OPEN DRIVE

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Application n°007
CAN BUS Interpolated position

INDEX

With this application, OPEN DRIVE can follow a space reference sent via can bus in real time.
The space's data are expressed in 32 bit with the16 more significant bit representing the number of revolutions and the 16 less significant bit representing the position related on the current revolution.
The velocity references are expressed in 32 bit with the same normalization of space data, intended per second, so 65536 meaning one revolution per second.
The synchronisation is created by using the CAN Open DS301object **"Synchronisation Object (SYNC)"**; this must be periodically generated by the axle control board with a time-period, programmable in the object 1006h **"Communication cycle period"** of the drive's Communication Profile. The drive performs a linear or cubic interpolation (selectable with C93) between the received reference's positions, and it calculates feed-forward velocity reference.
A homing function based on DS402 mode 8 and 12 or sensitive to the rising edge of a logic input (**I29**), has been implemented, with the consequent sending of TPDO3 if this is configured with transmission type = 255 (manufacturer specific).
A position capture sensitive to the rising edge of a logic input (**I33** thet has to be selected on **L.I.8**) has been implemented, with the consequent sending of TPDO4 if this is configured with transmission type = 255 (manufacturer specific).
It's also managed Extra stroke (**I31** and **I32**).

1. Application configuration

1.1. Application specific parameters

PAR	DESCRIPTION	RANGE	Default
P38	Position's regulator proportional gain	0.0÷50.0	0.0
P180	Accepted tracking max error (less significant word)	0÷65536	1000
P181	Accepted tracking max error (more significant word)	0÷16383	1
P182	Minimum accepted error on SYNC period measured (25ns unit)	1÷16383	400
P183	Maximum accepted error on SYNC period measured in microseconds	0÷19000	250
P184	Start-up time (cubic compensation) in milliseconds	0÷30000	0

1.2. Application's specific connections

CON	DESCRIPTION	RANGE	Default	Default meaning
C90	Enable position control via CAN 0:not enable 1: totally enable 2:only velocity reference	0-2	0	Not enable
C91	Active edge zero TOP 0: rising L → H 1: falling H → L	0,1	0	L→H
C92	Enable Extra-stroke managing 0:not enable 1: alarm on rising edge L → H 2:alarm on falling edge H → L	0-2	0	Not enable
C93	Interpolation mode selection 0:Linear interpolation 1: Cubic interpolation 2: Cubic interpolation with torque feedforward	0-2	0	Linear
C94	Control mode selection 0:classic 1: Control word DS402	0,1	0	classic
C95	Homing mode selection 0:not enable 1: Zero on I29 2: Homing DS402	0-2	0	Not enable

1.3. Input logic function used by the application

FUNCTION	
I29	Zero TOP
I30	Enable position control via CAN
I31	Positive Limit Switch
I32	Negative Limit Switch
I33	Position capture input

1.4. Analog output and application specific monitor

OUT	ASSIGNED INTERNAL VARIABLE	Normalization unit	Internal repr.
O41	Feed-forward Velocity reference	% n_{MAX}	16383
O45	Absolute position's regulator output	Electric pulses per PWM period	1
O51	Internal position reference (less significant word)	32767 = 180°	1
O52	SYNC measure delay – internal use	25ns	1
O53	PWM period counter between various SYNC	1	1
O54	Actual position (less significant word)	32767 = 180°	1
O56	Position reference received (less significant word)	32767 = 180°	1
O58	Final SYNC delay compensation – used	25ns	1
O59	SYNC period measured (less significant word)	25ns	1
O60	Absolute position error (less significant word)	32767 = 180°	1
O62	SYNC period corrected (less significant word)	25ns	1
O63	SYNC period error	25ns	1

1.5. Application Internal data

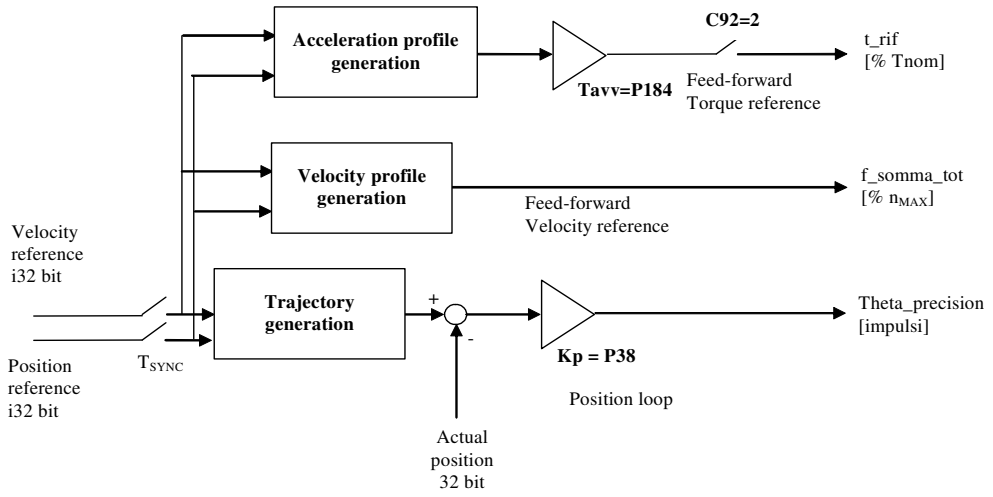
INT	ASSIGNED INTERNAL VARIABLE	Normalization unit
d50	Alarm sub-code	1
d51	Medium error between SYNC master and internal period	nanoseconds

1.6. Application alarms

ALARM	d50	Description
A12	1	Tracking error too big (greater than threshold P180 and P181)
A12	2	Life guarding Error
A12	3	SYNC Period too much different from theoretical value (error > P183)
A12	4	Extra stroke alarm

2. Block– diagram application

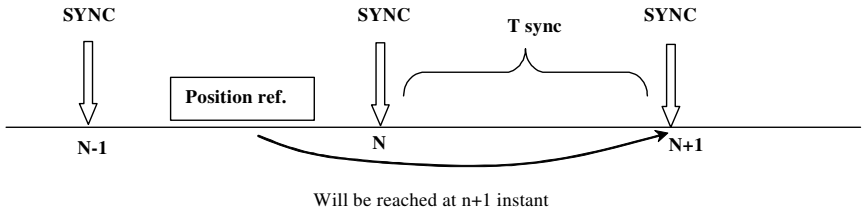
The position control via CAN bus has to be enabled or by putting the connection **C90=1** or by bringing to high level the logic input function **I.30=H** after having rightly configured it on one of the logic inputs of the terminal block.
The position control, when active, generates both of the velocity's references to the core, as it is possible to see in the following scheme:



To have a good dynamic response, Kp=P31, Ta=P32 and Tf=P33 speed-regulator' gains and Kp=P38 regulator-position's proportional gain, must be adjusted.
All these gains are expressed in engineering units. About the Kp proportional gain's normalization of the position regulator, it's valid the following theory:
" Setting Kp=1 the velocity request equals the maximum (P65) when the position error equals the space covered in one second at the maximum velocity".

2.1. Linear Interpolation

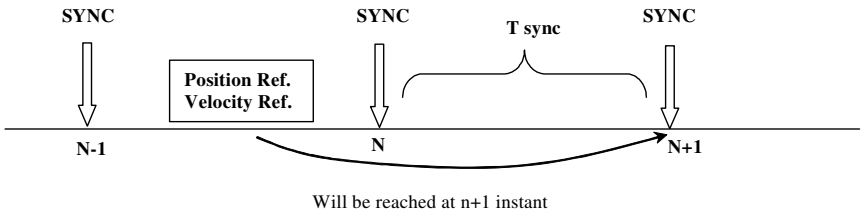
It's possible to choose linear interpolation clearing **C93=0.**
In this operating mode the converter wants to receive the new Position reference (32bit) every SYNC period set in the object 1006h **"Communication cycle period"** of the drive's Communication Profile
The n instant position reference will be reached at (n+1) instant, after one SYNC period.



The drive performs a linear interpolation between the received reference's positions, and it calculates feed-forward velocity reference, that in this way will be constant in the period.

2.2. Cubic interpolation

It's possible to choose cubic interpolation setting **C93=1 or 2.**
In this operating mode the converter wants to receive the new Position reference (32bit) and new Velocity reference every SYNC period set in the object 1006h **"Communication cycle period"** of the drive's Communication Profile
The n instant position reference will be reached at (n+1) instant, after one SYNC period.



The drive performs a cubic interpolation between the received reference's positions, and it calculates feed-forward velocity reference, that in this way will be quadratic.
Setting **C93=2** also the torque profile will be calculated: in this case it's necessary to set in **P184** parameter the total start-up time, for quantify total inertia.
" The start-up time is defined like the time necessary for the motor with full load to reach the maximum speed (P65) delivering nominal torque".

2.3. How to disable the position regulator

It is possible to disable the position regulator by setting **C90=2** working only with the feed forward speed reference. In this condition the control's functions about the tracking error are disabled.

2.4. Tracking-error alarm

Using **P180** (less significant word) and **P181** (more significant word) parameters, it's possible to set the maximum error accepted, (positive and negative) in the track of the position's reference. If the error exceeds this limit, the drive sets the **A12** alarm with **d50=1** code. The tracking error control is managed only if the position control via CAN (C90=1 or I30=H) is enabled.

2.5. References re-aligned

At converter start-up, after a few seconds reset period, the Position Reference is automatically set to Actual position, to avoid Tracking error alarm A12 with d50=1. The velocity reference is clear to 0. The reference re-align is executed also if the CAN node isn't in OPERATIONAL mode.

2.6. Extra stoke and A12 alarm

It's possible to enable this function setting connection **C92**:

C92=1 enable rising edge L → H of I31 and I32
C92=2 enable falling edge H → L of I31 and I32

Only if the converter is running with positive velocity reference the Positive Limit Switch **I31** is tested, on the active edge (with hardware filter of 2.2ms) the motor is stopped and alarm **A12** with **d50=4** is activated.
Vice versa, only if the converter is running with negative velocity reference the Negative Limit Switch **I32** is tested.
If the converter is in stop mode or it's running with velocity reference equals to zero, the extra stroke function is automatically disabled.

When an A12 alarm with d50 ≠ 0 is activated, the motor is immediately stopped with the linear ramps (P20-P23) and than the power is switched-off.

3. CAN BUS Can Open DS301 protocol management

See the specific documentation for CAN open DS301 about OPEN drive for the explanation of the implemented standard functions.
In particular we remind that the setting of the object 1006h "**communication cycle period** " of the communication profile is essential for the correct working of the position control.
Some peculiarities of this application are better explained hereinafter.

3.1. Dizionario degli oggetti : manufacturer specific profile area

Index (hex)	Object	Name	Description	Access
201E	ARRAY - INT16	**Application_data_Tab**	Variables related to position control	Reading/writing
2027	INTEGER32	**Actual position**	Actual position	Reading
2028	INTEGER32	**Captured position**	Captured position	Reading

The ARRAY is used for detailing the data exchange in the specific applications.
In this case the following Sub-Index are managed :

Index (hex)	Sub-Index	Name	Description	Access
201E	0	**New_ref_pos_lsw**	Position reference, less significant word	Reading/writing
201E	1	**New_ref_pos_msw**	Position reference, more significant word	Reading/writing
201E	2	**position_actual_lsw**	Actual position, less significant word	Reading
201E	3	**Position_actual_msw**	Actual position, more significant word	Reading
201E	4			
201E	5	**Status_word**	Status word	Reading
201E	6	**Zero_pos_lsw**	Zero TOP position, less significant word	Reading
201E	7	**Zero_pos_msw**	Zero TOP position, more significant word	Reading
201E	8	**New_rif_vel_lsw**	Velocity reference, less significant word	Reading/writing
201E	9	**New_rif_vel_msw**	Velocity reference, more significant word	Reading/writing

New_ref_pos (sub-index 0 and 1) = in this 32bit-object the position reference must be written

Actual position (su-index 2 and 3) = in this 32bit-object the actual position can be read

Status word (sub-index 5) = following the DS402 motion profile (see par4.2)

Zero_pos (sub-index 6 and 7) = in this 32bit-object it is available the position read on the zero TOP front.

New_rif_vel (Sub-Index 8 e 9) = in this 32bit-object the velocity reference must be written in pulses per second.

3.2. Manufacturer Specific (255)" transmission type of the third TPDO

On the third TPDO (communication parameter 1802h; mapping parameter 1A02h) , "Manufacturer specific (255) " transmission type is implemented to send TPDO3 just on the active rising edge of zero TOP.

3.3. Manufacturer Specific (255)" transmission type of the fourth TPDO

On the fourth TPDO (communication parameter 1803h; mapping parameter 1A03h) , "Manufacturer specific (255) " transmission type is implemented to send TPDO4 just on the active edge of I33 Postion Capture input (that has to be assigned to L.I.8)..

3.4. Emergency Object (EMCY)

The emergency object is transmitted by the drive when a new enabled alarm comes trough or when one or more alarms are reset. The Emergency telegram is made by 8 byte as shown in the following table:

Byte	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Meaning	Emergency Error Code		Error register	Manufacturer specific				
				Allarmi LSB –MSB		**Code**	00	00

In our implementation only two codes of the error code are implemented :

00xx = Error Reset or No Error
10xx = Generic Error

Speaking of the **Error register** (object 1001h), the following bits are managed corresponding to the following alarms:

Bit	Meaning	Corresponding alarms
0	General error	all
1	Current	A3
2	Voltage	A10 - A11 -A13
3	temperature	A4 - A5 - A6

In Manufacturer specific the bytes 3 and 4 are assigned which contain the state of the various alarms of the drive, additionally byte 5 gives information about alarm sub-code d49 and d50:

Description	Code
d49=d50=0	00
d49≠0	d49
d50≠0	**1**x with x=d50

3.5. Network Management Objects (NMT)

The Life guarding function is implemented as well: the drive (NMT slave) can be set up by the objects:

100Ch Guard time in ms

100Dh Life time factor (multiplier factor)

} their product yields the Node life time

note: node life time is internally saturated in the period time of 32767/fpwm sec.

Life guarding is enabled only if life time Node is different to zero; in this case the check-up starts after having received the first RTR from the NMT master.
Life guarding is automatically disabled when is received a store command (object "Store parameters (1010h)" Sub-Index 2) and/or when is set via CAN C63=1.
The check-up start again after having received a new RTR from the NTM master.

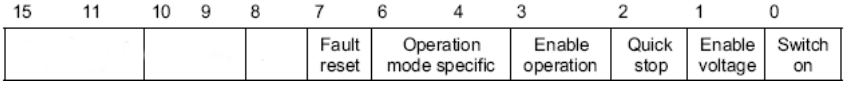
4. Control Mode

Setting **C94=1** it's possible to control the drive with the "**Device Profile Driver and Motion Control DS402**" **rev.2.0** Control Word.

The following objects of the device profile are supported:

Index	Object	Name	Type	Attr.	M/O
6040_h	VAR	*Controlword*	UNSIGNED16	rw	M
6041_h	VAR	*Statusword*	UNSIGNED16	ro	M
6060_h	VAR	*Modes of operation*	INTEGER8	rw	M
6061_h	VAR	*Modes of operation display*	INTEGER8	ro	M

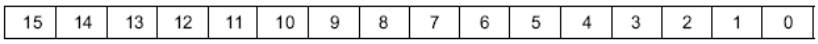
4.1. Control Word (6040h)



Command	control word Bit				
	Fault reset	**Enable operation**	**Quick stop**	**Enable voltage**	**Switch on**
Drive in stop	0	x	x	0	x
Drive in stop	0	x	x	x	0
Run with reference = 0	0	0	1	1	1
Enable operation	0	1	1	1	1
Quick stop	0	x	0	1	1
Fault reset	Edge ↑	x	x	x	x

Note: in series with software run command there is also the hardware run command.

4.2. Status Word (6041h)



State	Value in binary
Not ready to switch on	0000 0000 0000 0000 (0000h)
Ready to switch on	0000 0000 0010 0001 (0021h)
Switched on	xxxx xxxx 0011 0011 (xx33h)
Operation enabled	xxxx xxxx 0011 0111 (xx37h)
Quick stop active	xxxx xxxx 0001 0111 (xx17h)
Fault	0000 0000 0000 1000 (0008h)

4.3. Modes of operation (6060h)

Selecting mode 6, corresponding to Homing, automatically the system set **C95=2** enabling the DS402 Homing. With any other number **C95** is cleared to 0 .

5. Homing

Homing function is selected with connection **C95**.

5.1. Research on zero TOP (I29)

With **C95=1** is enabled an homing function based on the management of the logic function of the **I29** input, that will have to be rightly configured on one of the logic inputs available in the terminal block. The connection **C91** enables to set the active edge:

C91 = 0 activates rising edge L → H of I29

C91 = 1 activates falling edge H → L of I29

On the active edge is memorized the actual position in the variable "zero_pos" available in the object with Index = 201E and Sub-index = 6 and 7.

It is possible to configure TPDO3 with the transmission type 255; in this case TPDO3 will be sent just when the variable "Zero_pos " is refreshed.

5.2. Homing DS402

With **C95=2** is enabled a homing function based on two mode (8 and 12) of "**Device Profile Driver and Motion Control DS402**" rev.2.0.
The following objects of the device profile are supported:

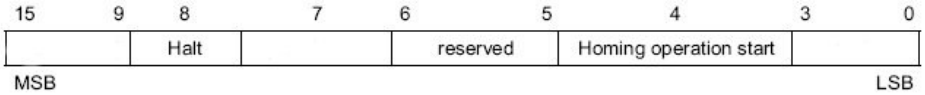
Index	Object	Name	Type	Chapter
6040_h	VAR	*Controlword*	UNSIGNED16	dc
6041_h	VAR	*Statusword*	UNSIGNED16	dc

Index	Object	Name	Type	Attr.	M/O
$607C_h$	VAR	*Home offset*	INTEGER32	rw	O
6098_h	VAR	*Homing method*	INTEGER8	rw	M
6099_h	ARRAY	*Homing speeds*	UNSIGNED32	rw	M
$609A_h$	VAR	*Homing acceleration*	UNSIGNED32	rw	O

Measures unit and limitations:

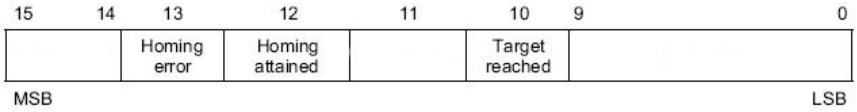
- **Home Offset** : **65536** pulses per motor revolution, homing position related to zero sensor
- **Homing method** : managed mode **8** and **12**
- **Homing speeds**: managed "Speed during search for switch" and "Speed during search for zero". **16384 = 100%** maximum motor speed (P65).
- **Homing acceleration** : for set the ramp times to reach from zero the maximum speed
  100 = 1 second

5.2.1. Control word (6040h)



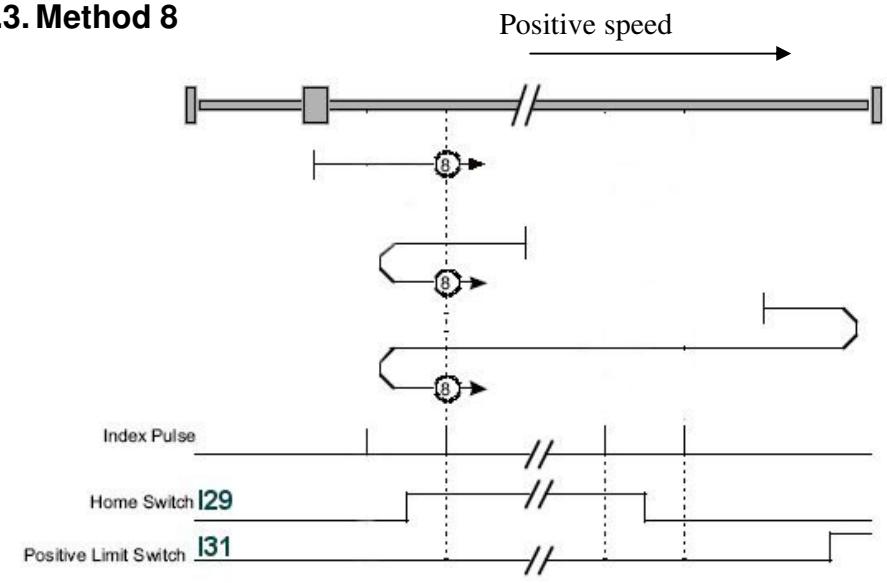
Name	Value	Description
Homing operation start	0	Homing mode inactive
	0 → 1	Start homing mode
	1	Homing mode active
	1 → 0	Interrupt homing mode
Halt	0	Execute the instruction of bit 4
	1	Stop axle with homing acceleration

5.2.2. Status word (6041h)



Nome	Valore	Descrizione
Target reached	0	Halt=0: Home position not reached Halt=1: Axle decelerates
	1	Halt=0: Home position reached Halt=1: Axle has velocity 0
Homing attained	0	Homing mode not yet completed
	1	Homing mode carried out successfully

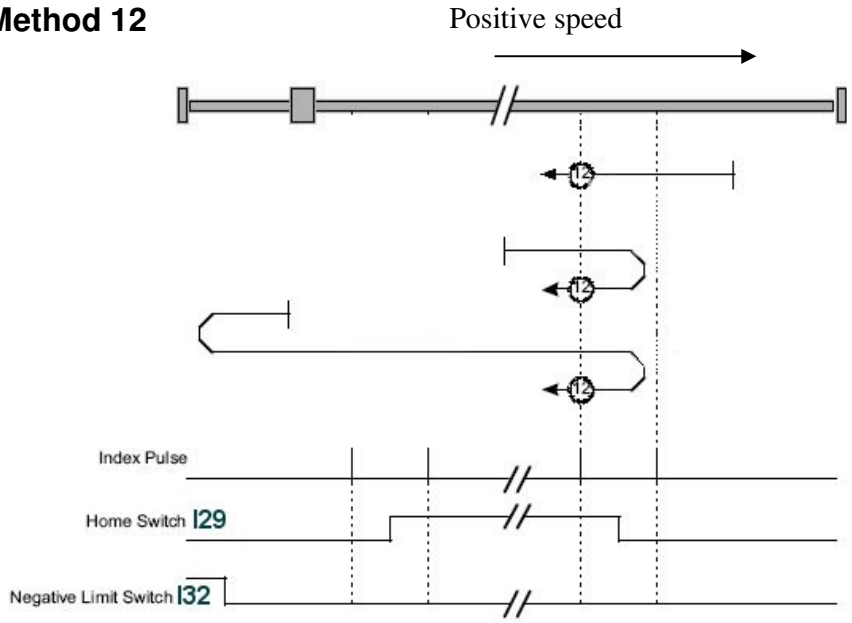
5.2.3. Method 8



The initial homing speed is positive and equals to object Index=6099h Subindex=1 "Speed during search for switch". The home position is at the first index pulse (zero sensor) with the Home switch (**I29**) at high level. The homing speed after Home switch rising edge is equal to object =6099h Subindex=2 "Speed during search for zero". If initially the Home switch is active the initial

homing speed is negative up to the Home switch falling edge, after that the speed is reversed and the home position is at the first index pulse (zero sensor) with the Home switch (**I29**) at high level. If during homing is encountering the Positive Limit Switch (I31) the speed is reversed and than has to be check the rising and the falling Home switch edge, after that the speed is reversed again and the home position is at the first index pulse (zero sensor) with the Home switch (**I29**) at high level.

5.2.4. Method 12



The initial homing speed is negative and equals to object Index=6099h Subindex=1 "Speed during search for switch". The home position is at the first index pulse (zero sensor) with the Home switch (**I29**) at high level. The homing speed after Home switch rising edge is equal to object =6099h Subindex=2 "Speed during search for zero". If initially the Home switch is active the initial homing speed is positive up to the Home switch falling edge, after that the speed is reversed and the home position is at the first index pulse (zero sensor) with the Home switch (**I29**) at high level. If during homing is encountering the Negative Limit Switch (I32) the speed is reversed and than has to be check the rising and the falling Home switch edge, after that the speed is reversed again and the home position is at the first index pulse (zero sensor) with the Home switch (**I29**) at high level.

6. Position capture

The position capture function is based on logical input function **I33** that has to be assigned to L.I.8 input.

The capture pulse width have to be at least 26us.

On rising edge L → H the actual position is stored on the variable "Position_capture" available in the object with Index = 2028

It's possible to configure TPDO4 with transmission type 255, in that case the TPDO4 will be automatically send when a new position is captured.