DS402 Implementation on Roboteq Motor Controllers

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NOTE: DS402 is available since firmware v1.9 beta. Please contact techsupport@roboteq.com for more details.

CONTENTS

FIGURES

TABLES

REVISION HISTORY

Date	Version	Changes
February, 24 2018	1.0	Initial Release

ABBREVIATIONS

C	Constant
CiA	CAN in Automation
FSA	Finite State Automation
PDS	Power Drive System
PP	Profile Position Mode
PV	Profile Velocity Mode
RO	Read Only
RW	Read Write
SDO	Service Data Object
TQ	Torque Mode
VL	Velocity Mode

1. INTRODUCTION

This documentation will describe the implementation of CiA DS402 standard on Roboteq motor controllers.

1.1 WHAT IS DS402

DS402 is an open standard, that is designed specifically for motion control. There are a number of CANOpen SDOs with which one can control the motor by commanding the motor controller.

The standard describes all the required SDOs, as long as the actions the motor controller should take upon receiving these SDOs. Additionally the standard describes a Finite State Machine (FSA) which should run on motor controller.

2. IMPLEMENTATION

The implementation has been directed under standard version 4.1.0.

2.1 INDEX RANGE & CHANNEL SELECTION

All the SDOs described in DS402 standard range from index 0x600 - 0x67FF. However these are only for controlling one motor channel. For multi channel controllers the controller should be able to accept index ranges for the other channels as well. These index ranges are shifted ranges of the abovementioned one as shown below:

- 0x6000 - 0x67FF, for channel 1.
- 0x6800 - 0x6FFF, for channel 2.
- 0x7000 - 0x77FF, for channel 3.

There are Roboteq motor controllers with up to three channels available.

2.2 MODES OF OPERATION

Roboteq Controllers support the following operation Modes:

A. Open Loop
B. Closed Loop Speed, controls Speed using Speed as feedback.
C. Closed Loop Speed Position, controls Speed using Position as feedback.
D. Closed Loop Count Position, controls Position.
E. Closed Loop Position Relative, controls Position within specific boundaries.
F. Closed Loop Position Tracking, controls Position within specific boundaries, with abrupt transition.

In order to conform the above operation modes to the operation modes described, the DS402 modes of operation supported by Roboteq are shown in Table 1 - Operation Table 1. Any other mode described in DS402 standard is not supported by Roboteq controllers.

TABLE 1 - OPERATION MODES

Value	Definition	Roboteq Operation Mode
-4[1]	Velocity Mode	Closed Loop Speed Position
-3[1]	Profile Velocity Mode	Closed Loop Speed Position
-2[1]	Profile Position Mode	Closed Loop Position Tracking Mode[2]
-1[1]	Profile Position Mode	Closed Loop Position Relative Mode[2]
0	No Mode	Open Loop Mode
1	Profile Position Mode	Closed Loop Count Position Mode
2	Velocity Mode	Closed Loop Speed Mode
3	Profile Velocity Mode	Closed Loop Speed Mode
4	Torque Profile Mode	Closed Loop torque Mode

[1]Roboteq Specific Modes
[2]Not all Profile Position features can be supported with this mode.

2.3 SUPPORTED SDOS

Table 2 shows the SDOs described in DS402 standard and supported by Roboteq Motor Controllers.

TABLE 2 - SUPPORTED SDO

Object	Description	Roboteq Command	Profile Position	Velocity	Profile Velocity	Torque Profile
6040_{00}	Control Word	CW	✓	✓	✓	✓
6041_{00}	Status Word	SW	✓	✓	✓	✓
6042_{00}	Target velocity (vl)	S		✓		
6043_{00}	vl velocity demand	RMP		✓		
6044_{00}	vl velocity actual value	F		✓		
6046_{XX}	vl velocity min max amount	SPL		✓		
6048_{XX}	vl velocity acceleration	SAC		✓		
6049_{XX}	vl velocity deceleration	SDC		✓		
6060_{00}	Modes of Operation	ROM				
6061_{00}	Modes of Operation Display	AOM				
6064_{00}	Position actual value	F	✓			
$606C_{00}$	Velocity actual value	F			✓	
6071_{00}	Target torque	TC			✓	✓
6077_{00}	Torque actual value	A				✓
$607A_{00}$	Target position	POS	✓			
6081_{00}	Profile velocity	PSP	✓			
6083_{00}	Profile acceleration	PAC	✓		✓	
6084_{00}	Profile deceleration	PDC	✓		✓	
6087_{00}	Torque slope	TSL				✓
$60FF_{00}$	Target velocity (pv)	S			✓	
6502_{00}	Supported Drive Modes	SDM				
$67FE_{00}$	Version Number	VNM				

2.4 PDS FSA

The standard requires the implementation of a specific finite state machine called FSA. The FSA is designed not only to react to CANOpen commands (Controlword and Statusword), but also to local commands (in this case the use of CW command and SW query). For backward compatibility reasons, the FSA is not active by default. It can be activated by using a special configuration command (^FSA 1, see Figure 1).

FIGURE 1 - FSA CONFIGURATION

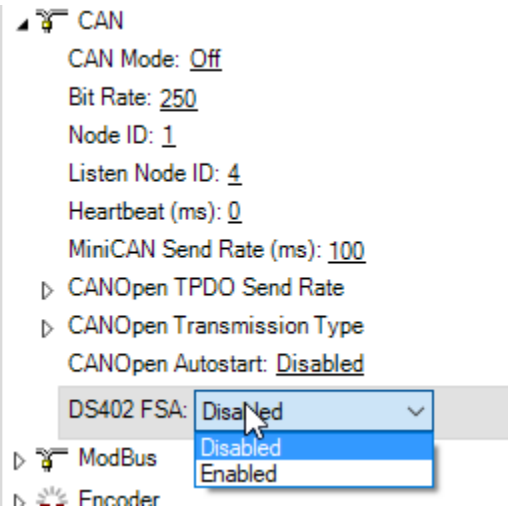


Figure 2 describes The states and the transitions of the finite state machine, while Table 3 describes the actions and the events of the transitions.

FIGURE 2 - POWER DRIVE SYSTEM FINITE STATE AUTOMATION

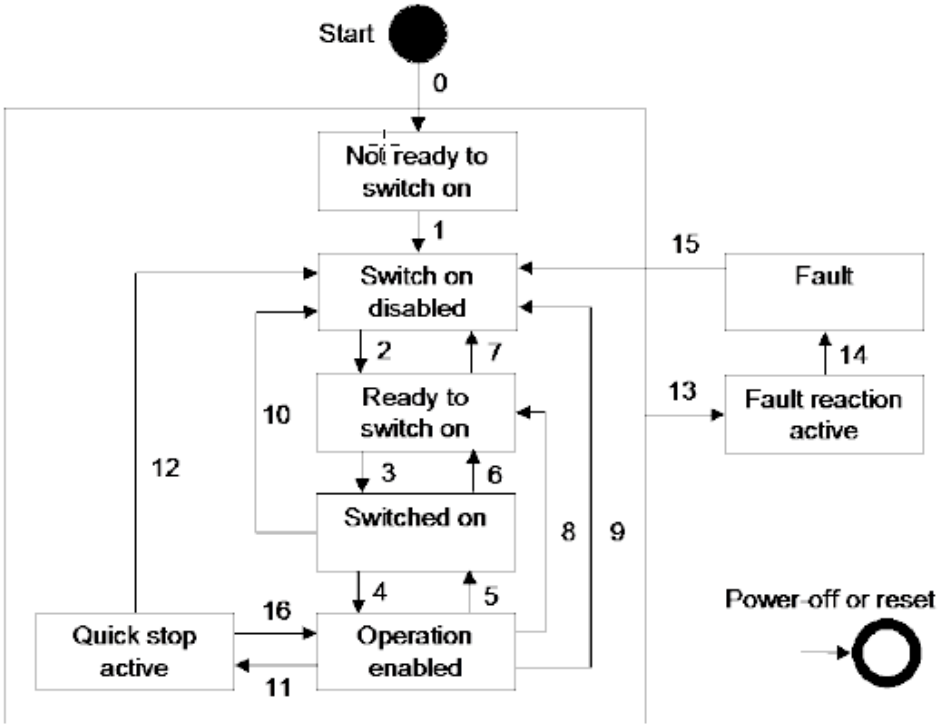


TABLE 3 - TRANSITION EVENTS AND ACTIONS

Transition	Event(s)	Action(s)
0	Automatic Transition after power on or reset application (if ^FSA 1), or when ^FSA is set from 0 to 1.	None
1	Automatic transition	None
2	Shutdown Command	None
3	Switch On Command	None
4	Enable Operation Command	The drive function shall be enabled and all internal set-points cleared.
5	Disable Operation Command	The drive function shall be disabled
6	Shutdown Command	None
7	Quick Stop or Disable Voltage Command	None
8	Shutdown Command	The drive function shall be disabled
9	Disable Voltage Command	The drive function shall be disabled
10	Quick Stop or Disable Voltage Command	None
11	Quick Stop Command	Quick Stop process is initiated
12	Automatic transition when the quick stop function is completed	The drive function shall be disabled
13	Fault Signal	None
14	Automatic Transition	The drive function shall be disabled
15	Fault Reset Command	The drive function shall be enabled

3. SDO DESCRIPTION

3.1 0X6040 - CONTROL WORD

TABLE 4 - CONTROL WORD

Sub-Index	00	Optional	N	Type	U16	Access	RW	PDO	R
Value Range	Discrete					Default	Operation specific		
RoboCommand	CW								
Description	The received command in order to control the PDS FSA.								

Table 4 gives a short description of the object, Table 5 the mapping of the respective variable and Table 6 the usage of the bits that are independent to operation mode.

TABLE 5 - CONTROL WORD MAPPING

15 … 11	10	9	8	7	6 … 4	3	2	1	0
R	R	OMS	H	FR	OMS	EO	QS	EV	SO
MSB									LSB

R → Reserved, OMS → Operation mode specific, H → Halt, FR → Fault reset,

EO → Enable operation QS → Quick stop, EV → Enable voltage, and SO → Switch on

TABLE 6 - COMMAND CODING

Command	Bits of the Control Word					Transition
	Bit 7	Bit 3	Bit 2	Bit 1	Bit 0	
Shutdown	0	X	1	1	1	2,6,8
Switch On	0	0	1	1	1	3
Switch On + Enable Operation	0	1	1	1	1	3+4
Disable Voltage	0	X	X	0	X	7,9,10,12
Quick Stop	0	X	0	1	X	7,10,11
Disable Operation	0	0	1	1	1	5
Enable Operation	0	1	1	1	1	4,16
Fault Reset	0->1	X	X	X	X	15

Bits 9, 6, 5, and 4 of the ControlWord are operation mode specific. The halt function (bit 8) behavior is operation mode specific. If the bit is 1, the commanded motion shall be interrupted, After releasing the halt function, the commanded motion shall be continued if possible, see Table 7.

TABLE 7 - HALT BIT (BIT 8)

Bit	Value	Definition
8	0	Positioning shall be executed or continued
	1	Axis shall be stopped. Slow down on quick stop ramp (EDEC) and stay in operation enabled

3.1.1 PROFILE POSITION MODE

TABLE 8 - CONTROL WORD MAPPING IN PROFILE POSITION MODE

15 10	9	8	7	6	5	4	3 0
see Table 4	Change on set-point	Halt	see Table 4	Abs/rel	Change Set Immediately	New Set Point	see Table 4
MSB							LSB

In Profile Position Mode the operation specific bits are mapped in Table 8. With bits 4, 5 and 9, user can define when the command for next Position (0x607A - POS) will be processed. Bit 6 defines whether the command is absolute or relative to the current position.

TABLE 9 - DEFINITION OF BITS 4,5,6 AND 9 IN PROFILE POSITION MODE

Bit 9	Bit 5	Bit 4	Definition
0	0	0->1	Positioning shall be completed (target reached) before the next one gets started.
X	1	0->1	Next positioning shall be started immediately
1	0	0->1	Positioning with the current profile velocity up to the current set-point shall be proceeded and then next positioning shall be applied
Bit	**Value**	**Definition**	
6	0	Target position shall be an absolute value	
	1	Target position shall be a relative value. Positioning moves shall be performed relative to the preceding (internal absolute) target position	

3.1.2 VELOCITY MODE

TABLE 10 - CONTROL WORD MAPPING IN VELOCITY MODE

15 9	8	7	6	5	4	3 0
see Table 4	Halt	see Table 4	Reference Ramp	Unlock Ramp	Enable Ramp	see Table 4
MSB						LSB

In Velocity Mode the operation specific bits are mapped on Table 10. With bits 4, 5 and 6, user can configure the available ramp related options as shown in Table 11.

TABLE 11 - DEFINITION OF BITS 4,5 AND 6 IN VELOCITY MODE

Bit	Value	Definition
4	0	Motor shall be halted. Slow down on quick stop ramp (EDEC) and stay in operation enabled
	1	Velocity demand value shall accord with ramp output value
5	0	Ramp output value shall be locked to current output value
	1	Ramp output value shall follow ramp input value
6	0	Ramp input value shall be set to zero
	1	Ramp input value shall accord with ramp reference

3.2 0x6041 - Status Word

Table 12 gives a short description of the object, Table 13 the mapping of the respective variable and Table 14 the usage of the bits that are independent to operation mode.

TABLE 12 - STATUS WORD

Sub-Index	00	Optional	N	Type	U16	Access	RO	PDO	T
Value Range	Discrete					Default	-		
RoboCommand	SW								
Description	The status of the PDS FSA.								

TABLE 13 - STATUS WORD MAPPING

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NU		OMS		ILA	TR	RM	MS	W	SOD	QS	VE	F	OE	SO	RTSO
MSB															LSB

NU → Not Used, OMS → Operation mode specific, ILA → Internal limit active
TR → Target reached, RM → Remote, W → Warning, SOD → Switch on disabled,
QS → Quick stop, VE → Voltage enabled, F → Fault, OE → Operation Enabled,
SO → Switch on RTSO → Ready to switch on.

If bit 4 (voltage enabled) of the status word is always 1. If bit 5 (quick stop) of the status word is 0, this shall indicate that the PDS is reacting on a quick stop request (quick stop mode is always 2). Bit 7 (warning) is always 0. Bit 9 (remote) of the status word is always 1. If bit 10 (target reached) of the status word is 1, this shall indicate that the PDS has reached the set-point. Bit 10 shall also be set to 1, if the operation mode has been changed. The change of a target value by software shall alter this bit. If halt occurred and the PDS has halted then bit 10 shall be set to 1, too. If the same internal value is commanded then bit 10 shall not alter, if bit 10 is supported(see Table 15). If bit 11 (internal limit active) of the statusword is 1, this shall indicate that an current limit has been reached.

TABLE 14 - STATE CODING

Status Word	PDS FSA state
xxxx xxxx x0xx 0000_b	Not ready to switch on
xxxx xxxx x1xx 0000_b	Switch on disabled
xxxx xxxx x01x 0001_b	Ready to switch on
xxxx xxxx x01x 0011_b	Switched on
xxxx xxxx x01x 0111_b	Operation enabled
xxxx xxxx x00x 0111_b	Quick stop active
xxxx xxxx x0xx 1111_b	Fault reaction active
xxxx xxxx x0xx 1000_b	Fault

TABLE 15 - DEFINITION OF BIT 10

Bit	Value	Definition
10	0	Halt (bit 8 in controlword) = 0: Speed or Position Target not reached Halt (bit 8 in controlword) = 1: Axis decelerates
	1	Halt (bit 8 in controlword) = 0: Speed or Position Target reached Halt (bit 8 in controlword) = 1: Velocity of axis is 0

3.2.1 PROFILE POSITION MODE

TABLE 16 - STATUS WORD MAPPING IN PROFILE POSITION MODE

15	14	13	12	11	10	9	0
see Table 12		Not Used	Set-Point Acknowledge	see Table 12	Target Reached	see Table 12	
MSB							LSB

In Profile Position Mode the operation specific bits are mapped in Table 16. With bits 10 and 12 user can acknowledge the status of the controller as shown in Table 15 and Table 17. Bit 13 is always 0.

TABLE 17 - DEFINITION OF BIT 12 IN PROFILE POSITION MODE

Bit	Value	Definition
12	0	Previous set-point already processed, waiting for new set-point
	1	Previous set-point still in process, set-point overwriting shall be accepted

3.2.2 PROFILE VELOCITY MODE

TABLE 18 - STATUS WORD MAPPING IN PROFILE VELOCITY MODE

15	14	13	12	11	10	9	0
see Table 12		Not Used	Speed	see Table 12	Target Reached	see Table 12	
MSB							LSB

In Profile Velocity Mode the operation specific bits are mapped in Table 18. With bits 10 and 12 user can acknowledge the status of the controller as shown in Table 15 and Table 19. Bit 13 is always 0.

TABLE 19 - DEFINITION OF BIT 12 IN PROFILE VELOCITY MODE

Bit	Value	Definition
12	0	Speed is not equal 0
	1	Speed is equal 0

3.3 0x6042 - VL Target Velocity

Table 20 gives a short description of the object.

TABLE 20 - TARGET VELOCITY

Sub-Index	00	Optional	N	Type	S16	Access	RW	PDO	R
Value Range						Default	0		
RoboCommand	S								
Description	This object shall indicate the required velocity of the system in RPM. Positive values shall indicate forward direction and negative values shall indicate reverse direction.								

3.4 0x6043 - VL Velocity Demand

Table 21 gives a short description of the object.

TABLE 21 - VELOCITY DEMAND

Sub-Index	00	Optional	N	Type	S16	Access	RO	PDO	T
Value Range						Default			
RoboCommand	RMP								
Description	This object shall provide the instantaneous velocity in RPM generated by the ramp function. It is an internal object of the drive device. Positive values shall indicate forward direction and negative values shall indicate reverse direction.								

3.5 0x6044 - VL Velocity Actual Value

Table 22 gives a short description of the object.

TABLE 22 - VELOCITY ACTUAL VALUE

Sub-Index	00	Optional	N	Type	S16	Access	RO	PDO	T
Value Range						Default			
RoboCommand	RMP								
Description	This object shall provide the velocity in RPM at the motor spindle or load. Depending on the implementation (simple drive device, without sensor, with sensor, etc.), the drive shall provide the appropriate image of the actual velocity derived for example from velocity demand or a sensor signal.								

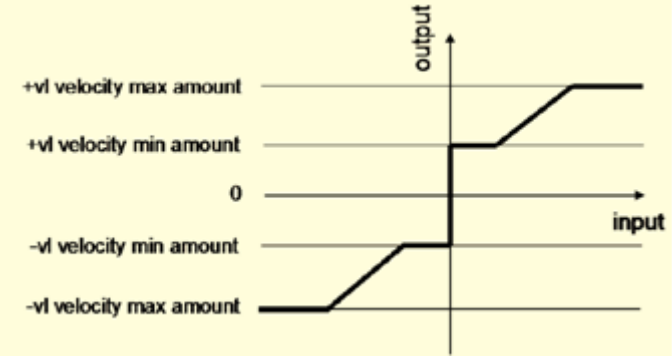
3.6 0x6046 - VL Velocity Min Max Amount

Table 23 gives a short description of the object.

TABLE 23 - VELOCITY MIN MAX AMOUNT

Sub-Index	01	Optional	N	Type	U32	Access	RW	PDO	R
Value Range						Default	0		
RoboCommand	SPL								
Description	VL velocity min amount.								
Sub-Index	02	Optional	N	Type	U32	Access	RW	PDO	R
Value Range						Default	1000		
RoboCommand	SPL								
Description	VL velocity max amount.								

FIGURE 3 - VELOCITY MIN MAX AMOUNT



This object shall indicate the configured minimum and maximum amount of velocity in RPM. The vl velocity max amount sub-object shall be mapped internally to the vl velocity max positive and vl velocity max negative values. The vl velocity min amount sub-object shall be mapped internally to the vl velocity min positive and vl velocity min negative values. as shown Figure 3.

3.7 0x6048 - VL Velocity Acceleration

Table 24 gives a short description of the object.

TABLE 24 - VELOCITY ACCELERATION

Sub-Index	01	Optional	N	Type	U32	Access	RW	PDO	R
Value Range						Default	MAC(20000)		
RoboCommand	SAC								
Description	Delta speed in RPM*10.								
Sub-Index	02	Optional	N	Type	U16	Access	RW	PDO	R
Value Range						Default	1		
RoboCommand	SAC								
Description	Delta time in seconds.								

3.8 0x6049 - VL Velocity Deceleration

Table 25 gives a short description of the object.

TABLE 25 - VELOCITY DECELERATION

Sub-Index	01	Optional	N	Type	U32	Access	RW	PDO	R
Value Range						Default	MDEC(20000)		
RoboCommand	SDC								
Description	Delta speed in RPM*10.								
Sub-Index	02	Optional	N	Type	U16	Access	RW	PDO	R
Value Range						Default	1		
RoboCommand	SDC								
Description	Delta time in seconds.								

3.9 0x6060 - Modes of Operation

Table 22 gives a short description of the object and Table 1shows the available modes.

TABLE 26 - MODES OF OPERATION

Sub-Index	00	Optional	CND	Type	S8	Access	RW	PDO	R
Value Range						Default	MMOD(0)		
RoboCommand	ROM								
Description	The requested operation mode.								

3.10 0x6061 - Modes of Operation Display

Table 27 gives a short description of the object and Table 1 shows the available modes.

TABLE 27 - MODES OF OPERATION DISPLAY

Sub-Index	00	Optional	CND	Type	S8	Access	RO	PDO	
Value Range						Default	MMOD(0)		
RoboCommand	AOM								
Description	The actual operation mode.								

3.11 0x6064 - Position Actual Value (PP)

Table 28 gives a short description of the object.

TABLE 28 - POSITION ACTUAL VALUE

Sub-Index	00	Optional	CND	Type	S32	Access	RO	PDO	T
Value Range						Default			
RoboCommand	F								
Description	This object shall provide the actual value of the position measurement device.								

The position unit are in sensor counts in Closed Loop Count Position mode. In Closed Loop Position Relative mode and in Closed Loop Tracking Position mode the position unit is in range -1000 to 1000 scaled by the minimum and maximum sensor value.

3.12 0x606C - Velocity Actual Value (PV)

Table 29 gives a short description of the object.

TABLE 29 - VELOCITY ACTUAL VALUE

Sub-Index	00	Optional	CND	Type	S32	Access	RO	PDO	T
Value Range						Default			
RoboCommand	F								
Description	This object shall provide the actual velocity value, in RPM, derived either from the velocity sensor or the position sensor.								

3.13 0x6071 - Target Torque (TQ)

Table 30 gives a short description of the object.

TABLE 30 - TARGET TORQUE

Sub-Index	00	Optional	CND	Type	S16	Access	RW	PDO	R
Value Range						Default	0		
RoboCommand	TC								
Description	This object shall indicate the configured input value, in Amperes*10, for the torque controller in profile torque mode.								

3.14 0x6077 - Torque Actual Value (TQ)

Table 31 gives a short description of the object.

TABLE 31 - TORQUE ACTUAL VALUE

Sub-Index	00	Optional	CND	Type	S16	Access	RO	PDO	T
Value Range						Default			
RoboCommand	A								
Description	This object shall provide the actual value of the torque, in Amperes*10. It shall correspond to the instantaneous torque in the motor.								

3.15 0x607A - Target Position (PP)

Table 32 gives a short description of the object.

TABLE 32 - TARGET POSITION

Sub-Index	00	Optional	CND	Type	S32	Access	RW	PDO	R
Value Range						Default	0		
RoboCommand	POS								
Description	The commanded 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. The value of this object shall be interpreted as absolute or relative depending on the abs/rel flag in the ControlWord.								

The position unit are in sensor counts in Closed Loop Count Position mode. In Closed Loop Position Relative mode and in Closed Loop Tracking Position mode the position unit is in range -1000 to 1000 scaled by the minimum and maximum sensor value.

3.16 0x6081 - Profile Velocity (PP)

Table 33 gives a short description of the object.

TABLE 33 - PROFILE VELOCITY

Sub-Index	00	Optional	CND	Type	U32	Access	RW	PDO	R
Value Range						Default	MVEL(1000)		
RoboCommand	PSP								
Description	This object shall indicate the configured velocity, in RPM, normally attained at the end of the acceleration ramp during a profiled motion and shall be valid for both directions of motion.								

3.17 0x6083 - Profile Acceleration (PP)

Table 34 gives a short description of the object.

TABLE 34 - PROFILE ACCELERATION

Sub-Index	00	Optional	CND	Type	U32	Access	RW	PDO	R
Value Range						Default	MAC(20000)		
RoboCommand	PAC								
Description	This object shall indicate the configured acceleration, in (RPM*10)/second.								

3.18 0x6084 - Profile Deceleration (PP)

Table 35 gives a short description of the object.

TABLE 35 - PROFILE DECELERATION

Sub-Index	00	Optional	Y	Type	U32	Access	RW	PDO	R
Value Range						Default	MDEC(20000)		
RoboCommand	PAC								
Description	This object shall indicate the configured deceleration, in (RPM*10)/second.								

3.19 0x6087 - Torque Slope (TQ)

Table 36 gives a short description of the object.

TABLE 36 - PROFILE DECELERATION

Sub-Index	00	Optional	CND	Type	U32	Access	RW	PDO	R
Value Range						Default	MAC(20000)		
RoboCommand	TSL								
Description	This object shall indicate the configured rate of change of torque, in (mAmperes*10)/second.								

3.20 0x60FF - Target Velocity (PV)

Table 37 gives a short description of the object.

TABLE 37 - TARGET VELOCITY

Sub-Index	00	Optional	CND	Type	U32	Access	RW	PDO	R
Value Range						Default	0		
RoboCommand	S								
Description	This object shall indicate the configured target velocity, in RPM, and shall be used as input for the trajectory generator.								

3.21 0x6502 - Supported Drive Modes

Table 38 gives a short description of the object.

TABLE 38 - SUPPORTED DRIVE MODES

Sub-Index	00	Optional	REQ	Type	U32	Access	C	PDO	N
Value Range						Default	0x0000000F		
RoboCommand	SDM								
Description	The supported drive modes.								

Roboteq Controllers support:

- Profile Position Mode (PP).
- Velocity Mode (VL).
- Profile Velocity Mode (PV).
- Torque Mode (TQ).

3.22 0x67FE - Version Number

Table 39 gives a short description of the object.

TABLE 39 - VERSION NUMBER

Sub-Index	00	Optional	REQ	Type	U32	Access	C	PDO	N
Value Range						Default	0x00040100		
RoboCommand	VNM								
Description	This object shall provide the version number of the CiA 402 profile, which is implemented in the device.								

REFERENCES

1. Roboteq Controllers User Manual v1.8, https://www.roboteq.com/index.php/docman/motor-controllers-documents-and-files/documentation/user-manual/272-roboteq-controllers-user-manual-v17/file.
2. CiA® 402 Draft Standard Proposal, v4.1.0, https://www.can-cia.org/can-knowledge/canopen/cia402/