §4.1).

This mode is driven by specific bits of the controlword and the statusword, as follow:

Command	*Controlword*	*Description*
Homing operation start	xxxx xxxx xxx1 xxxx	The transition 0→1 start the homing, the transition 1→0 interrupt the homing
Halt	xxxx xxx1 xxxx xxxx	Stop the motor with the profile deceleration (depend from the object 605Dh.0h); the homing procedure will restart from the beginning

For complete reference look at controlword (object 6040h.0h)

Table 22: Homing commands

State	*Statusword*	*Description*
Homing attained	xxx1 xxxx xxxx xxxx	Homing mode carried out successfully, motor is stopped
Homing error	xx1x xxxx xxxx xxxx	The selected method is not supported. This flag is activated when **Homing operation start** bit is activated
Homing done	1xxx xxxx xxxx xxxx	The homing is done, this bit remain active up to a node reset or a power-off

For complete reference look at statusword (object 6041h.0h)

Table 23: Homing status

6040h.0h: Controlword
6041h.0h: Statusword
605Dh.0h: Halt option code
607Ch.0h: Home offset
6098h.0h: Homing method
6099h: Homing speeds
609Ah.0h: Homing acceleration
6064h.0h: Position actual value
5330h.0h: Application Zero Position

Table 24: Homing Mode related objects

3.6.1. Homing methods 19 and 20

The initial direction of the movement is dependent on the state of the home switch. The home position is on the point where the home switch changes its state. The point at which the reversal direction of movement takes place is anywhere after the change of state of the home switch.
The seeking ends on high to low home switch transition and counterclockwise movement direction (19) or on low to high home switch transition and clockwise movement direction (20).

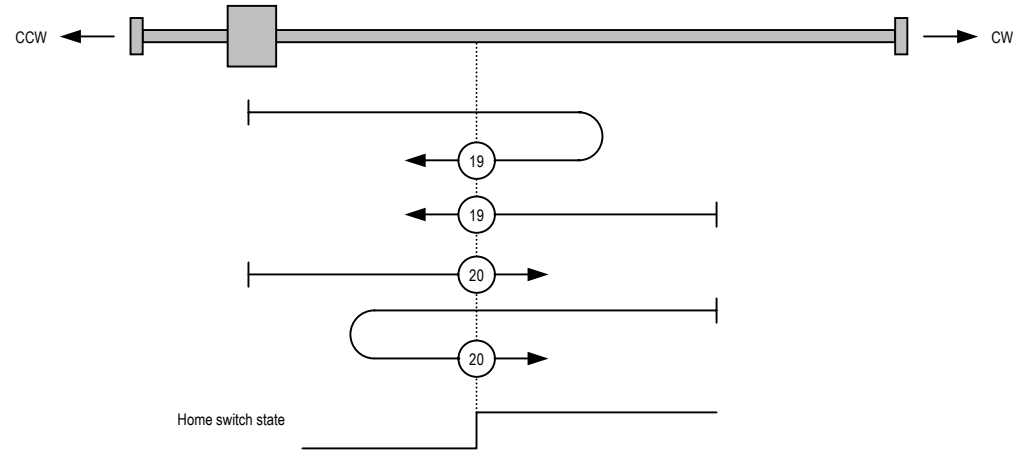


Figure 8: Homing method 19 and 20

3.6.2. Homing methods 21 and 22

The initial direction of the movement is dependent on the state of the home switch. The home position is on the point where the home switch changes its state. The point at which the reversal direction of movement takes place is anywhere after the change of state of the home switch.
The seeking ends on high to low home switch transition and clockwise movement direction (21) or on low to high home switch transition and counterclockwise movement direction (22).

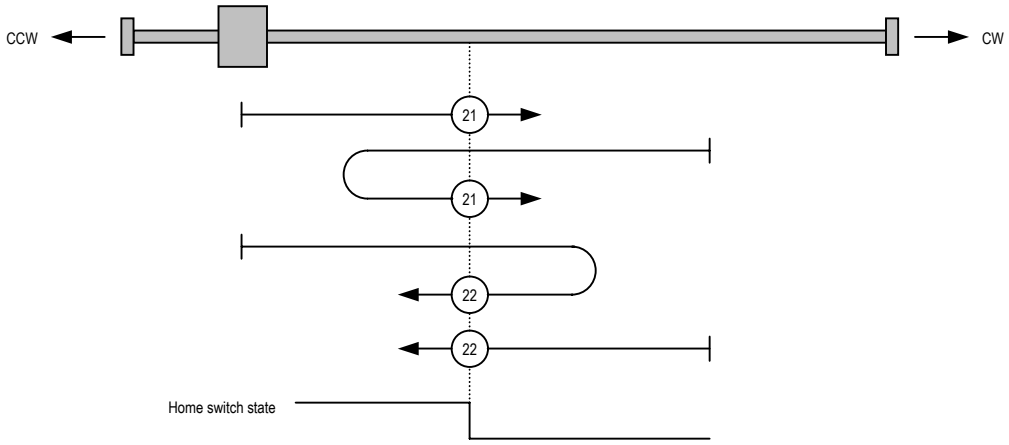


Figure 9: Homing method 21 and 22

3.6.3. Homing methods 26 and 30

These methods detect the transition high to low of the home switch as home position; if the home switch is low on starting, the drive ignore it and wait for the transition. The direction of the movement is clockwise (26) or counterclockwise (30).

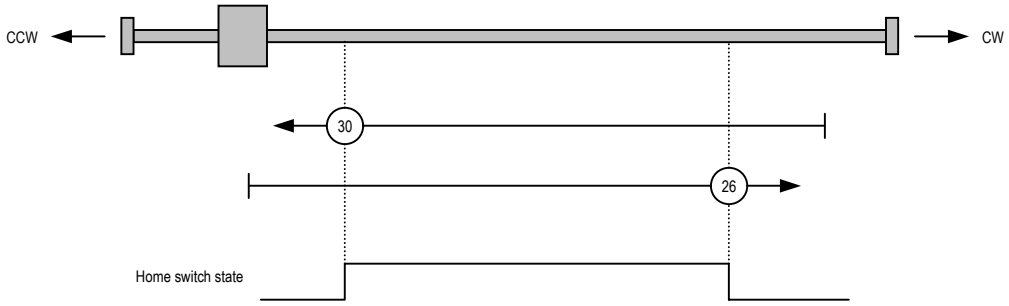


Figure 10: Homing method 26 and 30

3.7. Factor group

There is a need to interchange physical dimensions and sizes into the internal device units. To implement the interchange, several factors are necessary. The factors defined in the factor group set up a relationship between internal device units (from here d.u.) and physical units (p.u.). The factors are result of the calculation of two parameters called dimension index and notation index. These factors are directly used to normalize the physical values. Another parameters that take part in the factors calculation are the gear ratio (object 6091h) and the feed constant (object 6092h), that defines the ratio between the output shaft and the motor shaft, in case of gearbox between those two. See §5 to see which position, velocity and acceleration objects are affected by factor group.

The default setting of the Tw Motor is to use d.u.; those are the mathematical relations between d.u. and radians at motor output shaft (and reverse equations):

$$\theta[d.u.] = 65536 \cdot \frac{1}{2\pi} \cdot \theta[rad] \qquad \theta[rad] = 2\pi \cdot \frac{1}{65536} \cdot \theta[d.u.]$$

$$\omega[d.u.] = \frac{65536^2}{4000} \cdot \frac{1}{2\pi} \cdot \omega[rad/s] \qquad \omega[rad/s] = 2\pi \cdot \frac{4000}{65536^2} \cdot \omega[d.u.]$$

$$\dot{\omega}[d.u.] = \frac{65536^2}{4000^2} \cdot \frac{1}{2\pi} \cdot \dot{\omega}[rad/s^2] \qquad \dot{\omega}[rad/s^2] = 2\pi \cdot \frac{4000^2}{65536^2} \cdot \dot{\omega}[d.u.]$$

where θ, ω and $\dot{\omega}$ are respectively angular position, speed and acceleration. All computations are made using d.u., those three are all expressed as signed 32 bit integer value. Refer to §4.1 on how those relations are computed.

When user choose a p.u. set to express those values, the conversion between user defined units and d.u. is made at the communication interface level, this mean that internally all values are still stored and computed using d.u.; also, due to the unavoidable approximation, the value read from an object could slightly differ from the value written. Still the number format is signed 32 bit integer. If it is essential for user application the signed position value, refer to **Enable signed position** flag (§4.1).

The conversion of the units is made through a time-optimized algorithm, yielding it suitable both for SDO (§2.5) and PDO (§2.6). The conversion factor is computed using 32 bit floating point constants and variables, giving the computation in the form $y = k \cdot x$; then k is converted in a mantissa/exponent form $k = m \cdot 2^e$, where $1 < m \leq 0.5$; this value is converted to a 24 bit constant; all those computations are done offline. In the real-time computation the 32 bit input value is integer multiplied by the 24 bit constant, yielding an 48 bit result value (the least significant 8 bit are truncated); this value is shifted by e (left or right, depending from the sign) and then 32 bit output value is taken. This kind of conversion could yield an approximation that should be evaluated regarding the application, but expected to be in the range of $\pm 2^{-23}$ multiplied the value and rounded to the lower integer that is greater than or equal the resulting value (e.g., the approximation of the value 134200000 expressed in p.u. is calculated as: $134200000 \times 2^{-23} = 15.998$, then the real value is 134200000 ± 16 p.u.).
The k computation includes encoder resolution, gear ratio, feed constant, the selected p.u. and the magnitude.

The supported p.u. are both linear and rotational unit; the unit could be specified separately for position, speed and acceleration, but all three must be in the same group: linear, rotational or d.u. The p.u. are specified with two parameters for each of position, speed and acceleration: **dimension index** and **notation index**; the first define the kind of p.u. (e.g. radians, meters, revolutions per minute, etc.); the second define the desired magnitude in term of 10^n (e.g. if meters p.u. is chosen, then **mm** is 10^{-3}, **m** is 10^0, **km** is 10^3, etc.).

The relation between position internal units and user selected position p.u. is:

$$\theta[d.u.] = \frac{position\ encoder\ resolution \cdot gear\ ratio}{feed\ constant} \cdot \theta[p.u.]$$

where position encoder resolution (object 608Fh) is a constant ratio (equal to 65536); in this case the relation could be simplified in:

$$\frac{\theta[p.u.]}{\theta[rad]} = \frac{feed\ constant}{2\pi \cdot gear\ ratio}$$

where **p.u.** is referred to the desired output shaft and **rad** to the motor shaft radians rotational unit. Note that for the position p.u. the k is not related with the selected position dimension index (object 608Ah.0h) and the position notation index (object 6089h.0h). The purpose of these two is to establish the ratios between position p.u., velocity p.u. and acceleration p.u. These are computed internally depending on the respective dimension index (objects 608Ch.0h and 608Eh.0h) and notation index (objects 608Bh.0h and 608Dh.0h) selected.

The feed constant and gear ratio are defined as ratio of two 32 bit integer number; we suggest to use large number to define both ratios, this practice could reduce the overall approximation error.

Refer to §6.4 for examples on how to use the factor group.

6089h.0h: Position notation index
608Ah.0h: Position dimension index
608Bh.0h: Velocity notation index
608Ch.0h: Velocity dimension index
608Dh.0h: Acceleration notation index
608Eh.0h: Acceleration dimension index
608Fh: Position encoder resolution
6090h: Velocity encoder resolution
6091h: Gear ratio
6092h: Feed constant

Table 25: Factor group related objects

4. Tw Motor specific functions

Features described here are Tw Motor proprietary.

4.1. Position encoder

The Tw Motor is equipped with an **absolute single-turn encoder**, an **absolute multi-turn encoder** or a **two-poles resolver** (overall accuracy apart, this is this is functionally the same of the absolute single-turn encoder, so in the chapter is always referred as absolute single-turn); the term absolute refer to the capability of the encoder to give at power-up and without any initialization the right angular position. User has the capability to get information via software on which equipment is installed from the **hardware configuration object** (5311h.0h).

The **absolute single-turn encoder** has the capability to give the angular position over one turn, expressed as a 16 bit number; the drives equipped with this encoder simulate via software the multi-turn capability, giving the user the possibility to feed angular position up to 65536 turns; this means that the d.u. for the angular position is expressed as: the MSB 16 bit give the number of turns, the LSB 16 bit give the angular position in one turn, giving the relations shown in the §3.7. At each power-up the MSB 16 bit of the position actual value (object 6064h.0h) will be initialized to 0 or -1.

The **absolute multi-turn encoder** add to the absolute single turn encoder the capability of distinguish up to 4096 turns at power-up; in this case the drive do not simulate any multi-turn capability and then the user can feed angular position up to 4096 turns. If the user download angular position above this limit, the drive ignores the MSB 4 bit of the given position. By default, uploading position objects from the drive will give those bits at zero, always resulting as unsigned value between 0 and 268435455 (0FFF FFFFh). Enabling the **Enable signed position** flag (bit 9 of the object 5380h.0h) let the user to upload these values as signed: this is done by sign-extending the bit 27 of the position object: now the possible position values are between -134217728 (F800 0000h) and +134217727 (07FF FFFFh). E.g., if the real position is 041A 0031h the bit 27 is zero and then the uploaded value is the same; if the real position is 0D1A 0031h the bit 27 is

one and then the uploaded value is FD1A 0031h. This flag works in the same way also with the Factor group (§3.7). Note that the only position objects that are affected by this flag are those that in the object dictionary reference report exactly **position Factor Group** as unit of measure.

In both cases, when position reach upper or lower boundary the drive automatically wrap the position to the opposite boundary.

The position error is calculated as 32 bit difference from the reference and feedback positions (28 bit in case of the multi-turn encoder); then drive choose fastest direction to reach the target position: e.g., suppose that the present position is 65500 turns (single-turn encoder) and the user feed a target position equal to 30 turns, then the drive will advance the motor from 65500 to 65535, wrap to 0 and finally reach the 30 turns target position, reaching final position in 66 positive turns; the 32 bit difference of those two numbers is: 001E 0000h-FFDC 0000h=0042 0000h. The same example fits for the multi-turn encoder, the drive will make the difference of the positions as they would be 28 bit numbers: x01E 0000h-xFDC 0000h=0042 0000h.

The speed is calculated as difference between two consecutive reading of the position encoder (250μs) and then shifting into the MSB 16 bit, to improve the quality of the speed loop. The acceleration is simply computed as difference of the speed, still every 250μs.

4.1.1. Rotary axis mode

Enabling the **Enable rotary axis** flag (bit 8 of the object 5380h.0h) let the user to deal with an arbitrary sized rotary axis. This mode affects all the position objects and works in all mode of operations. When the actual position rises above the Table dimension / Rotary axle dimension (object 5321h.0h) the value is automatically wrapped to zero and viceversa. E.g., this mode is useful when using a rotating table with a gearbox ratio not power of 2.

Please also note that:

- When rotary axis is enabled, drive loose his absolute encoder feature: the position become a virtual position and an homing cycle (either manual or automatic) is required to find the zero point at power up
- The drive use the position actual value (object 6064h.0h) to check if wrapping has to be done or not; when this object reach the boundary it is possible that other position objects (e.g. the position demand value) falls outside the boundary. This is a normal behaviour, as the drive have to recognize which direction has to be taken to reach the desired reference position; this also means that user could send a target position outside the boundary, the drive will cover all travel as default manner (except interpolated position mode, §3.5)

WARNING: changing this bit will have effect on the drive only after a node reset or power off – power on cycle. In order to enable (or disable) set (or reset) the bit in the object 5380h.0h, then issue a store parameters command (object 1010h) and finally issue a NMT node reset command (§2.9).

WARNING: immediately after power on or after changing the objects 5321h.0h or 607Ch.0h (this could also done automatically by the Homing procedure), wait until the **Rotary axis enabled** bit in the statusword (object 6041h.0h) is set before using position objects, as the drive could need some time to update his internal status.

4.2. Current loops

The Tw Motor current loops are tuned in factory on the specific motor coupled to the drive, so they normally does not need to be accessed from the users. Anyway, in some applications could be useful to set-up a torque limit: the torque is directly related to the current, the torque limit could be customized by the output speed loop current limit parameter (object 60F9h.6h).

The d.u. (internal device units) for all current related parameters are:

$$I[Arms] = \frac{6.02}{32768} \cdot I[d.u.] \qquad I[d.u.] = \frac{32768}{6.02} \cdot I[Arms]$$

The current loops are updated at 8 khz.

4.3. Torque Mode

A target torque (current reference) is fed to the input of the current loop (object 5000h.0h); it generates instantaneously desired torque on the motor shaft.

This mode support the Halt command, as follow:

Command	*Controlword*	*Description*
Halt	xxxx xxx1 xxxx xxxx	Stop the motor with the profile deceleration (depend from the object 605Dh.0h)

For complete reference look at controlword (object 6040h.0h)

Table 26: Torque mode commands

No additional statusword bits are used in this mode.

6040h.0h: Controlword
6041h.0h: Statusword
605Dh.0h: Halt option code
6084h.0h: Profile deceleration
5000h.0h: Current quadrature reference
5001h.0h: Current direct reference
5010h.0h: Current quadrature feedback
5011h.0h: Current direct feedback

Table 27: Torque Mode related objects

4.4. Rotary table control

The user could select a position on a rotary table by an index (up to 126 positions). The positions are indexed by a target index (object 5323h.0h), user has to download all the absolute positions in the table positions array (object 5320h). It is possible to specify a gear play compensation (object 5322h.0h) to achieve a better accuracy on the positioning; the compensation is done only when the direction of rotation is counterclockwise by subtracting from the target position the desired over-travel.

Three possibilities exist for the rotary table positioning:

- Absolute with best-route selection: the drive compute the shortest route to reach the target, by choosing clockwise or counterclockwise rotation
- Absolute positioning: the sign of the target index determines the rotation direction
- Relative positioning: the signed target index is added to actual target (and wrapped, if necessary), the sign determines the rotation direction

WARNING: In order to use this profile the Rotary axis mode (§4.1) must be enabled.

This mode is driven by specific bits of the controlword and the statusword, as follow:

Command	*Controlword*	*Description*
Absolute best-route	xxxx xxxx x001 xxxx	Absolute positioning with best-route
Absolute positioning	xxxx xxxx x011 xxxx	Absolute positioning without best-route
Relative positioning	xxxx xxxx x1x1 xxxx	Relative positioning
Halt	xxxx xxx1 xxxx xxxx	Stop the motor with the profile deceleration (depend from the object 605Dh.0h); on reset resume the interrupted positioning

For complete reference look at controlword (object 6040h.0h)

Table 28: Rotary table commands

State	*Statusword*	*Description*
Warning	xxxx xxxx 1xxx xxxx	Something prevent the positioning, see in the following text
Target Reached	xxxx x1xx xxxx xxxx	The target position is reached (see object 6067h.0h and object 6068h.0h) or, if an halt command is issued, the velocity of the motor is zero
Set Point Acknowledge	xxx1 xxxx xxxx xxxx	Trajectory generator has assumed the new target index

For complete reference look at statusword (object 6041h.0h)

Table 29: Rotary table status

Issuing the command immediately start the positioning, this is signalled by the **Set Point Acknowledge** bit that remain active until user reset the command bits in the controlword. Once started, the positioning could be cancelled only using either halt or quick stop or device controls commands. If the **Warning** bit is issued in place of the **Set Point Acknowledge** then some of the following reason prevent the positioning:

- Rotary axis mode (§4.1) is not enabled
- The table positions array is either empty or has some entries outside the table dimension or NV storage is corrupted
- The absolute target index is zero or above the number of entries in the table positions array

Symmetrically around the target position a window (object 6067h.0h) is defined for the accepted position range, that is *target position±position window*. If a drive is situated (object 6064h.0h) in the accepted position range over the time position window time (object 6068h.0h) the **Target Reached** bit is set.

6040h.0h: Controlword
6041h.0h: Statusword
605Dh.0h: Halt option code
6081h.0h: Profile velocity
6083h.0h: Profile acceleration
6084h.0h: Profile deceleration
6067h.0h: Position window
6068h.0h: Position window time
5320h: Table positions array
5321h.0h: Table dimension / Rotary axis dimension
5322h.0h: Gear play compensation
5323h.0h: Rotary table target index
5380h.0h: Global option flags

Table 30: Rotary table related objects

4.5. Speed loop control

In the Tw drives the speed loop control act both as closed loop position control and closed loop speed control; in the first case the position demand generated by the trajectory generator or by the interpolator is fed to the input of the closed loop; in the second case the speed demand is integrated, thus generating a position demand to be fed to the input of the closed loop.

Then the position demand is optionally limited, in order to keep the absolute value of the position error below an user specified value; this function, jointly with the output speed loop current limit, allow the shaft to run at different speed than the demanded value when an external torque greater than the limit is applied, without saturating the closed loop.
After that the position demand value is filtered, then differentiate two times to obtain the speed reference value and the acceleration reference value.

The encoder position value is optionally sign-inverted and/or offset, giving the user the ability to choose which rotating direction the shaft should move giving incrementing position (or positive velocity) and to select the preferred zero position. The user could choose which appliance comes first, sign-inversion or offset.
Then the resulting value is differentiate two times to obtain the speed feedback value and the acceleration feedback value.

Now all the reference and feedback values goes into the closed loop regulator, which is combined with different gains; one is for the position error, one for each speed and one for each acceleration. By default the gain for the speed value is the same for the reference and the feedback (in favour of the compatibility with the old applications), resulting in a gain for the speed error. With the acceleration reference gain the user could reduce the following error during acceleration and deceleration stages.
Then the sum is fed into a limited integrator block and the output is added to the previous sum, giving the output value of the closed loop regulator. Now this value is optionally filtered, magnitude (of power of 2) scaled and limited, then it is fed as input of the current closed loop regulator.

Optionally the user could enable the field weakening function, that decreases the loss of torque at higher speed (refer to the object 5380h.0h bit 3).

The speed loop control is updated at 4 khz.

For further information refer to Appendix A and to §4.1.

4.5.1. Performance measurements

In order to have some feedback from the drive about the speed loop control performance, five parameters are provided, as follow.

The following error at maximum speed (object 5120h.0h) is measured at the beginning of the deceleration ramp: this value is useful in those applications in which the position error during movement is crucial, like flying cutting machine. For ordinary positioning this value could be ignored.
In order to get faster positioning, e.g. reducing the time the drive enter and stay in the position window, three measurements are employed. The overshoot at the end of the deceleration ramp (object 5123h.0h) give a measure of the position error at the time in which the motor theoretically should be in the target position; reducing this error is a good starting point to reduce the positioning time. The position window entering time (object 5122h.0h) tell how much time is spent from the end of the deceleration ramp until the position error remain stable inside the position window, thus setting the target reached bit. The maximum overshoot from the end of the deceleration ramp (object 5121h.0h) is the maximum value reached from the position error entering in the position window: higher gain on the control loop could shift the system to the instability, giving high values on this measurement and rising positioning time; on the opposite end, lower gain give a very stable but slow system, giving low values on this measurement and again rising positioning time.
The average windings current (object 5124h.0h) tells if the long time machine cycle could lead in a overtemperature of the system: this value should stay below the datasheet continuative current. This measurement is done with a long time constant, thus giving reliable values after long time running (e.g. 1 hour).

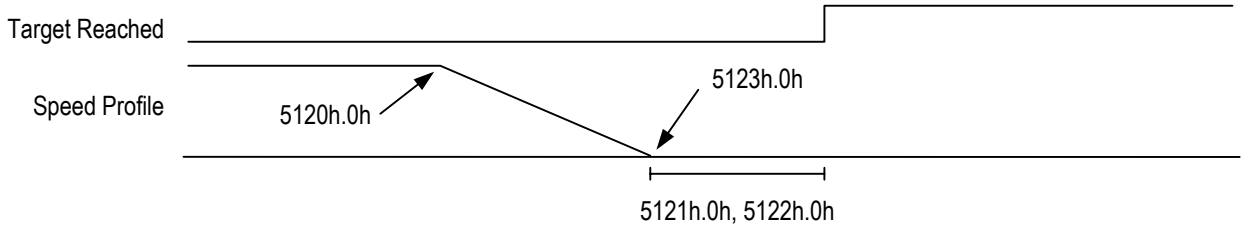


Figure 11: Control loop performance measurements

4.6. Auxiliary digital input

This 24V digital input has three different and standalone functions, that could also be used together.

The first is to provide an external and CAN-independent emergency action, that could be an immediate power disable or a quick stop and power disable functions. By default this option is disabled, that means ignore the input. If enabled, the emergency action is activated on 24V power loss: so, on behalf of normal operation the 24V on the input must be applied. This function is controlled by object 5300h.0h. For further information refer to §3.2.

The second function could be used to sample some internal parameters on rising or falling of the digital input with accuracy up to 125μs, e.g. to get the position actual value when an external switch is activated. In order to enable this feature, one TPDO has to be chosen (e.g. #5), then filled-up with one or more parameters to be sampled. The communication parameters have to be as in the table:

PDO	TPDO #5
COB-ID	4000 0xxxh
Type	1 (synchronous cyclic) or 254 (asynchronous on event)
Inhibit time	0

Write in the object 530Ah.0h the number of TPDO chosen (in our example the value 5) and the configuration is done. When the drive detect state transition (rising or falling, depending on object 5380h.0h bit 5) on the digital input, it sample the parameters, then dispatch the TPDO on the next SYNC (if transmission type chosen is 1) or immediately (if transmission type chosen is 254). For further information refer to §2.6.

The third function is to connect the home switch to be used in homing mode. For further information refer to §3.6.

4.7. Digital filters

User has the opportunity to setup a programmable 2nd order digital IIR filter on the position demand value (object 6062h.0h), on the speed loop output value and on the position set-point value (object 60C1h.1h); the filter constants are respectively on the objects 5307h, 5308h and 5309h. All those filters are based on the same principle and they are independent from each other. These filters could be used to remove a mechanical resonating frequency, allowing improve the quality of the speed loop; they could be used as jerk-limiting, especially in the interpolated profile mode, giving the ability to increase the interpolation time without weakening the output profile; they could be used to reduce the noise on the output shaft when driven from a master encoder. As counterpart beware of the time-delay introduced by

some filters, e.g. the low pass: if it is applied on the position demand value it could yield a bigger following error when speed is different than zero, especially in the acceleration/deceleration stage.

The generic 2nd order filter, in the Z domain, letting $U(z)$ the input signal and $Y(z)$ the filtered signal, is expressed as:

$$Y(z) = \frac{m_0 + m_1 z^{-1} + m_2 z^{-2}}{n_0 + n_1 z^{-1} + n_2 z^{-2}} U(z)$$

that becomes, in the discrete time domain:

$$y(k) = \frac{1}{n_0}\left[m_0 u(k) + m_1 u(k-1) + m_2 u(k-2) - n_1 y(k-1) - n_2 y(k-2)\right]$$

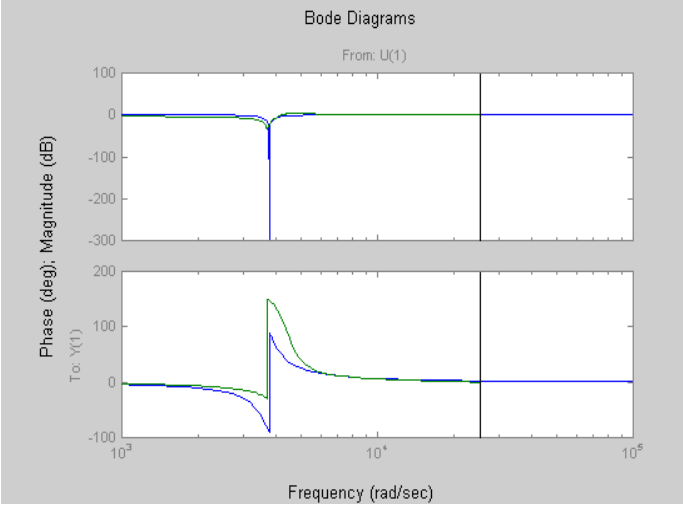
where $u(k)$, $u(k-1)$ and $u(k-2)$ are respectively the input value at present time, at previous cycle and 2 cycle back, and where $y(k)$, $y(k-1)$ and $y(k-2)$ are respectively the output value at present time, at previous cycle and 2 cycle back; for convenient calculation we assume $a_i = \frac{m_i}{n_0}$ and $b_j = -\frac{n_j}{n_0}$, thus yielding:

$$y(k) = a_0 u(k) + a_1 u(k-1) + a_2 u(k-2) + b_1 y(k-1) + b_2 y(k-2)$$

The drive executes only fixed point number calculation, so those constants have to be adjusted to the internal representation by multiplying each constant per 2^{13} (equal to 8192); then those value have to be submitted by one-complement's at 16 bit, bringing in each constant in the range (-4.0 ; +4.0). Take care that the algebraic sum of all constants have to be equal to 8192.

The **notch filter** transfer function in the continuous time domain is expressed as:

$$F(s) = \frac{s^2 + \omega_0^2}{s^2 + \zeta s + \omega_0^2}$$



The blue diagrams are referred to the continuos time domain.
The green diagrams are referred to the discrete time domain
Notch at $\omega_0 = 3770$ *rad/s,* $\zeta = 0.05$

where $\omega_0 \left[rad/s \right]$ is the resonance frequency and ζ is the damping factor (greater the damping factor, greater the damped band width); making the discretization with the bilinear transformation the constants to be submitted are:

$$a_0 = \frac{4 + T_S^2 \omega_0^2}{4 + 2\zeta T_S + T_S^2 \omega_0^2}$$

$$a_1 = \frac{2T_S^2 \omega_0^2 - 8}{4 + 2\zeta T_S + T_S^2 \omega_0^2}$$

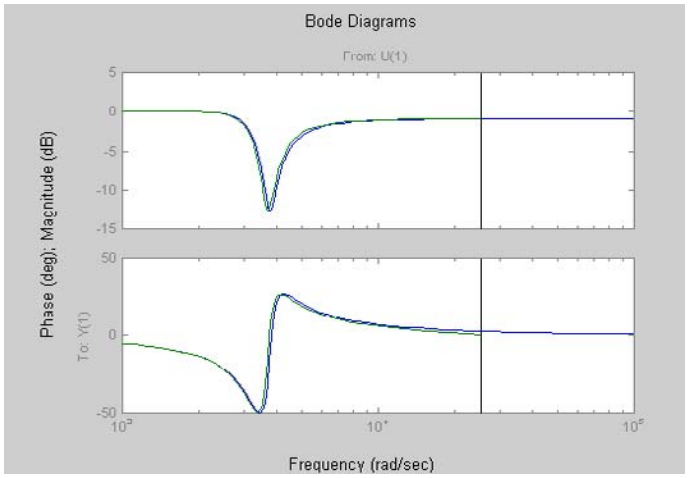
$$a_2 = \frac{4 + T_S^2 \omega_0^2}{4 + 2\zeta T_S + T_S^2 \omega_0^2}$$

$$b_1 = -\frac{2T_S^2 \omega_0^2 - 8}{4 + 2\zeta T_S + T_S^2 \omega_0^2}$$

$$b_2 = -\frac{4 - 2\zeta T_S + T_S^2 \omega_0^2}{4 + 2\zeta T_S + T_S^2 \omega_0^2}$$

The **biquad filter** transfer function in the continuous time domain is expressed as:

$$F(s) = \frac{\omega_p^2}{\omega_z^2} \cdot \frac{s^2 + 2\xi_z \omega_z s + \omega_z^2}{s^2 + 2\xi_p \omega_p s + \omega_p^2}$$



The blue diagrams are referred to the continuos time domain.
The green diagrams are referred to the discrete time domain
Biquad at $\omega_z = 3770$ *rad/s,* $\omega_p = 3581$ *rad/s,* $\xi_z = 0.05$, $\xi_p = 0.2$

where $\omega_z \left[rad/s \right]$ and $\omega_p \left[rad/s \right]$ are respectively the resonance frequency and the anti-resonating frequency, also ξ_p and ξ_z are the damping factors; making the discretization with the bilinear transformation the constants to be submitted are:

$$a_0 = \frac{4\omega_p^2 + 4\xi_z \omega_z \omega_p^2 T_S + T_S^2 \omega_z^2 \omega_p^2}{4\omega_z^2 + 4\xi_p \omega_z^2 \omega_p T_S + T_S^2 \omega_z^2 \omega_p^2}$$

$$a_1 = \frac{2T_S^2 \omega_z^2 \omega_p^2 - 8\omega_p^2}{4\omega_z^2 + 4\xi_p \omega_z^2 \omega_p T_S + T_S^2 \omega_z^2 \omega_p^2}$$

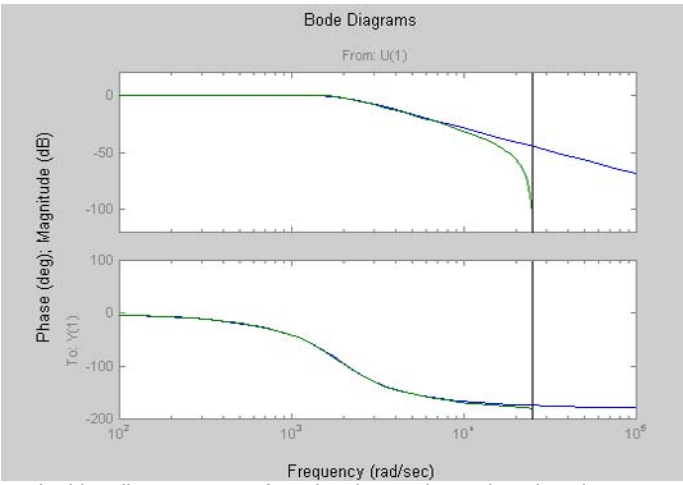
$$a_2 = \frac{4\omega_p^2 - 4\xi_z \omega_z \omega_p^2 T_S + T_S^2 \omega_z^2 \omega_p^2}{4\omega_z^2 + 4\xi_p \omega_z^2 \omega_p T_S + T_S^2 \omega_z^2 \omega_p^2}$$

$$b_1 = -\frac{2T_S^2 \omega_z^2 \omega_p^2 - 8\omega_z^2}{4\omega_z^2 + 4\xi_p \omega_z^2 \omega_p T_S + T_S^2 \omega_z^2 \omega_p^2}$$

$$b_2 = -\frac{4\omega_z^2 - 4\xi_p \omega_z^2 \omega_p T_S + T_S^2 \omega_z^2 \omega_p^2}{4\omega_z^2 + 4\xi_p \omega_z^2 \omega_p T_S + T_S^2 \omega_z^2 \omega_p^2}$$

The **low pass filter** transfer function in the continuous time domain is expressed as:

$$F(s) = \frac{\omega_0^2}{s^2 + 2\xi\omega_0 s + \omega_0^2}$$



The blue diagrams are referred to the continuos time domain.
The green diagrams are referred to the discrete time domain
Low pass at $\omega_0 = 1885$ *rad/s,* $\xi = 0.6$

where $\omega_0 \left[rad/s \right]$ is the cut-off frequency and ξ is the damping factor; making the discretization with the bilinear transformation the constants to be submitted are:

$$a_0 = \frac{T_S^2\omega_0^2}{4 + 4\xi\omega_0 T_S + T_S^2\omega_0^2}$$
$$a_1 = \frac{2T_S^2\omega_0^2}{4 + 4\xi\omega_0 T_S + T_S^2\omega_0^2}$$
$$a_2 = \frac{T_S^2\omega_0^2}{4 + 4\xi\omega_0 T_S + T_S^2\omega_0^2}$$
$$b_1 = -\frac{2T_S^2\omega_0^2 - 8}{4 + 4\xi\omega_0 T_S + T_S^2\omega_0^2}$$
$$b_2 = -\frac{4 - 4\xi\omega_0 T_S + T_S^2\omega_0^2}{4 + 4\xi\omega_0 T_S + T_S^2\omega_0^2}$$

In the above filters T_S is the sample time period, that is related on how many times per second the filter is iterated; it is associated to the object the filter applies, refer to the respective filter constants objects.

As example, we calculate a low pass filter with ω_0 = 1885 rad/s (300 Hz) and ζ = 0.6; with T_S = 250μs it yields the following constants:

$$a_0 = 0.04148 \Rightarrow 340\ (0154h)$$
$$a_1 = 0.08297 \Rightarrow 680\ (02A8h)$$
$$a_2 = 0.04148 \Rightarrow 340\ (0154h)$$
$$b_1 = 1.41151 \Rightarrow 11563\ (2D2Bh)$$
$$b_2 = -0.57745 \Rightarrow -4731\ (ED85h)$$

For further information refer to Appendix A, to §3.5 and to §4.5.

4.8. Motor Led Behaviour

The Tw Motor is equipped with two couples of leds, which indicate the motor status (leds on the upper and lower side of the motor give redundant information).

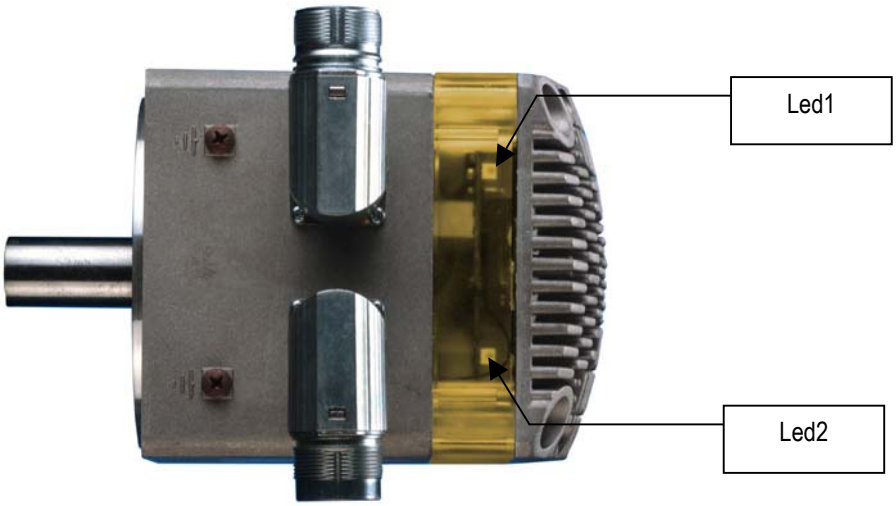


Figure 12: Leds identification

Led1	*Led2*	*Motor Status*
Blinking	Off	Power supply Ok. Power output disabled
On	Blinking	Power supply Ok. Power output enabled
Blinking alternately		Fault condition
Blinking simultaneously		Waiting for firmware download (due to Firmware download activation or wrong firmware CRC check)
Off	Two fast blink	Low DC link circuit voltage, refer to / 4
On (one side)	Off (both side)	Flash memory corrupted, contact technical service

Table 31: Leds behaviour

4.9. Firmware upgrade

At regular intervals on the Phase Motion Control web site is released a firmware upgrade, that could includes new functions and generic enhancements. The firmware download could be done completely via SDO (master CANopen, PC with **Cockpit** (/ 6), PC with CANopen configuration tool, PLC, etc.) and without disconnecting the drive from the network.

Due to the internal hardware limitation, after the upgrade all stored parameters will be lost, but the baud rate and the node-ID. The flash programming is done on the fly during download: this means that after beginning of the download the operation have to be successfully completed in order to get again the drive working.

The firmware upgrade has to be done in two steps: the first enable the drive to receive the firmware, the second is the real transfer of it.
In order to enable the drive to receive the firmware the user has to download the string **PmcS** (or the 32 bit number 5363 6D50h) in the object 5EF0h.0h. After about 100ms the driver will enter in the firmware download wait status, signaled by all leds blinking simultaneously.
Now the user has to download the complete **.SRE** file in the object 1F50h.1h. When download is successfully completed, the drive wills bootup and after about 1.5 seconds it will send the bootup message (see §2.9).

If a communication error (SDO abort) occurs during firmware download it is necessary to start again the download of the **.SRE** file; in this case the drive will remain in the firmware download wait status. If the download is successfully completed but the drive remain in the firmware download wait status means that the drive does not support the downloaded firmware; in this case please contact the technical service.

Abort code	*Description*
0503 0000h	SDO toggle bit not alternated during segmented transfer.
0504 0000h	SDO protocol timed out.
0504 0001h	SDO client/server command specifier not valid or unknown.
0601 0000h	Unsupported SDO access.
0602 0000h	Object does not exist in the object dictionary.
0604 0043h	Corrupted .SRE file.
0606 0000h	Access failed due to a hardware error of the internal flash.

Table 32: Firmware download abort code

5. Object Dictionary Reference

The complete Tw Motor object dictionary objects are listed here. For each object there is a set of attributes, as follow:

Object	This is the object index and sub-index, and the name of the parameter
Object Code	Kind of the object: **var** is single value, **array** is multiple value with same basic data type, **record** is multiple value where data fields could be any data type combination
Data Type	Could be **integer8** (signed 8 bit), **integer16** (signed 16 bit), **integer32** (signed 32 bit), **unsigned8**, **unsigned16**, **unsigned32**, **visible_string** (ASCII string without termination)
Access	Read-only (**ro**), write-only (**wo**) or read-write (**rw**); could be limited to read-only depending on the state of the drive, see the **Write override** attribute below.
Write override	Some objects cannot be written when the NMT state machine is in operational state (**operational**, see §2.9) and/or the output power is enabled (**power enabled**, see §3.2).
Unit	Measure unit of the object or if affected by the factor group (position, velocity and acceleration, see §3.7)
Default value	The value the object has with the factory settings
PDO mappable	Specify if the object could be mapped in a PDO
NV storage	If yes the object will be permanently stored in non-volatile memory when the user issues the command on object 1010h

5.1. Communication objects

Those are all implemented objects from the application layer and communication profile CiA DS301 V4.02; for further information on those objects refer to / 1.

5.1.1. 1000h.0h: Device Type

Object:	**1000h.0h**	**Device Type**	
Object Code:	var	*Data Type:*	unsigned32
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	0002 0192h
PDO mappable:	no	*NV storage:*	n/a

Describes the type of device and its functionality. It is composed of a 16-bit (LSB) field, which describes the device profile that is used, and a second 16-bit (MSB) field, which gives additional information about optional functionality of the device. In this case the device profile is 402 (0192h) and the additional information indicate that is a servo drive (0002h).

MSB	LSB
Additional information (16 bit)	Device profile type (16 bit)

Figure 13: Structure of Device Type

5.1.2. 1001h.0h: Error register

Object:	**1001h.0h**	**Error register**	
Object Code:	var	*Data Type:*	unsigned8
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	n/a
PDO mappable:	yes	*NV storage:*	n/a

This object is an error register for the drive. It is a part of the EMCY object (§2.8).

5.1.3. 1002h.0h: Manufacturer Status Register

Object:	**1002h.0h**	**Manufacturer Status Register**	
Object Code:	var	*Data Type:*	unsigned32
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	n/a
PDO mappable:	yes	*NV storage:*	n/a

This is the common status register specific for the manufacturer. It is a part of the EMCY object (§2.8).

5.1.4. 1005h.0h: COB-ID Sync Message

Object:	**1005h.0h**	**COB-ID Sync Message**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	0000 0080h
PDO mappable:	no	*NV storage:*	yes

Defines the COB-ID of the Synchronization Object (§2.7). Bits 0-10 define the COB-ID, bits 11-31 should be leaved 0.

MSB	LSB
Unused (21 bit), should be 0	COB-ID (11 bit)

Figure 14: Structure of COB-ID Sync Message

5.1.5. 1008h.0h: Manufacturer Device Name

Object:	**1008h.0h**	**Manufacturer Device Name**	
Object Code:	var	*Data Type:*	visible_string
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	n/a
PDO mappable:	no	*NV storage:*	n/a

Contain the device code of the Tw Motor.

5.1.6. 100Ah.0h: Manufacturer Software Version

Object:	**100Ah.0h**	**Manufacturer Software Version**	
Object Code:	var	*Data Type:*	visible_string
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	n/a
PDO mappable:	no	*NV storage:*	n/a

Contain the software release number and the release date.

5.1.7. 100Ch.0h: Guard Time

Object:	**100Ch.0h**	**Guard Time**	
Object Code:	var	*Data Type:*	unsigned16
Access:	rw	*Write override:*	operational
Unit:	ms	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

The objects at index 100Ch and 100Dh include the guard time in milliseconds and the life time factor. The life time factor multiplied with the guard time gives the life time for the Node Guarding Protocol (§2.9). If 0 then it is disabled.

5.1.8. 100Dh.0h: Life Time Factor

Object:	**100Dh.0h**	**Life Time Factor**	
Object Code:	var	*Data Type:*	unsigned8
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

The life time factor multiplied with the guard time gives the life time for the Node Guarding Protocol (§2.9). If 0 then it is disabled.

5.1.9. 1010h: Store Parameters

Object:	**1010h**	**Store Parameters**	
Object Code:	array	*Data Type:*	unsigned32

This object let the drive to save all parameters in non-volatile memory. By read access the device provides information about its saving capabilities.

Sub-index:	**0h**	**Large sub-index supported**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	no
PDO mappable:	no	*NV storage:*	no

The large sub-index supported for this object, in this case 1.

Sub-index:	**1h**	**Store all**	
Data type:	unsigned32		
Access:	rw	*Write override:*	operational, power enabled
Unit:	n/a	*Default value:*	no
PDO mappable:	no	*NV storage:*	no

This command let the drive store all parameters that have the attribute NV storage. In order to avoid storage of parameters by mistake, storage is only executed when a specific signature is written to the appropriate sub-Index. The signature is the string **save** (or the 32 bit number 6576 6173h). On read the drive provides information about its storage functionality, in this case storage is executed only on command, not autonomously.
It is possible to store a configuration version in the object 5312h.0h.

5.1.10. 1011h: Restore Default Parameters

Object:	**1011h**	**Restore Default Parameters**	
Object Code:	array	*Data Type:*	unsigned32

With this object the default values of parameters according to the communication or device profile are restored.

Sub-index:	**0h**	**Large sub-index supported**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	no
PDO mappable:	no	*NV storage:*	no

The large sub-index supported for this object, in this case 1.

Sub-index:	**1h**	**Restore all defaults**	
Data type:	unsigned32		
Access:	rw	*Write override:*	operational, power enabled
Unit:	n/a	*Default value:*	no
PDO mappable:	no	*NV storage:*	no

This command let the drive restore all parameters to the factory settings. In order to avoid restore of parameters by mistake, restore is only executed when a specific signature is written to the appropriate sub-Index. The signature is the string **load** (or the 32 bit number 6461 6F6Ch). This command have to be completed by issuing a **reset** command (§2.9).

5.1.11. 1014h.0h: COB-ID Emergency Object

Object:	**1014h.0h**	**COB-ID Emergency Object**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	0000 0080h + node-ID
PDO mappable:	no	*NV storage:*	yes

Defines the COB-ID of the EMCY (§2.8). Bits 0-10 define the COB-ID, bit 31 defines if the EMCY is enabled (equal to 0) or if it is disabled (equal to 1); bits 11-30 should be leaved 0.

MSB		LSB
E	Unused (20 bit), should be 0	COB-ID (11 bit)

Figure 15: Structure of COB-ID Emergency Message

5.1.12. 1015h.0h: Inhibit Time of Emergency Object

Object:	**1015h.0h**	**Inhibit Time of Emergency Object**	
Object Code:	var	*Data Type:*	unsigned16
Access:	rw	*Write override:*	operational
Unit:	100 µs	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

The inhibit time for the EMCY (§2.8) can be adjusted via this entry. To guarantee that no starvation on the network occurs for data objects with low priorities, data objects can be assigned an inhibit time; this defines the minimum time that has to elapse between two consecutive invocations of a transmission service for that data object.

5.1.13. 1017h.0h: Producer Heartbeat Time

Object:	**1017h.0h**	**Producer Heartbeat Time**	
Object Code:	var	*Data Type:*	unsigned16
Access:	rw	*Write override:*	operational
Unit:	ms	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

The producer heartbeat time defines the cycle time of the heartbeat for the Node Guarding Protocol (§2.9). If 0 then it is disabled.

5.1.14. 1018h: Identity Object

Object:	**1018h**	**Identity Object**	
Object Code:	array	*Data Type:*	unsigned32

The object at index 1018h contains general information about the device.

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	4
PDO mappable:	no	*NV storage:*	no

Sub-index:	**1h**	**Vendor ID**	
Data type:	unsigned32		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	no
PDO mappable:	no	*NV storage:*	no

This is a unique value assigned to each manufacturer by CiA, in this case for Phase Motion Control is 0000 00D9h.

Sub-index:	**2h**	**Product Code**	
Data type:	unsigned32		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	no
PDO mappable:	no	*NV storage:*	no

This is the product code of the device.

Sub-index:	**3h**	**Revision Number**	
Data type:	unsigned32		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	no
PDO mappable:	no	*NV storage:*	no

This is the firmware release number, with the subfields structured as follow:

MSB		LSB
major (16 bit)	mid (8 bit)	minor (8 bit)

Figure 16: Structure of Revision Number

Sub-index:	**4h**	**Serial number**	
Data type:	unsigned32		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	no
PDO mappable:	no	*NV storage:*	no

This is the serial number of the Tw Motor, the same appears on the side of the case.

5.1.15. 1400h: Receive PDO Communication Parameter

Object:	**1400h**	**Receive PDO Communication Parameter**	
Object Code:	record	*Data Type:*	n/a

The purpose of this data structure is to define the communication parameters for all RPDO; for each RPDO exist one object, the object index range from 1400h (RPDO #1) to 1407h (RPDO #8).
Prior to any modification of the following parameters, the desired PDO have to be disabled, by setting to 1 the bit 31 of the COB-ID.

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	2
PDO mappable:	no	*NV storage:*	no

Sub-index:	**1h**	**COB-ID of the PDO**	
Data type:	unsigned32		
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	yes (see Appendix B)
PDO mappable:	no	*NV storage:*	yes

Define the COB-ID and the state (enabled/disabled) of the RPDO. Bits 0-10 define the COB-ID, bit 31 defines if the PDO is enabled (equal to 0) or if it is disabled (equal to 1); bit 30 should be leaved 1, while bits 11-29 should be leaved 0. COB-ID have to be defined between 181h and 57Fh.

MSB			LSB
E	1	Unused (19 bit), should be 0	COB-ID (11 bit)

Figure 17: Structure of RPDO's COB-ID

Sub-index:	**2h**	**Transmission type**	
Data type:	unsigned8		
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	yes (see Appendix B)
PDO mappable:	no	*NV storage:*	yes

This field defines the transmission type of RPDO and then when received data should be used.

Transmission type	*cylic*	*acyclic*	*synchronous*	*asynchronous*
0		X	X	
1-240	X		X	
255				X

For further information on RPDOs refer to §2.6, to the below chapter for mapping and to §6.2 for examples.

5.1.16. 1600h: Receive PDO Mapping Parameter

Object:	**1600h**	**Receive PDO Mapping Parameter**	
Object Code:	array	*Data Type:*	unsigned32

The purpose of this data structure is to define the data mapping for all RPDO; for each RPDO exist one object, the object index range from 1600h (RPDO #1) to 1607h (RPDO #8).
Prior to any modification of the following parameters, the desired PDO have to be disabled, by setting to 1 the bit 31 of the COB-ID.

Sub-index:	**0h**	**Number of object mapped**	
Data type:	unsigned8		
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	yes (see Appendix B)
PDO mappable:	no	*NV storage:*	yes

This parameter determines the valid number of objects that have been mapped. For changing the PDO mapping first the PDO has to be deleted, this parameter has to be set to 0 (mapping is deactivated). Then the objects can be remapped. After all objects are mapped this parameter is to be written with the valid number of mapped objects.

Sub-index:	**1h-8h**	**PDO Mapping**	
Data type:	unsigned32		
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	yes (see Appendix B)
PDO mappable:	no	*NV storage:*	yes

These entries describe the PDO contents by their index, sub-index and length. The length entry contains the length of the object in bit (8, 16, 32) and has to match the object length. This parameter is used to verify the overall mapping length.

MSB		LSB
Index (16 bit)	Sub-index (8 bit)	Object length (8 bit)

Figure 18: Structure of PDO Mapping Entry

When a new object is mapped by writing a sub-index between 1 and 8, the drive checks whether the object specified by index / sub-index exists. If the object does not exist or the object cannot be mapped, an abort SDO is issued.

If data types (index 0002h-0007h) are mapped they serve as **dummy entries**. The corresponding data in the PDO is not evaluated by the device. This optional feature is useful e.g. to transmit data to several devices using one PDO, each device only using its own part of the PDO. E.g., if the first 16 bit of a RPDO is to be discarded, map the value 0003 0010h or 0006 0010h (refer to Figure 18) on the first object (sub-index 1).

Index	*Object type*
0002h	INTEGER8
0003h	INTEGER16
0004h	INTEGER32
0005h	UNSIGNED8
0006h	UNSIGNED16
0007h	UNSIGNED32

For further information on RPDOs refer to §2.6 and to §6.2 for examples.

5.1.17. 1800h: Transmit PDO Communication Parameter

Object:	**1800h**	**Transmit PDO Communication Parameter**	
Object Code:	record	*Data Type:*	n/a

The purpose of this data structure is to define the communication parameters for all TPDO; for each TPDO exist one object, the object index range from 1800h (TPDO #1) to 1807h (TPDO #8).
Prior to any modification of the following parameters, the desired PDO have to be disabled, by setting to 1 the bit 31 of the COB-ID.

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	3
PDO mappable:	no	*NV storage:*	no

Sub-index:	**1h**	**COB-ID of the PDO**	
Data type:	unsigned32		
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	yes (see Appendix B)
PDO mappable:	no	*NV storage:*	yes

Define the COB-ID and the state (enabled/disabled) of the TPDO. Bits 0-10 define the COB-ID, bit 31 defines if the PDO is enabled (equal to 0) or if it is disabled (equal to 1); bit 30 defines if RTR is allowed (equal to 0) or not (equal to 1) on this PDO; bits 11-29 should be leaved 0. COB-ID have to be defined between 181h and 57Fh.

MSB LSB

E	R	Unused (19 bit), should be 0	COB-ID (11 bit)

Figure 19: Structure of TPDO's COB-ID

Sub-index:	**2h**	**Transmission type**	
Data type:	unsigned8		
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	yes (see Appendix B)
PDO mappable:	no	*NV storage:*	yes

This field defines the transmission type of TPDO and then when the data should be transmitted.

Transmission type	*cylic*	*acyclic*	*synchronous*	*asynchronous*	*RTR only*
0		X	X		
1-240	X		X		
252			X		X
253				X	X
254				X	
255				X	

Sub-index:	**3h**	**Inhibit time**	
Data type:	unsigned16		
Access:	rw	*Write override:*	operational
Unit:	100 µs	*Default value:*	yes (see Appendix B)
PDO mappable:	no	*NV storage:*	yes

This defines the minimum time that has to elapse between two consecutive invocations of a transmission service for the TPDO; it is possible to set this object only for asynchronous TPDO.

For further information on TPDOs refer to §2.6, to the below chapter for mapping and to §6.2 for examples.

5.1.18. 1A00h: Transmit PDO Mapping Parameter

Object:	**1A00h**	**Transmit PDO Mapping Parameter**	
Object Code:	array	*Data Type:*	unsigned32

The purpose of this data structure is to define the data mapping for all TPDO; for each TPDO exist one object, the object index range from 1A00h (TPDO #1) to 1A07h (TPDO #8).
Prior to any modification of the following parameters, the desired PDO have to be disabled, by setting to 1 the bit 31 of the COB-ID.

Sub-index:	**0h**	**Number of object mapped**	
Data type:	unsigned8		
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	yes (see Appendix B)
PDO mappable:	no	*NV storage:*	yes

This parameter determines the valid number of objects that have been mapped. For changing the PDO mapping first the PDO has to be deleted, this parameter has to be set to 0 (mapping is deactivated). Then the objects can be remapped. After all objects are mapped this parameter is to be written with the valid number of mapped objects.

Sub-index:	**1h-8h**	**PDO Mapping**	
Data type:	unsigned32		
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	yes (see Appendix B)
PDO mappable:	no	*NV storage:*	yes

These entries describe the PDO contents by their index, sub-index and length. The length entry contains the length of the object in bit (8, 16, 32) and have to match the object length (see Figure 18). This parameter is used to verify the overall mapping length. When a new object is mapped by writing a sub-index between 1 and 8, the drive checks whether the object specified by index / sub-index exists. If the object does not exist or the object cannot be mapped, an abort SDO is issued.

For further information on TPDOs refer to §2.6 and to §6.2 for examples.

5.2. Profile specific objects

Those are all implemented objects from the device profile drives and motion control CiA DSP402 V2.0; for further information on those objects refer to / 3.

5.2.1. 6007h.0h: Abort connection option code

Object:	**6007h.0h**	**Abort connection option code**	
Object Code:	var	*Data Type:*	integer16
Access:	rw	*Write override:*	operational, power enabled
Unit:	n/a	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

The content of this object selects the function to be performed when the connection to the network is lost: CAN bus-off, CAN in error passive mode, life guard error (if active), sync controller error or nmt state changed (except the PRE-OPERATIONAL to OPERATIONAL transition). The action could be one of the following:

Option code	*Description*
0	No action
2	Issue a device control command **Disable Voltage**
3	Issue a device control command **Quick Stop**

For further information look at §2.8 and §3.2.

5.2.2. 603Fh.0h: Error code

Object:	**603Fh.0h**	**Error code**	
Object Code:	var	*Data Type:*	unsigned16
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	0
PDO mappable:	yes	*NV storage:*	n/a

The Error code captures the code of the last error that occurred in the drive. It corresponds to the value of the first 16 bits of the EMCY object (§2.8).

5.2.3. 6502h.0h: Supported drive modes

Object:	**6502h.0h**	**Supported drive modes**	
Object Code:	var	*Data Type:*	unsigned32
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	n/a
PDO mappable:	yes	*NV storage:*	n/a

A drive can support more than one and several distinct modes of operation. This object gives an overview of the implemented operating modes in the device. In the Tw Motor this is equal to 0000 0065h: this means that are supported profile position (§3.3), profile velocity (§3.4), interpolated position (§3.5) and homing mode (§3.6).

5.2.4. 6504h.0h: Manufacturer Name

Object:	**6504h.0h**	**Manufacturer Name**	
Object Code:	var	*Data Type:*	visible_string
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	n/a
PDO mappable:	no	*NV storage:*	n/a

The manufacturer name.

5.2.5. 6040h.0h: Controlword

Object:	**6040h.0h**	**Controlword**	
Object Code:	var	*Data Type:*	unsigned16
Access:	rw	*Write override:*	n/a
Unit:	n/a	*Default value:*	no
PDO mappable:	yes	*NV storage:*	no

The controlword contains the bits for controlling the state machine (§3.2) and for controlling the specific operating mode.

MSB LSB

reserved (7 bit)	halt	fault reset	O3	O2	O1	enable oper.	quick stop	enable volt.	switch on

Figure 20: Structure of controlword

The O1, O2, O3 are operating mode specific bits:

Bit	*Position profile*	*Velocity profile*	*Interpolated profile*	*Torque mode*	*Homing mode*	*Rotary table*
O1	new set-point	reserved	enable ip mode	reserved	homing operation start	new set-point
O2	change set immediately	reserved	reserved	reserved	reserved	absolute without best-route
O3	abs/rel	reserved	reserved	reserved	reserved	relative

Table 33: Controlword operating mode specific bits

The reserved bit are for future enhancements, should be kept to 0.

5.2.6. 6041h.0h: Statusword

Object:	**6041h.0h**	**Statusword**	
Object Code:	var	*Data Type:*	unsigned16
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	no
PDO mappable:	yes	*NV storage:*	no

The statusword indicates the current state of the drive (§3.2) and the current state of the specific operating mode.

Bit	*Name*	*Description*
0	Ready to switch on	see Device Control (§3.2)
1	Switched on	see Device Control (§3.2)
2	Operation enabled	see Device Control (§3.2)
3	Fault	see Device Control (§3.2)
4	Voltage enabled	Power output is enabled to the drive when this bit is set to 1
5	Quick stop	see Device Control (§3.2)
6	Switch on disabled	see Device Control (§3.2)
7	Warning	Used only in Rotary table control, issued if some incorrect parameter, refer to §4.4
8	reserved	
9	Remote	If set, then parameters may be modified via the CAN bus, and the drive executes the content of a command message. If the bit remote is reset, then the drive is in local mode and will not execute the command message.
10	Target reached	If set, then a set-point has been reached (not used in Torque Mode and Homing Mode). The set-point is dependent on the operating mode. The change of a target value by software alters this bit. If quick stop option code is 5 or 6 this bit is set when the quick stop operation is finished and the drive is halted. If halt occurred and the drive has halted then this bit is set too.

11	Internal limit active	It signal that the target position (if in Profile Position Mode) or the set-point (if in Interpolated Mode) was wrapped between minimum and maximum Software position limit (object 607Dh), due to exceeding value. It is reset with a new target position or set-point between the limits (not used in Torque Mode).
12	O1	
13	O2	
14	Rotary axis enabled	The rotary axis mode is enabled and the position objects are valid, refer to §4.1
15	Homing done	The homing is done, this bit remain active up to a node reset or a power-off, refer to §3.6

Table 34: Structure of the statusword

The O1 and O2 are operating mode specific bits:

Bit	*Position profile*	*Velocity profile*	*Interpolated profile*	*Torque mode*	*Homing mode*	*Rotary table*
O1	Set point acknowledge	Zero speed	Ip mode active	reserved	Homing attained	Set point acknowledge
O2	Following error	Max slippage error	reserved	reserved	Homing error	reserved

Table 35: Statusword operating mode specific bits

The reserved bit is for future enhancements, it has to be ignored.

5.2.7. 605Bh.0h: Shutdown option code

Object:	**605Bh.0h**	**Shutdown option code**	
Object Code:	var	*Data Type:*	integer16
Access:	rw	*Write override:*	operational,power enabled
Unit:	n/a	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

This parameter determines what action should be taken if there is a transition from **Operation enable** to **Ready to switch on** (transition 8). The action could be one of the following:

Option code	*Description*
0	Disable drive function
1	Slow down with slow down ramp; disable of the drive function

For further information look at §3.2.

5.2.8. 605Ch.0h: Disable operation option code

Object:	**605Ch.0h**	**Disable operation option code**	
Object Code:	var	*Data Type:*	integer16
Access:	rw	*Write override:*	operational,power enabled
Unit:	n/a	*Default value:*	1
PDO mappable:	no	*NV storage:*	yes

This parameter determines what action should be taken if there is a transition from **Operation enable** to **Switched on** (transition 5). The action could be one of the following:

Option code	*Description*
0	Disable drive function
1	Slow down with slow down ramp; disable of the drive function

For further information look at §3.2.

5.2.9. 605Ah.0h: Quick stop option code

Object:	**605Ah.0h**	**Quick stop option code**	
Object Code:	var	*Data Type:*	integer16
Access:	rw	*Write override:*	operational,power enabled
Unit:	n/a	*Default value:*	2
PDO mappable:	no	*NV storage:*	yes

This determines what action should be taken if the **Quick stop** function is executed (transition 11). The action could be one of the following:

Option code	*Description*
0	Disable drive function
1	Slow down with slow down ramp; disable of the drive function
2	Slow down with quick stop ramp; disable of the drive function
5	Slow down with slow down ramp and stay in quick stop
6	Slow down with quick stop ramp and stay in quick stop

For further information look at §3.2.

5.2.10. 605Dh.0h: Halt option code

Object:	**605Dh.0h**	**Halt option code**	
Object Code:	var	*Data Type:*	integer16
Access:	rw	*Write override:*	operational,power enabled
Unit:	n/a	*Default value:*	1
PDO mappable:	no	*NV storage:*	yes

This determines what action should be taken if the bit 8 (**halt**) in the controlword is active. The action could be one of the following:

Option code	*Description*
0	Disable drive, motor is free to rotate
1	Slow down with slow down ramp
2	Slow down with quick stop ramp

For further information look at §3.2.

5.2.11. 605Eh.0h: Fault reaction option code

Object:	**605Eh.0h**	**Fault reaction option code**	
Object Code:	var	*Data Type:*	integer16
Access:	rw	*Write override:*	operational,power enabled
Unit:	n/a	*Default value:*	2
PDO mappable:	no	*NV storage:*	yes

The parameter fault reaction option code determines what action should be taken if a non-fault occurs in the drive. The action could be one of the following:

Option code	*Description*
0	Disable drive, motor is free to rotate
1	Slow down with slow down ramp
2	Slow down with quick stop ramp

For further information look at §3.2.

5.2.12. 6060h.0h: Modes of operation

Object:	**6060h.0h**	**Modes of operation**	
Object Code:	var	*Data Type:*	integer8
Access:	rw	*Write override:*	no
Unit:	n/a	*Default value:*	1
PDO mappable:	yes	*NV storage:*	yes

This parameter switches the operation mode. The possible values are:

Value	*Description*
1	Profile position mode
3	Profile velocity mode
6	Homing mode
7	Interpolated position mode
-128	Torque mode
-127	Rotary table control

A read of **modes of operation** shows only the value of the parameter. The present mode of the drive is reflected in the object **modes of operation display** (object 6061h.0h).

For further information look at §3.2.

5.2.13. 6061h.0h: Modes of operation display

Object:	**6061h.0h**	**Modes of operation display**	
Object Code:	var	*Data Type:*	integer8
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	1
PDO mappable:	yes	*NV storage:*	n/a

The modes of operation display shows the current mode of operation. The meaning of the returned value corresponds to that of the modes of operation option code (object 6060h.0h).
For further information look at §3.2.

5.2.14. 6089h.0h: Position notation index

Object:	**6089h.0h**	**Position notation index**	
Object Code:	var	*Data Type:*	integer8
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

This is the magnitude of the position p.u.: for example, micro (**µ**) is 10^{-6}, milli (**m**) is 10^{-3}, unit is 10^{0}, kilo (**k**) is 10^{3}, mega (**M**) is 10^{6}. For further information look at §3.7.

5.2.15. 608Ah.0h: Position dimension index

Object:	**608Ah.0h**	**Position dimension index**	
Object Code:	var	*Data Type:*	unsigned8
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	FFh
PDO mappable:	no	*NV storage:*	yes

This is the chosen position p.u. The possible values are:

Value	*Description*
01h	Meters [m]
10h	Radians [rad]
41h	Degrees [°]
FFh	Internal device units

For further information look at §3.7.

5.2.16. 608Bh.0h: Velocity notation index

Object:	**608Bh.0h**	**Velocity notation index**	
Object Code:	var	*Data Type:*	integer8
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

This is the magnitude of the velocity p.u.: for example, micro (**µ**) is 10^{-6}, milli (**m**) is 10^{-3}, unit is 10^{0}, kilo (**k**) is 10^{3}, mega (**M**) is 10^{6}. For further information look at §3.7.

5.2.17. 608Ch.0h: Velocity dimension index

Object:	**608Ch.0h**	**Velocity dimension index**	
Object Code:	var	*Data Type:*	unsigned8
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	FFh
PDO mappable:	no	*NV storage:*	yes

This is the chosen velocity p.u. The possible values are:

Value	*Description*
A3h	Revolution/second [rev/s]
A4h	Revolution/minute [rev/min]
A6h	Meters/second [m/s]
A7h	Meters/minute [m/min]
FFh	Internal device units

For further information look at §3.7.

5.2.18. 608Dh.0h: Acceleration notation index

Object:	**608Dh.0h**	**Acceleration notation index**	
Object Code:	var	*Data Type:*	integer8
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

This is the magnitude of the acceleration p.u.: for example, micro (**µ**) is 10^{-6}, milli (**m**) is 10^{-3}, unit is 10^{0}, kilo (**k**) is 10^{3}, mega (**M**) is 10^{6}. For further information look at §3.7.

5.2.19. 608Eh.0h: Acceleration dimension index

Object:	**608Eh.0h**	**Acceleration dimension index**	
Object Code:	var	*Data Type:*	unsigned8
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	FFh
PDO mappable:	no	*NV storage:*	yes

This is the chosen acceleration p.u. The possible values are:

Value	*Description*
A3h	Revolution/squared_second [rev/s^2]
A6h	Meters/squared_second [m/s^2]
FFh	Internal device units

For further information look at §3.7.

5.2.20. 608Fh: Position encoder resolution

Object:	**608Fh**	**Position encoder resolution**	
Object Code:	array	*Data Type:*	unsigned32

The position encoder resolution defines the ratio of encoder increments per motor revolution:

$$position\ encoder\ resolution = \frac{encoder\ increments}{motor\ revolutions}$$

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	2
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**1h**	**Encoder increments**	
Data type:	unsigned32		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	65536
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**2h**	**Motor revolutions**	
Data type:	unsigned32		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	1
PDO mappable:	no	*NV storage:*	n/a

For further information look at §3.7.

5.2.21. 6090h: Velocity encoder resolution

Object:	**6090h**	**Velocity encoder resolution**	
Object Code:	array	*Data Type:*	unsigned32

The velocity encoder resolution defines the ratio of encoder increments/second per motor revolutions/second:

$$velocity\ encoder\ resolution = \frac{encoder\ \frac{increments}{second}}{motor\ \frac{revolutions}{second}}$$

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	2
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**1h**	**Encoder increments per second**	
Data type:	unsigned32		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	268435456
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**2h**	**Motor revolutions per second**	
Data type:	unsigned32		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	250
PDO mappable:	no	*NV storage:*	n/a

For further information look at §3.7.

5.2.22. 6091h: Gear ratio

Object:	**6091h**	**Gear ratio**	
Object Code:	array	*Data Type:*	unsigned32

The gear ratio defines the ratio of feed in position units per driving shaft revolutions:

$$gear\ ratio = \frac{motor\ shaft\ revolutions}{driving\ shaft\ revolutions}$$

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	2
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**1h**	**Motor revolutions**	
Data type:	unsigned32		
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	1
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**2h**	**Shaft revolutions**	
Data type:	unsigned32		
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	1
PDO mappable:	no	*NV storage:*	yes

For further information look at §3.7.

5.2.23. 6092h: Feed constant

Object:	**6092h**	**Feed constant**	
Object Code:	array	*Data Type:*	unsigned32

The feed constant defines the ratio of feed in position units per driving shaft revolutions:

$$feed\ constant = \frac{feed}{driving\ shaft\ revolutions}$$

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	2
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**1h**	**Feed**	
Data type:	unsigned32		
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	1
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**2h**	**Shaft revolutions**	
Data type:	unsigned32		
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	1
PDO mappable:	no	*NV storage:*	yes

For further information look at §3.7.

5.2.24. 607Ah.0h: Target position

Object:	**607Ah.0h**	**Target position**	
Object Code:	var	*Data Type:*	integer32
Access:	rw	*Write override:*	no
Unit:	position Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	no

The target position is the position that the drive should move to in position profile mode using the current settings of motion control parameters such as velocity, acceleration, deceleration, motion profile type etc.
At start-up the content is unforeseeable, then the first positioning should be only absolute.
For further information look at §3.3.

5.2.25. 607Dh: Software position limit

Object:	**607Dh**	**Software position limit**	
Object Code:	array	*Data Type:*	n/a

These parameters define the absolute position limits (in the position profile mode or interpolated position mode only) for the **position demand value**. Every new **target position** or **position set-point** is verified and trimmed to remain between those limits. It affects the **Internal limit active** bit in the Statusword (object 6041h).
Those limits could be deactivated acting on bit 7 of the object 5380h.0h.

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	2
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**1h**	**Min position limit**	
Data type:	integer32		
Access:	rw	*Write override:*	no
Unit:	position Factor group	*Default value:*	-2147483648
PDO mappable:	yes	*NV storage:*	yes

Sub-index:	**2h**	**Max position limit**	
Data type:	integer32		
Access:	rw	*Write override:*	no
Unit:	position Factor group	*Default value:*	2147483647
PDO mappable:	yes	*NV storage:*	yes

For further information look at §3.3 and at §3.5.

5.2.26. 6081h.0h: Profile velocity

Object:	**6081h.0h**	**Profile velocity**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	no
Unit:	velocity Factor group	*Default value:*	23068672 (~135 rad/s)
PDO mappable:	yes	*NV storage:*	yes

The profile velocity is the velocity normally attained at the end of the acceleration ramp during a profiled move and is valid for both directions of motion. For further information look at §3.3.

5.2.27. 6082h.0h: End velocity

Object:	**6082h.0h**	**End velocity**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	no
Unit:	velocity Factor group	*Default value:*	0
PDO mappable:	yes	*NV storage:*	yes

The end velocity defines the velocity, which the drive must have on reaching the target position. Normally, the drive stops at the target position, i.e. the end velocity = 0. For further information look at §3.3.

5.2.28. 6083h.0h: Profile acceleration

Object:	**6083h.0h**	**Profile acceleration**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	no
Unit:	acceleration Factor group	*Default value:*	4096 (~95.9 rad/s^2)
PDO mappable:	yes	*NV storage:*	yes

The profile acceleration is given in user defined acceleration units. For further information look at §3.3 and at §3.4.

5.2.29. 6084h.0h: Profile deceleration

Object:	**6084h.0h**	**Profile deceleration**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	no
Unit:	acceleration Factor group	*Default value:*	4096 (~95.9 rad/s^2)
PDO mappable:	yes	*NV storage:*	yes

The profile deceleration is given in user defined acceleration units. It is used also for the slow down ramp when selected as option code. For further information look at §3.2, §3.3 and at §3.4.

5.2.30. 6085h.0h: Quick stop deceleration

Object:	**6085h.0h**	**Quick stop deceleration**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	no
Unit:	acceleration Factor group	*Default value:*	16384 (~383 rad/s^2)
PDO mappable:	yes	*NV storage:*	yes

The quick stop deceleration is the deceleration used to stop the motor if the quick stop ramp is selected as option code. For further information look at §3.2.

5.2.31. 6086h.0h: Motion profile type

Object:	**6086h.0h**	**Motion profile type**	
Object Code:	var	*Data Type:*	Integer16
Access:	rw	*Write override:*	no
Unit:	n/a	*Default value:*	0
PDO mappable:	yes	*NV storage:*	yes

The motion profile type is used to select the type of motion profile used to perform a profiled move. The Tw Motor supports only the linear ramp (trapezoidal profile) that is the type 0. To smooth the edges of this kind of profile (like the jerk-limited profile), Tw Motor provide a 2nd order digital filter (refer to §4.7).
For further information look at §3.3.

5.2.32. 607Ch.0h: Home offset

Object:	**607Ch.0h**	**Home offset**	
Object Code:	var	*Data Type:*	integer32
Access:	rw	*Write override:*	no
Unit:	position Factor group	*Default value:*	0
PDO mappable:	yes	*NV storage:*	yes

The home offset object is the difference between the zero position for the application and the machine home position (found during homing). This object affects the values read from the position encoder:

$$position\ actual\ value = encoder\ \ position + home\ offset$$

The object could be written also when the power output is enabled and the shaft is running, as the writing does not affect any internal system status variables.

The sequence on which Home offset and Rotation polarity (object 5301h) are applied are affected by the object 5380h.0h bit 6. By default (Home offset before Rotation polarity) the value to be written to zero the position actual value is the sign inverted present position in case of positive polarity, it is the present position in case of negative polarity.

For further information look at Appendix A and at §4.5.

5.2.33. 6098h.0h: Homing method

Object:	**6098h.0h**	**Homing method**	
Object Code:	var	*Data Type:*	integer8
Access:	rw	*Write override:*	no
Unit:	n/a	*Default value:*	26
PDO mappable:	yes	*NV storage:*	yes

This object determines the method that will be used during homing. The possible values are: 19,20,21,22,26 and 30.

For further information look at §3.6.

5.2.34. 6099h: Homing speeds

Object:	**6099h**	**Homing speeds**	
Object Code:	array	*Data Type:*	n/a

This parameter define the speed in velocity units at which the home switch is sought during homing mode.

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	2
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**1h**	**Speed during search for home switch**	
Data type:	unsigned32		
Access:	rw	*Write override:*	no
Unit:	velocity Factor group	*Default value:*	23068672 (~135 rad/s)
PDO mappable:	yes	*NV storage:*	yes

Sub-index:	**2h**	**Not used**	
Data type:	unsigned32		
Access:	rw	*Write override:*	no
Unit:	velocity Factor group	*Default value:*	0
PDO mappable:	yes	*NV storage:*	yes

For further information look at §3.6.

5.2.35. 609Ah.0h: Homing acceleration

Object:	**609Ah.0h**	**Homing acceleration**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	no
Unit:	acceleration Factor group	*Default value:*	4096 (~95.9 rad/s^2)
PDO mappable:	yes	*NV storage:*	yes

This parameter define the acceleration at which the home switch is sought during homing mode. The homing acceleration is given in user defined acceleration units. For further information look at §3.6.

5.2.36. 6062h.0h: Position demand value

Object:	**6062h.0h**	**Position demand value**	
Object Code:	var	*Data Type:*	integer32
Access:	ro	*Write override:*	n/a
Unit:	position Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This object represents the present position demand value output from the trajectory generator. For further information look at Appendix A.

5.2.37. 6064h.0h: Position actual value

Object:	**6064h.0h**	**Position actual value**	
Object Code:	var	*Data Type:*	integer32
Access:	ro	*Write override:*	n/a
Unit:	position Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This object represents the present value of the position measurement device, normalized with home offset and polarized with the direction object. For further information look at Appendix A.

5.2.38. 6065h.0h: Following error window

Object:	**6065h.0h**	**Following error window**	
Object Code:	var	*Data Type:*	integer32
Access:	rw	*Write override:*	no
Unit:	position Factor group	*Default value:*	12288 (~1.178 rad)
PDO mappable:	yes	*NV storage:*	yes

The following error window defines the maximum tolerance on the following error; if the following error actual value is greater than following error window, a following error occurs. A following error might occur when a drive is blocked, unreachable profile velocity occurs, or at wrong closed loop coefficients. For further information look at §3.3.

5.2.39. 6066h.0h: Following error time out

Object:	**6066h.0h**	**Following error time out**	
Object Code:	var	*Data Type:*	unsigned16
Access:	rw	*Write override:*	no
Unit:	ms	*Default value:*	10
PDO mappable:	yes	*NV storage:*	yes

When a following error occurs longer than the defined value of the time-out, the corresponding bit 13 following error in the statusword will be set to one. For further information look at §3.3.

5.2.40. 6067h.0h: Position window

Object:	**6067h.0h**	**Position window**	
Object Code:	var	*Data Type:*	integer32
Access:	rw	*Write override:*	no
Unit:	position Factor group	*Default value:*	256 (~0.025 rad)
PDO mappable:	yes	*NV storage:*	yes

The position window defines a symmetrical range of accepted positions relatively to the target position:

$$(target\ position - position\ window; target\ position + position\ window)$$

If the present value of the position encoder is within the position window, this target position is regarded as reached. For further information look at §3.3.

5.2.41. 6068h.0h: Position window time

Object:	**6068h.0h**	**Position window time**	
Object Code:	var	*Data Type:*	unsigned16
Access:	rw	*Write override:*	no
Unit:	ms	*Default value:*	20
PDO mappable:	yes	*NV storage:*	yes

When the present position is within the position window during the defined position window time, the corresponding bit 10 target reached in the statusword will be set to one. For further information look at §3.3.

5.2.42. 60F4h.0h: Following error actual value

Object:	**60F4h.0h**	**Following error actual value**	
Object Code:	var	*Data Type:*	integer32
Access:	ro	*Write override:*	n/a
Unit:	position Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This object represents the present value of the following error.
For further information look at Appendix A.

5.2.43. 60C1h: Interpolation data record

Object:	**60C1h**	**Interpolation data record**	
Object Code:	array	*Data Type:*	integer32

The interpolation data record is the data words, which are necessary to perform the interpolation algorithm. For the linear interpolation mode each interpolation data record simply is regarded as a new position set-point. Those set-points could be optionally filtered by a user-defined 2nd order filter.

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	1
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**1h**	**Position set-point**	
Data type:	integer32		
Access:	rw	*Write override:*	no
Unit:	position Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	no

For further information look at §3.5 and to §4.7.

5.2.44. 60C2h: Interpolation time period

Object:	**60C2h**	**Interpolation time period**	
Object Code:	record	*Data Type:*	n/a

The interpolation time period is used for time synchronized interpolation position modes, that is:

$$time\ period = time\ units \cdot 10^{interpolation\ time\ index}$$

The interpolation time period has to be multiple of 250μs.

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	2
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**1h**	**Interpolation time units**	
Data type:	unsigned8		
Access:	rw	*Write override:*	no
Unit:	n/a	*Default value:*	1
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**2h**	**Interpolation time index**	
Data type:	integer8		
Access:	rw	*Write override:*	no
Unit:	n/a	*Default value:*	-3
PDO mappable:	no	*NV storage:*	yes

For further information look at §3.5.

5.2.45. 60C3h: Interpolation sync definition

Object:	**60C3h**	**Interpolation sync definition**	
Object Code:	array	*Data Type:*	unsigned8

Devices in the interpolation position mode often interact with other devices. Therefore it is necessary to define a communication object, which is used to synchronize these interactions. Synchronize on group could be only 0, this mean that SYNC is used.

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	2
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**1h**	**Synchronize on group**	
Data type:	unsigned8		
Access:	rw	*Write override:*	no
Unit:	n/a	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**2h**	**ip sync every n event**	
Data type:	unsigned8		
Access:	rw	*Write override:*	no
Unit:	n/a	*Default value:*	1
PDO mappable:	no	*NV storage:*	yes

For further information look at §3.5.

5.2.46. 6069h.0h: Velocity sensor actual value

Object:	**6069h.0h**	**Velocity sensor actual value**	
Object Code:	var	*Data Type:*	integer32
Access:	ro	*Write override:*	n/a
Unit:	velocity d.u., see Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

The velocity sensor present value describes the velocity read from the encoder in d.u.

5.2.47. 606Bh.0h: Velocity demand value

Object:	**606Bh.0h**	**Velocity demand value**	
Object Code:	var	*Data Type:*	integer32
Access:	ro	*Write override:*	n/a
Unit:	velocity Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This is the output value of the trajectory generator. For further information look at Appendix A.

5.2.48. 606Ch.0h: Velocity actual value

Object:	**606Ch.0h**	**Velocity actual value**	
Object Code:	var	*Data Type:*	integer32
Access:	ro	*Write override:*	n/a
Unit:	velocity Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This object represents the present value of the velocity measurement device.
For further information look at Appendix A.

5.2.49. 606Dh.0h: Velocity window

Object:	**606Dh.0h**	**Velocity window**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	no
Unit:	velocity Factor group	*Default value:*	1310720 (~7.67 rad/s)
PDO mappable:	yes	*NV storage:*	yes

The velocity window monitors whether the required process velocity has been achieved after an eventual acceleration or deceleration (braking) stage, looking for the actual velocity being between:

$$(\textit{target velocity} - \textit{velocity window}; \textit{target velocity} + \textit{velocity window})$$

For further information look at §3.4.

5.2.50. 606Eh.0h: Velocity window time

Object:	**606Eh.0h**	**Velocity window time**	
Object Code:	var	*Data Type:*	unsigned16
Access:	rw	*Write override:*	no
Unit:	ms	*Default value:*	30
PDO mappable:	yes	*NV storage:*	yes

The corresponding bit 10 target reached is set in the statusword when the difference between the target velocity and the velocity actual value is within the velocity window longer than the velocity window time. For further information look at §3.4.

5.2.51. 606Fh.0h: Velocity threshold

Object:	**606Fh.0h**	**Velocity threshold**	
Object Code:	var	*Data Type:*	integer32
Access:	rw	*Write override:*	no
Unit:	velocity Factor group	*Default value:*	327680 (~1.92 rad/s)
PDO mappable:	yes	*NV storage:*	yes

As soon as the velocity actual value exceeds the velocity threshold longer than the velocity threshold time bit 12 is reset in the statusword. Below this threshold the bit is set and indicates that the axle is stationary. For further information look at §3.4.

5.2.52. 6070h.0h: Velocity threshold time

Object:	**6070h.0h**	**Velocity threshold time**	
Object Code:	var	*Data Type:*	unsigned16
Access:	rw	*Write override:*	no
Unit:	ms	*Default value:*	80
PDO mappable:	yes	*NV storage:*	yes

The velocity threshold time. For further information look at §3.4.

5.2.53. 60FFh.0h: Target velocity

Object:	**60FFh.0h**	**Target velocity**	
Object Code:	var	*Data Type:*	integer32
Access:	rw	*Write override:*	no
Unit:	velocity Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	no

The target velocity is the input for the trajectory generator. For further information look at §3.4.

5.2.54. 60F9h: Velocity control parameter set

Object:	**60F9h**	**Velocity control parameter set**	
Object Code:	array	*Data Type:*	integer16

In order to control the behaviour of the speed control loop, one or more parameters are necessary. This object defines the parameter set for a speed loop of the Tw Motor. The p.u. for each parameter here is expressed assuming the **Output scaling magnitude** equal to 0 and then the final multiplication by 1.

WARNING: the values of this object could be written also during the normal drive working cycle, thus with power enabled and moving shaft. Be careful as modifying the values of this object with power enabled could yield in a loss of axle control.

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	11
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**1h**	**Kp Speed reference**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	$8.55 \cdot 10^6$ [Arms·s/rad]	*Default value:*	24576
PDO mappable:	yes	*NV storage:*	yes

Sub-index:	**2h**	**Kp Position**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	$1.71 \cdot 10^4$ [Arms/rad]	*Default value:*	4096
PDO mappable:	yes	*NV storage:*	yes

Sub-index:	**3h**	**Ki**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	8.19 [1/s]	*Default value:*	32
PDO mappable:	yes	*NV storage:*	yes

Sub-index:	**4h**	**Kp acceleration feedback**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	$1.67 \cdot 10^7$ [Arms·s^2/rad]	*Default value:*	0
PDO mappable:	yes	*NV storage:*	yes

Sub-index:	**5h**	**Kp acceleration reference**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	$1.67 \cdot 10^7$ [Arms·s^2/rad]	*Default value:*	0
PDO mappable:	yes	*NV storage:*	yes

Sub-index:	**6h**	**Output limiter**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	current d.u., see Current loops	*Default value:*	30720 (~5.64Arms)
PDO mappable:	yes	*NV storage:*	yes

Sub-index:	**7h**	**Reserved, do not use**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	n/a	*Default value:*	n/a
PDO mappable:	yes	*NV storage:*	yes

Sub-index:	**8h**	**Reserved, do not use**	
Data type:	integer16		
Access:	rw	*Write override:*	No
Unit:	n/a	*Default value:*	n/a
PDO mappable:	yes	*NV storage:*	Yes

Sub-index:	**9h**	**Output scaling magnitude**	
Data type:	integer16		
Access:	rw	*Write override:*	No
Unit:	n/a	*Default value:*	yes (see Appendix C)
PDO mappable:	yes	*NV storage:*	yes

Sub-index:	**Ah**	**Kp Speed feedback**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	$8.55 \cdot 10^6$ [Arms·s/rad]	*Default value:*	24576
PDO mappable:	yes	*NV storage:*	yes

Sub-index:	**Bh**	**Position error limitation**	
Data type:	integer16		
Access:	rw	*Write override:*	No
Unit:	position d.u., see Factor group	*Default value:*	16384 (~1.571 rad)
PDO mappable:	yes	*NV storage:*	Yes

For a complete schema blocks of the Tw Motor closed loop and the interaction between these parameters refer to Appendix A and to §4.5; for further information about p.u. refer to §3.7 and to Appendix C.

5.2.55. 6079h.0h: DC link circuit voltage

Object:	**6079h.0h**	**DC link circuit voltage**	
Object Code:	var	*Data Type:*	unsigned32
Access:	ro	*Write override:*	n/a
Unit:	mV	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This parameter describes the instantaneous DC link current voltage at the drive controller.
For further information look at §2.8 and the objects 5302h.0h and 5306h.0h.

5.3. Manufacturer specific objects

5.3.1. 5000h.0h: Current quadrature reference

Object:	**5000h.0h**	**Current quadrature reference**	
Object Code:	var	*Data Type:*	integer16
Access:	rw	*Write override:*	no
Unit:	current d.u., see Current loops	*Default value:*	no
PDO mappable:	yes	*NV storage:*	no

This is the quadrature current feed as reference for the quadrature current loop; this value is output from the speed loop. It is also used as torque reference in the Torque mode (§4.3). For further information look at §4.2 and at Appendix A.

5.3.2. 5001h.0h: Current direct reference

Object:	**5001h.0h**	**Current direct reference**	
Object Code:	var	*Data Type:*	integer16
Access:	rw	*Write override:*	no
Unit:	current d.u., see Current loops	*Default value:*	no
PDO mappable:	yes	*NV storage:*	no

This is the direct current feed as reference for the direct current loop; it is normally set to 0.
For further information look at §4.2.

5.3.3. 5003h.0h: Electrical angle feedback

Object:	**5003h.0h**	**Electrical angle feedback**	
Object Code:	var	*Data Type:*	integer16
Access:	ro	*Write override:*	n/a
Unit:	$9.587 \cdot 10^{-5}$ [rad]	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This is the feedback electrical position of the motor.

5.3.4. 5010h.0h: Current quadrature feedback

Object:	**5010h.0h**	**Current quadrature feedback**	
Object Code:	var	*Data Type:*	integer16
Access:	ro	*Write override:*	n/a
Unit:	current d.u., see Current loops	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This is the feedback quadrature current.

5.3.5. 5011h.0h: Current direct feedback

Object:	**5011h.0h**	**Current direct feedback**	
Object Code:	var	*Data Type:*	integer16
Access:	ro	*Write override:*	n/a
Unit:	current d.u., see Current loops	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This is the feedback direct current.

5.3.6. 5012h.0h: Current PID output quadrature

Object:	**5012h.0h**	**Current PID output quadrature**	
Object Code:	var	*Data Type:*	integer16
Access:	ro	*Write override:*	n/a
Unit:	-	*Default value:*	no
PDO mappable:	Yes	*NV storage:*	n/a

This is the output of the quadrature current loop.

5.3.7. 5013h.0h: Current PID output direct

Object:	**5013h.0h**	**Current PID output direct**	
Object Code:	var	*Data Type:*	integer16
Access:	ro	*Write override:*	n/a
Unit:	-	*Default value:*	no
PDO mappable:	Yes	*NV storage:*	n/a

This is the output of the direct current loop.

5.3.8. 5100h.0h: Power section temperature

Object:	**5100h.0h**	**Power section temperature**	
Object Code:	var	*Data Type:*	integer16
Access:	ro	*Write override:*	n/a
Unit:	°C	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

For further information look at §2.8 and object 5303h.0h.

5.3.9. 5101h.0h: Device temperature

Object:	**5101h.0h**	**Device temperature**	
Object Code:	var	*Data Type:*	integer16
Access:	ro	*Write override:*	n/a
Unit:	°C	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

For further information look at §2.8 and object 5304h.0h.

5.3.10. 5102h.0h: Filtered position demand value

Object:	**5102h.0h**	**Filtered position demand value**	
Object Code:	var	*Data Type:*	integer32
Access:	ro	*Write override:*	n/a
Unit:	position Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This object represents the present position demand value output from the 2nd order filter. For further information look at Appendix A and at §4.7.

5.3.11. 5103h.0h: Filtered velocity demand value

Object:	**5103h.0h**	**Filtered velocity demand value**	
Object Code:	var	*Data Type:*	integer32
Access:	ro	*Write override:*	n/a
Unit:	velocity Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This object represents the present velocity demand value output from the 2nd order filter. For further information look at Appendix A and at §4.7.

5.3.12. 5110h.0h: SYNC statistics min time

Object:	**5110h.0h**	**SYNC statistics min time**	
Object Code:	var	*Data Type:*	unsigned16
Access:	ro	*Write override:*	n/a
Unit:	µs	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This is the minimum recognized delta time in the last sampled period.
For further information look at §2.7.

5.3.13. 5111h.0h: SYNC statistics max time

Object:	**5111h.0h**	**SYNC statistics max time**	
Object Code:	var	*Data Type:*	unsigned16
Access:	ro	*Write override:*	n/a
Unit:	µs	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This is the maximum recognized delta time in the last sampled period.
For further information look at §2.7.

5.3.14. 5112h.0h: SYNC statistics average time

Object:	**5112h.0h**	**SYNC statistics average time**	
Object Code:	var	*Data Type:*	unsigned16
Access:	ro	*Write override:*	n/a
Unit:	µs	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This is the average recognized delta time in the last sampled period.
For further information look at §2.7.

5.3.15. 5120h.0h: Following error at maximum speed

Object:	**5120h.0h**	**Following error at maximum speed**	
Object Code:	var	*Data Type:*	integer32
Access:	ro	*Write override:*	n/a
Unit:	position Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

In every task in which the trapezoidal profile parameters are involved (acceleration/deceleration/velocity) this object give a measure of the following error at the beginning of the deceleration ramp.
For further information look at Appendix A and at §4.5.

5.3.16. 5121h.0h: Maximum overshoot from the end of the deceleration ramp

Object:	**5121h.0h**	**Maximum overshoot from the end of the deceleration ramp**	
Object Code:	var	*Data Type:*	integer32
Access:	ro	*Write override:*	n/a
Unit:	position Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

In every task in which the trapezoidal profile parameters are involved (acceleration/deceleration/velocity) this object give a measure of the maximum overshoot (maximum following error) from the time in which the velocity demand is set to zero until the target bit reached is set.
For further information look at Appendix A and at §4.5.

5.3.17. 5122h.0h: Position window entering time

Object:	**5122h.0h**	**Position window entering time**	
Object Code:	var	*Data Type:*	unsigned32
Access:	ro	*Write override:*	n/a
Unit:	µs	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

In every task in which the trapezoidal profile parameters are involved (acceleration/deceleration/velocity) this object measure how much time is spent from the time in which the velocity demand is set to zero until the target bit reached is set.
For further information look at Appendix A and at §4.5.

5.3.18. 5123h.0h: Overshoot at the end of the deceleration ramp

Object:	**5123h.0h**	**Overshoot at the end of the deceleration ramp**	
Object Code:	var	*Data Type:*	integer32
Access:	ro	*Write override:*	n/a
Unit:	position Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

In every task in which the trapezoidal profile parameters are involved (acceleration/deceleration/velocity) this object give a measure of the overshoot (following error) at the time in which the velocity demand is set to zero.
For further information look at Appendix A and at §4.5.

5.3.19. 5124h.0h: Average windings current

Object:	**5124h.0h**	**Average windings current**	
Object Code:	var	*Data Type:*	integer16
Access:	ro	*Write override:*	n/a
Unit:	current d.u., see Current loops	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

This object is the averaged motor windings current with a long time constant, in order to measure the thermal work cycle of the drive. This is closely related to the user application.
For further information look at Appendix A and at §4.5.

5.3.20. 5300h.0h: Auxiliary input option code

Object:	**5300h.0h**	**Auxiliary input option code**	
Object Code:	var	*Data Type:*	integer16
Access:	rw	*Write override:*	operational, power enabled
Unit:	n/a	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

The content of this object selects the function to be performed when the auxiliary external input voltage is lost. The action could be one of the following:

Option code	*Description*
0	No action
2	Issue a device control command **Disable Voltage**
3	Issue a device control command **Quick Stop**

For further information look at §2.8, at §3.2 and at §4.6.

5.3.21. 5301h.0h: Rotation polarity

Object:	**5301h.0h**	**Rotation polarity**	
Object Code:	var	*Data Type:*	integer16
Access:	rw	*Write override:*	power enabled
Unit:	n/a	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

This object could invert the rotation polarity of the Tw Motor; by default (0000h), looking from the motor shaft side and giving incrementing position (or positive velocity) the shaft rotate clockwise. Writing the value –1 (FFFFh) the shaft rotate counter clockwise. This object affects the values read from the position encoder. The sequence on which Home offset (object 607Ch) and Rotation polarity are applied are affected by the object 5380h.0h bit 6.
For further information look at Appendix A and to §4.5.

5.3.22. 5302h.0h: DC link circuit overvoltage threshold

Object:	**5302h.0h**	**DC link circuit overvoltage threshold**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	no
Unit:	mV	*Default value:*	400000 (400V)
PDO mappable:	no	*NV storage:*	yes

The DC link circuit overvoltage threshold could be decreased from the maximum (default) value of 400Vdc; this is the threshold that generates the **DC link overvoltage** fault. For further information look at §2.8 and object 6079h.0h.

5.3.23. 5303h.0h: Power section overtemperature threshold

Object:	**5303h.0h**	**Power section overtemperature threshold**	
Object Code:	var	*Data Type:*	integer16
Access:	rw	*Write override:*	no
Unit:	°C	*Default value:*	100
PDO mappable:	no	*NV storage:*	yes

The Power section overtemperature threshold could be decreased from the maximum (default) value of 100°C; this is the threshold that generates the **Power section overtemperature** fault. For further information look at §2.8 and object 5100h.0h.

5.3.24. 5304h.0h: Device overtemperature threshold

Object:	**5304h.0h**	**Device overtemperature threshold**	
Object Code:	var	*Data Type:*	integer16
Access:	rw	*Write override:*	no
Unit:	°C	*Default value:*	100
PDO mappable:	no	*NV storage:*	yes

The Device overtemperature threshold could be decreased from the maximum (default) value of 100°C; this is the threshold that generates the **Device overtemperature** fault. For further information look at §2.8 and object 5101h.0h.

5.3.25. 5305h.0h: Motor blocked threshold

Object:	**5305h.0h**	**Motor blocked threshold**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	no
Unit:	position Factor group	*Default value:*	131072 (~12.57 rad)
PDO mappable:	no	*NV storage:*	yes

This object establish the maximum acceptable following error in all applications; above this value the drive assume that the motor could be blocked and then a **Motor blocked / following error overlimit** fault is generated. For further information look at §2.8.

5.3.26. 5306h.0h: DC link circuit overvoltage max delta threshold

Object:	**5306h.0h**	**DC link circuit overvoltage max delta threshold**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	no
Unit:	mV	*Default value:*	50000 (50V)
PDO mappable:	no	*NV storage:*	yes

In case of lower DC link capacity and no braking unit, it could happen that the DC link rise so fast that when it cross the overvoltage threshold it stop rising at higher voltage; to prevent damages from this situation, Tw Motor monitor the DC link every 62.5μs; if the difference between two consecutive sample is more than this parameter a **DC-link rising too fast** fault is generated. For further information look at §2.8 and at object 6079h.0h.

5.3.27. 5307h: Position demand filter constants

Object:	**5307h**	**Position demand filter constants**	
Object Code:	array	*Data Type:*	integer16

Those are the constants to build the 2nd order filter to be applied to the position demand value. For this filter the sample time period to be used for the constants calculations is fixed to 250μs.

WARNING: the values of this object could be written also during the normal drive working cycle, thus with power enabled and moving shaft. Be careful as modifying the values of this object with power enabled could yield in a loss of axle control.

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	5
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**1h**	**b_2**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**2h**	**b_1**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**3h**	**a_2**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**4h**	**a_1**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**5h**	**a_0**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	8192
PDO mappable:	no	*NV storage:*	yes

For further information look at Appendix A and at §4.7.

5.3.28. 5308h: Velocity loop output filter constants

Object:	**5308h**	**Velocity loop output filter constants**	
Object Code:	array	*Data Type:*	integer16

Those are the constants to build the 2nd order filter to be applied to the velocity loop output value. For this filter the sample time period to be used for the constants calculations is fixed to 250μs. Default values are hardware configuration dependant (see Appendix C).

WARNING: the values of this object could be written also during the normal drive working cycle, thus with power enabled and moving shaft. Be careful as modifying the values of this object with power enabled could yield in a loss of axle control.

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	5
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**1h**	**b_2**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	yes (see Appendix C)
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**2h**	**b_1**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	yes (see Appendix C)
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**3h**	**a_2**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	yes (see Appendix C)
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**4h**	**a_1**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	yes (see Appendix C)
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**5h**	**a_0**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	yes (see Appendix C)
PDO mappable:	no	*NV storage:*	yes

For further information look at Appendix A and at §4.7.

5.3.29. 5309h: Position set-point filter constants

Object:	**5309h**	**Position set-point filter constants**	
Object Code:	array	*Data Type:*	integer16

Those are the constants to build the 2nd order filter to be applied to the position demand value. For this filter the sample time period to be used for the constants calculations is the same as the interpolation time period (object 60C2h).

WARNING: the values of this object could be written also during the normal drive working cycle, thus with power enabled and moving shaft. Be careful as modifying the values of this object with power enabled could yield in a loss of axle control.

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	5
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**1h**	**b_2**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**2h**	**b_1**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**3h**	**a_2**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**4h**	**a_1**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

Sub-index:	**5h**	**a_0**	
Data type:	integer16		
Access:	rw	*Write override:*	no
Unit:	1/8192	*Default value:*	8192
PDO mappable:	no	*NV storage:*	yes

For further information look at §3.5 and at §4.7.

5.3.30. 530Ah.0h: Aux input triggered PDO number

Object:	**530Ah.0h**	**Aux input triggered PDO number**	
Object Code:	var	*Data Type:*	unsigned16
Access:	rw	*Write override:*	operational
Unit:	n/a	*Default value:*	0
PDO mappable:	no	*NV storage:*	yes

This parameter defines which TPDO is to be used as aux input triggered; the possible values range from 1 to 8; 0 disable this function.
For further information look at §2.6 and at §4.6.

5.3.31. 530Bh.0h: SYNC statistics update time

Object:	**530Bh.0h**	**SYNC statistics update time**	
Object Code:	var	*Data Type:*	unsigned16
Access:	rw	*Write override:*	no
Unit:	ms	*Default value:*	2000
PDO mappable:	yes	*NV storage:*	yes

The sample period time the SYNC statistics variables are updated.
For further information look at §2.7.

5.3.32. 5311h.0h: Hardware configuration

Object:	**5311h.0h**	**Hardware configuration**	
Object Code:	var	*Data Type:*	unsigned32
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	no
PDO mappable:	yes	*NV storage:*	n/a

The hardware configuration of the Tw drives that affect the software interface is shown in this object, where every bit refer to a specific equipment:

Bit	*Equipment*
4	absolute multi turn encoder (**N** suffix)
5	absolute single turn encoder (**M** suffix)
7	two-poles resolver (**R** suffix)

Bits not shown here are all reserved for future enhancements, they have to be ignored.
For further information look at §4.1.

5.3.33. 5312h.0h: User configuration version

Object:	**5312h.0h**	**User configuration version**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	no
Unit:	no	*Default value:*	0
PDO mappable:	yes	*NV storage:*	yes

This parameter could be used to store and retrieve any information the user needs for it's own application, for example to store the configuration version number to be checked at every power-up. For further information look at the objects 1010h and 1011h.

5.3.34. 5320h: Table positions array

Object:	**5320h**	**Table positions array**	
Object Code:	array	*Data Type:*	integer32

This array contain all the positions for the rotary table control, those are always expressed as d.u. Due to internal drive management, this array is stored in NV memory at same time as downloading.
Follow these points to download the array:

- first object to be downloaded is in the sub-index 1, this also prepare the NV storage
- download all the positions with incrementing sub-index
- the last valid position has to be followed by a position equal to –1, this close the NV storage and determines the number of entries (that could be read from sub-index 0)
- all following download (for every sub-index but 1) are ignored and do not return any error

Sub-index:	**0h**	**Number of entries**	
Data type:	unsigned8		
Access:	ro	*Write override:*	n/a
Unit:	n/a	*Default value:*	0
PDO mappable:	no	*NV storage:*	n/a

Sub-index:	**01h - 7Eh**	**Position setting**	
Data type:	integer32		
Access:	rw	*Write override:*	operational, power enabled
Unit:	position d.u., see Factor group	*Default value:*	-1
PDO mappable:	no	*NV storage:*	done automatically during download

For further information look at §4.4.

5.3.35. 5321h.0h: Table dimension / Rotary axis dimension

Object:	**5321h.0h**	**Table dimension / Rotary axis dimension**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	no
Unit:	position d.u., see Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	yes

This object contain the dimension of the generic rotary axis used to wrap the position objects; this is the same also for the rotary table control dimension. The wrapping keep position objects between *0* and <*table dimension*>*-1*.

WARNING: the values of this object could be written also during the normal drive working cycle, thus with power enabled and moving shaft. Wait until the **Rotary axis enabled** bit in the statusword (object 6041h.0h) is set before using position objects, as the drive could need some time to update his internal status.

For further information look at §4.4 and to §4.1.

5.3.36. 5322h.0h: Gear play compensation

Object:	**5322h.0h**	**Gear play compensation**	
Object Code:	var	*Data Type:*	unsigned32
Access:	rw	*Write override:*	no
Unit:	position d.u., see Factor group	*Default value:*	no
PDO mappable:	yes	*NV storage:*	yes

This object define how much over-travel has to be done to compensate the gearbox play when the Rotary table control mode is enabled. The compensation is done only when the direction of rotation is counterclockwise by subtracting from the target position the gear play compensation value.

For further information look at §4.4.

5.3.37. 5323h.0h: Rotary table target index

Object:	**5323h.0h**	**Rotary table target index**	
Object Code:	var	*Data Type:*	integer16
Access:	rw	*Write override:*	no
Unit:	n/a	*Default value:*	no
PDO mappable:	yes	*NV storage:*	no

The target index for the Rotary table control. It have to be between 1 and the number of positions in the Table positions array (object 5320h), with positive or negative sign. It could be the absolute index on the rotary table that will be translated in a target position or a relative index that will be added to the current target index and wrapped to the number of positions of the Table positions array.

For further information look at §4.4.

5.3.38. 5330h.0h: Application Zero Position

Object:	**5330h.0h**	**Application Zero Position**	
Object Code:	var	*Data Type:*	integer32
Access:	rw	*Write override:*	no
Unit:	position Factor group	*Default value:*	0
PDO mappable:	yes	*NV storage:*	yes

This value is used during homing procedure to preset the position actual value to a value other than zero when home position is found.

For further information look at §3.6.

5.3.39. 5380h.0h: Global option flags

Object:	**5380h.0h**	**Global option flags**	
Object Code:	var	*Data Type:*	unsigned16
Access:	rw	*Write override:*	no
Unit:	n/a	*Default value:*	0000 0000 0000 0100b (0004h)
PDO mappable:	yes	*NV storage:*	yes

This object enable (set to 1) / disable (set to 0) several operating modes of the Tw Motor; every bit is related to a specific option flag, as described in the following table.

WARNING: the values of this object could be written also during the normal drive working cycle, thus with power enabled and moving shaft. Be careful as modifying the values of this object with power enabled could yield in a loss of axle control.

Bit	*Name*	*Description*
0	Enable max position error	Limits the position error employed in the speed loop to a specified value, refer to Appendix A and to §4.5
1	Enable different Kp speed	Use different coefficient for Kp speed reference and Kp speed feedback, refer to Appendix A and to §4.5
2	Enable internal synchronization	Enable the internal machine cycle synchronization with the SYNC object (and SYNC controller EMCY generation), refer to §2.7
3	Enable field weakening	Decrease the loss of torque at higher speed
5	Negative pulse aux input triggered PDO	Trigger the aux input triggered PDO with low→high transition (rising) if disabled or with high→low transition (falling) if enabled, refer to §4.6
6	Swap Home Offset/Rotation Polarity	Swap the sequence on which Home Offset and Rotation Polarity are applied, refer to Appendix A and to §4.5
7	Disable software position limits	If enabled the verification against the software position limits is deactivated, refer to object 607Dh
8	Enable rotary axis	If enabled, the position objects are wrapped between 0 and the rotary axis dimension object 5321h. **WARNING**: the modification of this bit will have effect on the drive only after a node reset or power off – power on cycle. Refer to §4.1
9	Enable signed position	Let the user to get all position objects from the drive as signed integer, useful only with absolute multi-turn encoder. This setting affects only those object that has the unit as **position Factor Group**. Refer to §4.1

Bits not shown here are all reserved for future enhancements; keep it to zero.

5.3.40. 5EF0h.0h: Firmware download activation flag

Object:	**5EF0h.0h**	**Firmware download activation flag**	
Object Code:	var	*Data Type:*	unsigned32
Access:	wo	*Write override:*	operational,power enabled
Unit:	n/a	*Default value:*	no
PDO mappable:	no	*NV storage:*	no

This object enable the firmware download on the Tw Motor. Look at §4.9 for the complete procedure.

5.3.41. 1F50h.1h: Firmware download storage

Object:	**1F50h.1h**	**Firmware download storage**	
Object Code:	var	*Data Type:*	visible_string
Access:	wo	*Write override:*	see text below
Unit:	n/a	*Default value:*	no
PDO mappable:	no	*NV storage:*	n/a

This is the object on which the complete firmware has to be downloaded. This object is invisible until firmware download is activated. Look at §4.9 for the complete procedure.

6. Beginner's Tips

This section would give to the reader some useful tips and practical examples on the programming basic steps from a factory default configuration to the user application. It would be a practical introduction to the CiA standards and Tw Motor, view from the CAN bus interface level.
User should send the below described COBs on the network via any CAN diagnostic tools, such as the Phase Motion Control's CANdiagno (and CanPC-S1 interface, refer to / 5).

6.1. Basic communication settings

In order to create a network of CANopen devices, user has to choose first the CAN baud rate (one chosen from Table 3) that defines the communication speed and then the performance of the network. Faster speed means higher data rate throughput (quantity of data carried per time period) but also shorter overall bus length and less reliability in a high-noise environment. The recommendations for the overall bus length are approximately 30m at 1000kbps, 100m at 500kbps, 250m at 250kbps and 500m at 125kbps (for more information refer to / 4).
In a CANopen network each device must belongs to an unique node-ID, in order to uniquely access to any node on the network: then user has to assign node-ID to each device that will be connected on the network.

Those settings have to be done physically connecting one device to the CAN master per time, in order to keep coherency on the CAN bus (if two devices has different baud rate, all the network will be unusable, if two devices has the same node-ID it is not possible to distinguish between two). Then, via LSS (§2.4), user stores the chosen baud rate and node-ID on each node.

As example, this is the sequence of LSS commands to send on the network to set-up a node for 500kbps and node-ID 14 (0Eh):

Switch to configuration mode:

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E5h	04h	01h	reserved					

Set node-ID:

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E5h	11h	0Eh node-ID	reserved					

Set baud rate:

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E5h	13h	00h	02h baud rate	reserved				

Store configuration:

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E5h	17h	reserved						

Switch to normal operation mode:

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
7E5h	04h	00h	reserved					

This sequence should be repeated for all other devices. Subsequently, user can connect all devices together on the network.

For further details please look at §2.4 and at / 6.

6.2. Configuring an application

We will show two sample applications, the first is a positioner with the necessity of changing the profile velocity dynamically between two consecutive positioning and following error monitoring; the second is a speed-controlled motor with dynamic torque limitation. For both applications we will configure particular PDO (§2.6) mapping, specifically optimized for the function we need, and some parameters. Finally, we suppose to deal with the node configured in the previous chapter, the node-ID 14.
To make all needed configuration we have to access to the object dictionary using SDO (§2.5). From here the notation **xxxxh → yyyyh.zzh** means **download the value xxxxh in the object yyyyh.zzh**.

For the first application we have to deal with five parameters: controlword (object 6040h.0h), target position (object 607Ah.0h), profile velocity (object 6081h.0h), statusword (object 6041h.0h) and following error actual value (object 60F4h.0h). The first three are parameters that the master has to send to the Tw Motor for proper operation, the last two are monitoring parameters for the master. As this is not a time-critical application, there is no need to use a synchronized PDO communication, so all RPDOs and TPDOs will be asynchronous on event; in order to avoid bus congestion, we will specify also the inhibit time for the TPDOs.

Here the mappings of all PDOs necessary for this application:

RPDO #1:

COB-ID	B0	B1
20Eh	6040h.0h	

RPDO #2:

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
30Eh	607Ah.0h				6081h.0h			

TPDO #1:

COB-ID	B0	B1	B2	B3	B4	B5
18Eh	6041h.0h		60F4h.0h			

For the RPDO #1 we can keep the factory setting, it contains just the controlword and has the right transmission type.

For the RPDO #2 configuration first we have to disable it:
C000 030Eh → 1401h.1h
Then we set the asynchronous transmission type (255):
FFh → 1401h.2h
Now we have to change the mapping:
607A 0020h → 1601h.1h
6081 0020h → 1601h.2h
and then write the number of parameters mapped in the PDO:
02h → 1601h.0h
Finally we re-enable the RPDO:
4000 030Eh → 1401h.1h
We can leave the RPDO #3 and #4 enabled or disabled, as we will never use them.

As before this is the sequence for TPDO #1:
C000 018Eh → 1800h.1h
FFh → 1800h.2h
Here we have to specify also the inhibit time: we suppose that we do not want more than 10 feedback PDO per second, then inhibit time will be 100ms, that is 1000 x 100μs:
03E8h → 1800h.3h
6041 0010h → 1A00h.1h
60F4 0020h → 1A00h.2h
02h → 1A00h.0h
4000 018Eh → 1800h.1h
Finally we will disable TPDO #2, #3 and #4 that by default are enabled:
C000 028Eh → 1801h.1h
C000 038Eh → 1802h.1h
C000 048Eh → 1803h.1h

We have still to choose our default application at start-up that is the Profile Position Mode (§3.3):
01h → 6060h.0h

and we need faster acceleration and deceleration ramps (~200 rad/s^2) than the factory preset values:
0000 2160h → 6083h.0h
0000 2160h → 6084h.0h

Although it is not necessary, we want to permanently store all configurations in non-volatile flash memory:
6576 6173h → 1010h.1h

For the second application we have to deal with four parameters: controlword (object 6040h.0h), target velocity (object 60FFh.0h), speed loop output limiter (object 60F9h.6h) and statusword (object 6041h.0h). The first three are parameters that the master has to send to the Tw Motor for proper operation, the last is monitoring parameter for the master. As previous application this is not a time-critical, then the behaviour of PDOs will be the same.

Here the mappings of all PDOs necessary for this application:

RPDO #1:

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
20Eh	6040h.0h		60FFh.0h				60F9h.6h	

TPDO #1:

COB-ID	B0	B1
18Eh	6041h.0h	

For the RPDO #1 configuration do the following:
C000 020Eh → 1400h.1h
FFh → 1400h.2h
6040 0010h → 1600h.1h

60FF 0020h → 1600h.2h
60F9 0610h → 1600h.3h
03h → 1600h.0h
4000 020Eh → 1400h.1h

For the TPDO #1 configuration do the following:
C000 018Eh → 1800h.1h
03E8h → 1800h.3h
The type of transmission and mapping is not necessary here because of the factory default.
4000 018Eh → 1800h.1h
Finally we will disable TPDO #2, #3 and #4 that by default are enabled:
C000 028Eh → 1801h.1h
C000 038Eh → 1802h.1h
C000 048Eh → 1803h.1h

We have still to choose our default application at start-up that is the Profile Velocity Mode (§3.4):
03h → 6060h.0h

and we have to select the **Enable max position error** bit in the global option flags object, in order to let the shaft stop (if higher braking torque than limit torque is applied) and restart without saturating the Speed control loop:
0005h → 5380h.0h

At last, the store command:
6576 6173h → 1010h.1h

6.3. Running an application

The default state of the NMT (§2.9) at start-up is the pre-operational state; to let PDO communication, the node must be switched in the operational state; we suppose to switch all nodes in the network, then the following command has to be issued:

COB-ID	B0	B1
000h	01h	00h

Now, suppose we have configured the Tw Motor with the first example of the previous chapter: we send the following two commands to switch the device control state machine (see Figure 3) from switch on disabled to operation enabled:

COB-ID	B0	B1
20Eh	0006h	

COB-ID	B0	B1
20Eh	000Fh	

At this point the Tw Motor output shaft is powered and the speed loop keep it steady.
We want to make an absolute positioning of 100 turn and 45 degrees with a speed of 2000rpm; first, we calculate the position and the velocity in d.u. (§3.7), that are 0064 2000h and 0222 2222h respectively; then we send those two parameters:

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
30Eh	0064 2000h				0222 2222h			

Finally, the new set point bit (see Table 13) have to be enabled, in order to let positioning start:

COB-ID	B0	B1
20Eh	001Fh	

At this point motor begin positioning, then the new set point bit could be disabled, in order to let another positioning to be executed:

COB-ID	B0	B1
20Eh	000Fh	

The user could see how statusword and following error actual value changes before and during positioning looking at the TPDO #1 (COB-ID 18Eh).

Now we run the second example of the previous chapter: we send the following two commands to switch the device control state machine (see Figure 3) from switch on disabled to operation enabled, setup zero speed and zero torque:

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
20Eh	0006h		0000 0000h				0000h	

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
20Eh	000Fh		0000 0000h				0000h	

At this point the Tw Motor output shaft is powered, but the speed loop cannot keep it steady because we also wrote zero maximum torque.
We want to run the motor at 1500rpm with maximum current of 3Arms: first, we calculate the velocity and the current in d.u. (§3.7 and §4.2), that are 0199 9999h and 3FC9h respectively; then we send those two parameters, together with the same controlword as before:

COB-ID	B0	B1	B2	B3	B4	B5	B6	B7
20Eh	000Fh		0199 9999h				3FC9h	

At this point motor spin up to desired velocity. Note that with the Profile Velocity Mode (§3.4) there is no set point to enable but the target velocity is taken immediately.

As before, the user could see how statusword changes looking at the TPDO #1 (COB-ID 18Eh).

6.4. Factor group setting

The factor group is useful when user need to send reference values (position, speed and acceleration) expressed in multiple of p.u. For example, suppose we have the Tw Motor output shaft connected to a belt, with ratio of 9.6 revolutions (~60.31858 rad) per one meter of belt's linear movement. Now we want to express all reference values in mm, cm/s and m/s^2.

First, we have to calculate the ratio between belt feeding and motor output shaft, using the relations shown in the §3.7, supposing the gear ratio equal to 1:

$$feed\ constant = 2\pi \cdot gear\ ratio \cdot \frac{\theta[p.u.]}{\theta[rad]} = 2\pi \cdot 1 \cdot \frac{1000mm}{60.31858rad} = 104.16421$$

In order to reduce the overall approximation ratio we express the resulting number as ratio of two large 32 bit numbers:

$$feed\ constant = 104.16421 \cong \frac{7FFF\ FFBDh}{013A\ 9487h}$$

Now we can download to the proper objects:
feed constant:

7FFF FFBDh → 6092h.1h
013A 9487h → 6092h.2h
gear ratio is 1 by factory default;
position dimension index, meters:
01h → 608Ah.0h
Position notation index, milli (10^{-3}):
FDh → 6089h.0h
Velocity dimension index, m/s:
A6h → 608Ch.0h
Velocity notation index, centi (10^{-2}):
FEh → 608Bh.0h
Acceleration dimension index, m/s^2:
A6h → 608Eh.0h
Acceleration notation index:
00h → 608Dh.0h

Do not forget to store the settings with the command:
6576 6173h → 1010h.1h

For further information refer to §3.7.

A. Speed control loop schema

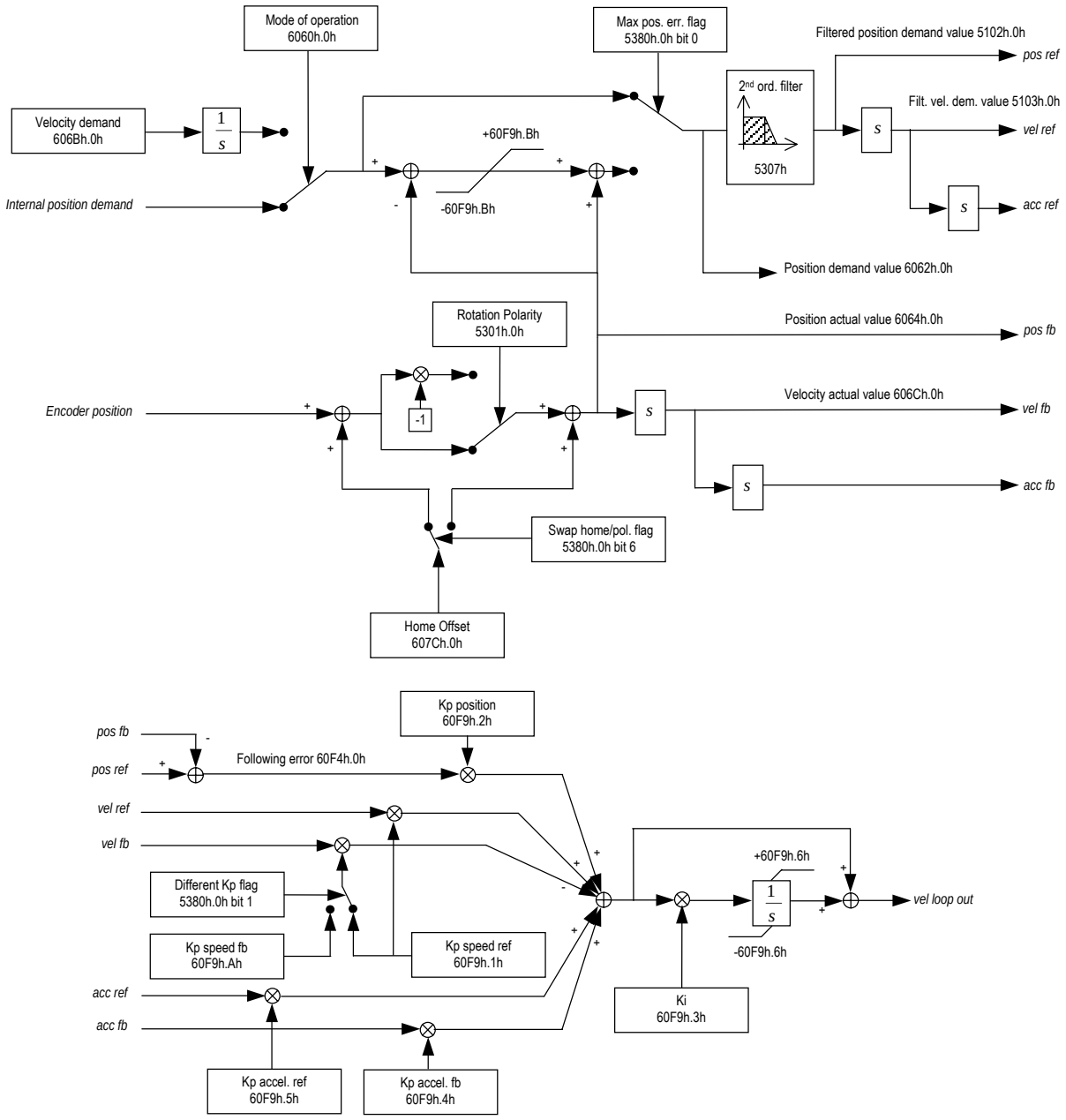


Figure 21: Speed loop main schema

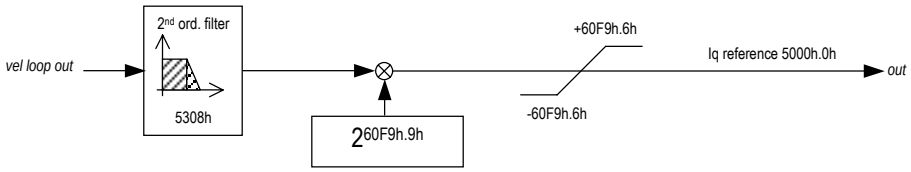


Figure 22: Speed loop output schema

For further information refer to §4.5.

B. Tw Motor default PDO parameters

Those are the default PDO communication and mapping parameters for the Tw Motor:

PDO	RPDO #1
COB-ID	4000 0200h+node-ID (enabled)
Type	255 (asynchronous)

COB-ID	B0	B1
200h+node-ID	Controlword 6040h.0h	

PDO	RPDO #2
COB-ID	4000 0300h+node-ID (enabled)
Type	255 (asynchronous)

COB-ID	B0	B1	B2
300h+node-ID	Controlword 6040h.0h		Mode of operation 6060h.0h

PDO	RPDO #3
COB-ID	4000 0400h+node-ID (enabled)
Type	255 (asynchronous)

COB-ID	B0	B1	B2	B3	B4	B5
400h+node-ID	Controlword 6040h.0h		Target position 607Ah.0h			

PDO	RPDO #4
COB-ID	4000 0500h+node-ID (enabled)
Type	255 (asynchronous)

COB-ID	B0	B1	B2	B3	B4	B5
500h+node-ID	Controlword 6040h.0h		Target velocity 60FFh.0h			

PDO	RPDO #5
COB-ID	C000 0000h (disabled)
Type	255 (asynchronous)

PDO	RPDO #6
COB-ID	C000 0000h (disabled)
Type	255 (asynchronous)

PDO	RPDO #7
COB-ID	C000 0000h (disabled)
Type	255 (asynchronous)

PDO	RPDO #8
COB-ID	C000 0000h (disabled)
Type	255 (asynchronous)

RPDO from #5 to #8 have no default mapping parameters.

PDO	TPDO #1	
COB-ID	4000 0180h+node-ID (enabled)	
Type	255 (asynchronous)	
Inhibit Time	0	
COB-ID	B0	B1
180h+node-ID	Statusword 6041h.0h	

PDO	TPDO #2		
COB-ID	4000 0280h+node-ID (enabled)		
Type	0 (synchronous acyclic)		
Inhibit Time	0		
COB-ID	B0	B1	B2
280h+node-ID	Statusword 6041h.0h		Mode of op.display 6061h.0h

PDO	TPDO #3					
COB-ID	4000 0380h+node-ID (enabled)					
Type	0 (synchronous acyclic)					
Inhibit Time	0					
COB-ID	B0	B1	B2	B3	B4	B5
380h+node-ID	Statusword 6041h.0h		Position actual value 6064h.0h			

PDO	TPDO #4					
COB-ID	4000 0480h+node-ID (enabled)					
Type	0 (synchronous acyclic)					
Inhibit Time	0					
COB-ID	B0	B1	B2	B3	B4	B5
480h+node-ID	Statusword 6041h.0h		Velocity actual value 606Ch.0h			

PDO	TPDO #5
COB-ID	C000 0000h (disabled)
Type	255 (asynchronous)
Inhibit Time	0

PDO	TPDO #6
COB-ID	C000 0000h (disabled)
Type	255 (asynchronous)
Inhibit Time	0

PDO	TPDO #7
COB-ID	C000 0000h (disabled)
Type	255 (asynchronous)
Inhibit Time	0

PDO	TPDO #8
COB-ID	C000 0000h (disabled)
Type	255 (asynchronous)
Inhibit Time	0

TPDO from #5 to #8 have no default mapping parameters.

C. Tw Motor default control parameters

Those are the factory default values for some objects hardware configuration dependant (object 5311h.0h).

Object	*Absolute Encoder (**N** and **M**)*	*Two-poles Resolver (**R**)*
60F9h.9h: Velocity control – Output Scaling Magnitude	4 ($\times 2^4$)	3 ($\times 2^3$)
5308h: Velocity loop output filter constants	None Costants: 0,0,0,0,8192	LPF, $\omega_0 = 630$ rad/s, $\xi = 0.707$ Constants: -6564,14575,45,91,45

Table 36: Default control parameters

D. Physical units vs. internal device units conversion

Current: $I[d.u.] =\sim 5.443 \cdot 10^{3} \cdot I[Arms]$ $I[Arms] =\sim 1.837 \cdot 10^{-4} \cdot I[d.u.]$

Position: $\theta[d.u.] =\sim 1.043 \cdot 10^{4} \cdot \theta[rad]$ $\theta[rad] =\sim 9.587 \cdot 10^{-5} \cdot \theta[d.u.]$

Velocity: $\omega[d.u.] =\sim 1.709 \cdot 10^{5} \cdot \omega[{}^{rad}/_{s}]$ $\omega[{}^{rad}/_{s}] =\sim 5.852 \cdot 10^{-6} \cdot \omega[d.u.]$

Acceleration: $\dot{\omega}[d.u.] =\sim 4.272 \cdot 10^{1} \cdot \dot{\omega}[{}^{rad}/_{s^2}]$ $\dot{\omega}[{}^{rad}/_{s^2}] =\sim 2.341 \cdot 10^{-2} \cdot \dot{\omega}[d.u.]$

E. Sorted index of the Object Dictionary