Technical Information

Application Note | Servo Pump Control

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1 Preface

The described hardware and/or software are developments of the KEB Automation KG. The enclosed documents correspond to conditions valid at printing. Misprint, mistakes and technical changes reserved.

The application notes describe solved applications or application scenarios. They serve designers and developers as an approach to be taken in the implementation of own applications. However, they are considered for information only without responsibility. The selection with regard to their suitability for the intended use can only be made by the user.

The use of our units in the target products is beyond of our control and therefore exclusively the responsibility of the machine manufacturer, system integrator or customer.

1.1 Signal words and symbols

The used signal words and symbols have the following meaning:

⚠ DANGER	➢ Dangerous situation, which will cause death or serious injury in case of non-observance of this safety instruction.
⚠ WARNING	➢ Dangerous situation, which may cause death or serious injury in case of non-observance of this safety instruction.
⚠ CAUTION	➢ Dangerous situation, which may cause minor injury in case of non-observance of this safety instruction.
ATTENTION	➢ Situation, which can cause damage to property in case of non-observance.

RESTRICTION

Is used when certain conditions must meet the validity of statements or the result is limited to a certain validity range.

i	➢ Is used when the result will be better, more economic or trouble-free by following these procedures.

► This arrow starts an action step.

• / - Enumerations are marked with dots or indents.

=> Cross reference to another chapter or another page.

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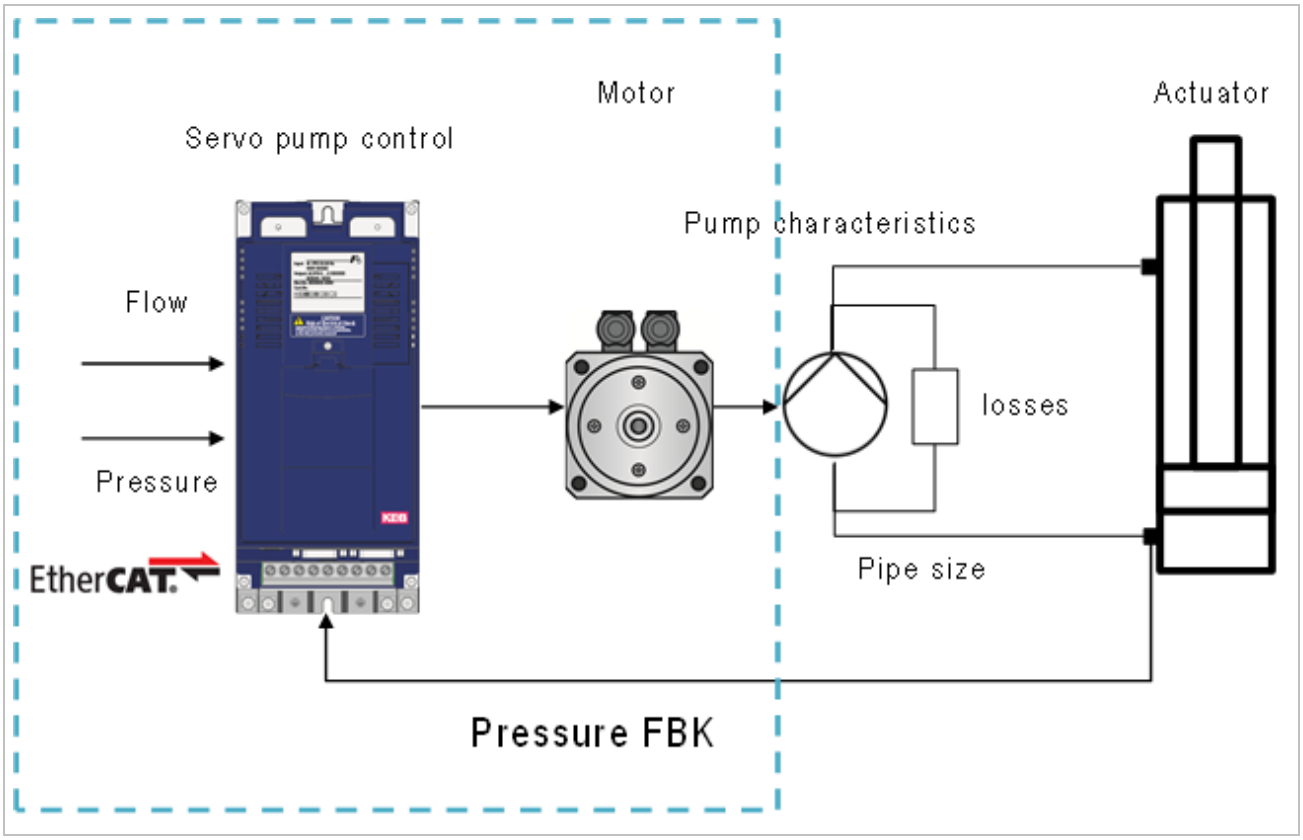
2 Servo pump control

2.1 Introduction



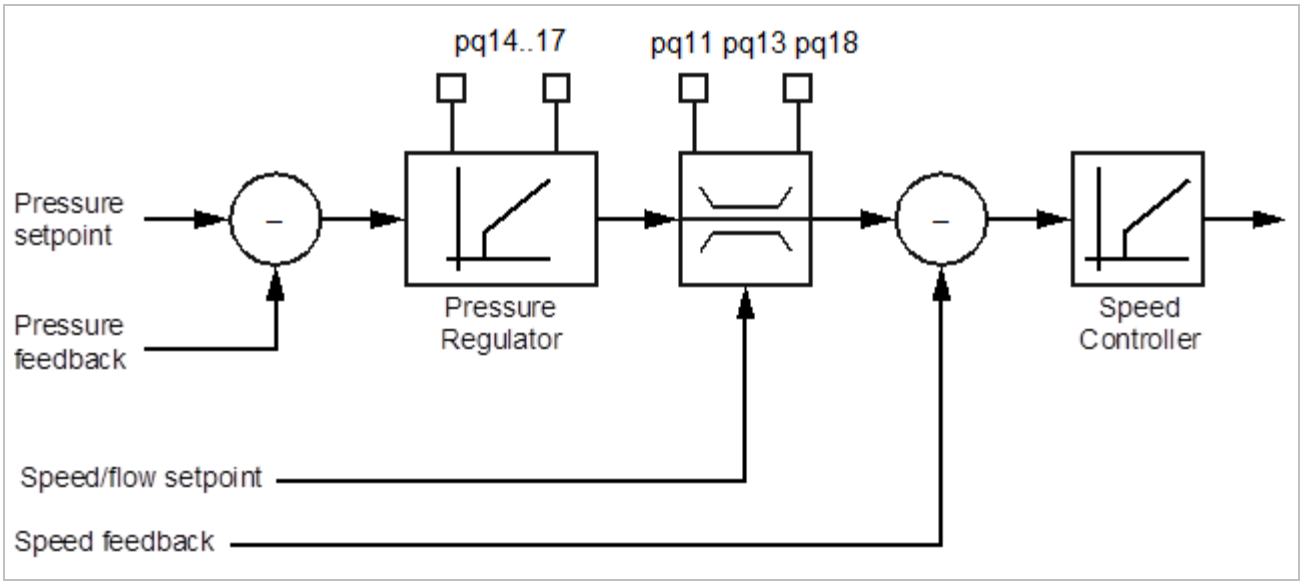
Picture 1: Circuit principle

The servo pump control is a function to manage pressure and flow rate of a hydraulic circuit managed by a servo pump (gear pump). This function can be activated/ deactivated by a parameter and when it is active it will impose the appropriate speed reference for the motor, vice versa it will leave the user the possibility to decide the preferred operating mode.

The operating mode used by the servo pump function is the velocity mode, defined by parameter co01 = 2.

In order to properly control the system it is necessary to set up a sensor to read the pressure in the hydraulic circuit to be managed.

To adjust the pressure the servo pump control generates a speed command limited by the speed/flow rate setpoint.



Picture 2: Speed regulation

The servo pump control can be adapted to various hydraulic configurations and different actuators (up to 8 parameter sets are available).

The hydraulic characteristics of the various contexts can be identified by the tools provided (COMBIVIS wizard) always guaranteeing the best settings.

The servo pump control is designed to protect the pump in contexts where the system would require a command that could be critical for the life of the pump itself.

2.2 Control word

Servo pump (PQ) controller is controlled over the Control word parameter (pq01).

pq01	PQ controller control word		0x3951
Bit	Name	Value	Note
0	enable pq controller	0	Disable PQ controller.
		1	Enable PQ controller.
1	mechanical stop enable	0	Disable mechanical stop check.
		2	Enable mechanical stop check.
2..3	multi pump selector 1	0	Use pump displacement stored in pq08.
		4	Use pump displacement stored in pq32.
	multi pump selector 2	8	Slave Mode (not implemented).
		12	Use pump displacement difference: pq32 - pq08.
4	enable wire break monitor	16	Enables pressure feedback signal monitor.
5	pause pq controller	32	Switches the output of the pq controller to the manual speed setting.

The main difference of the paused PQ controller compared to disabled PQ controller is in the fact, that in pause mode the actual values of the pressure and flow proceed to be calculated according to configured settings.

⚠ CAUTION

➢ Switching to disabled as well as to paused state has to be taken carefully, since the high pressure levels in the system could be developed if the improper output speed is set.

2.3 Status word

Status word parameter (pq00) is used to identify the state of the servo pump (PQ) controller.

pq00	Status PQ	0x3950
Bit	Name	Note
0	PQ run	Controller is running.
1	Mechanical Stop	A mechanical stop is detected. See chapter: *2.13 Mechanical stop check.*
2	Speed Check	Internal condition, for debug only.
3	Detect Upper Limit	Speed command reached upper limit (determined with the speed/flow setpoint (pq07) or safe speed (pq18).
4	Detect Lower Limit	Speed command reached lower limit (determined with pq11 or pq13). See chapter: *2.11.1 Reverse speed operation.*
5	Current Check	Current command reached saturation (determined with pq22).
6	PQ stop	Speed output is forced to zero (condition determined with pq27 and pq28). See chapter: *2.17 Speed stop at minimum pressure.*
7	Auto tuning procedure active	Hydraulic capacity autotuning running. See chapter: *2.18 PQ controller (hydraulic) autotuning.*
8	PQ paused	Manual setting (vl20/vl21) takes over the speed control.

2.4 Servo pump specific exceptions

Servo pump control application introduces specific faults conditions displayed in ru01 together with standard firmware faults.

ru01	Error text	Description	st01
136	ERROR PQ-Controller pressure feedback wire break	Signal from the pressure sensor is lost (week).	0x1000
137	ERROR PQ-Controller reverse speed	Pump goes in reverse speed longer than time defined in parameter pq29.	0x1000

2.5 System configuration set

Some of the servo pump controller parameters (pq02, pq14, pq15, pq16, pq17 and pq31) are stored in configuration sets from maximal eight possible configurations where each set can be switched during run time through the parameter pq12 or the binary value of the digital inputs I2, I3 and I4 depending on the configuration in the parameter pq38. The parameter pq12 also reflects the actual index selection when configuration over digital inputs is used.

Index	Id-Text	Name	Function
0x395C	pq12	hydraulic system selector	Index of the applied configuration set. Directly written or reflects the status in case when digital input selection is configured (pq38).
0x3976	pq38	hydraulic system selector source	Selection of the hydraulic system using the value in pq12 or binary value of the digital inputs I2, I3 and I4.

pq38	hydraulic system selector source	0x3976
Value	Configuration	Note
0	Digital inputs [I2, I3, I4]	Selection of the configuration sets over digital inputs I2, I3 and I4. Set value equals the digital inputs binary value + 1.
1	Bus [pq12]	Selection of the configuration sets over the value written in pq12.

2.6 Pressure feedback

The pressure feedback source is determined with pq02 where maximal eight possible configurations are stored. For each configuration, the selection between Analog Input 1 and Analog Input 2 is available. Which analog input from these two will be active depends on the parameter pq12 where the actual selection of eight possible configurations is stored (see chapter 2.5).
Reading of the actual pressure value in three possible pressure units (bar, MPa or psi) is available through the parameter pq05. The actual selection of the pressure unit is determined with the parameter pq44.
Maximum value of pressure sensor, corresponding to 100% of feedback signal, is defined in pq09 and it is divided in two elements, one corresponding to Analog Input 1 and the other corresponding to Analog Input 2. Parameter pq09 is always expressed in bars, independent of the selection in pq44.

Index	Id-Text	Name	Function
0x3952	pq02	pressure feedback source	Configures pressure feedback source.
0x3955	pq05	pressure feedback value	Shows actual pressure expressed in units selected by pq44.
0x3959	pq09	pressure equivalent	Determinates the scaling factor of the Analog Input 1 and Analog Input 2. The entered value defines the pressure in [bar] equivalent to 100% of the selected analog input.
0x395C	pq12	hydraulic system selector	Index of the applied pressure feedback source. Directly written or reflects the status in case when digital input selection is config-

			ured (pq38).
0x3976	pq38	hydraulic system selector source	Selection of the hydraulic system using the value in pq12 or binary value of the digital inputs I2, I3 and I4.
0x397C	pq44	pressure unit selection	Selects the pressure unit of the value shown in pq05.

pq02	pressure feedback source	0x3952
Value	Configuration	Note
1	AN1	Use Analog Input 1 as pressure feedback.
2	AN2	Use Analog Input 2 as pressure feedback.

pq44	pressure unit selection	0x397C
Value	Configuration	Note
0	bar	Pressure value expressed in bar.
1	MPa	Pressure value expressed in MPa.
2	psi	Pressure value expressed in psi.

ATTENTION

➢ Pressure unit selection in parameter pq44 is only applied on the pressure feedback signal, pressure set point and pressure ramp out. All other pressure relevant parameter settings are always expressed in bars.

Through the activation of the “enable wire break monitor” in the PQ controller control word it is possible to detect if the signal from the pressure sensor is lost (week). The signal will be considered to be lost if its value fails under certain level. This level is in the case of voltage interface selection around 0.3 V while in case of current (0/4-20mA) interface selection around 1.6 mA. In case of such detection the error code “136: ERROR PQ-Controller pressure feedback wire break” will be triggered.

2.7 Pressure setpoint

Pressure setpoint source is defined in pq03 between Analog Input 1, Analog Input 2 and PDO. Setting of the actual pressure value in three possible pressure units (bar, MPa or psi) is available through the parameter pq06. The actual selection of the pressure unit is determined with the parameter pq44 (see chapter 2.6).
If PDO is selected, the value written in pq06 is considered as pressure setpoint. In case of the analog input selection the pressure set point value is scaled according the value written in the pq09 (always in bar – see chapter 2.6). In this case, parameter pq06 reflects the scaled value of the analog input.

Index	Id-Text	Name	Function
0x3953	pq03	pressure setpoint source	Selects pressure setpoint source.
0x3956	pq06	pressure setpoint	Digital (PDO) pressure setpoint expressed in units selected by pq44. In case of the analog source configuration reflects the scaled value of the analog input.
0x3959	pq09	pressure equivalent	Determinates the scaling factor of the Analog Input 1

			and Analog Input 2. The entered value defines the pressure in [bar] equivalent to 100% of the selected analog input.
0x397C	pq44	pressure unit selection	Selects the pressure unit of the value shown in pq06.

pq03	pressure setpoint source	0x3953
Value	Configuration	Note
0	Digital [pq06]	Use value written in pq06 as pressure set-point.
1	AN1	Use Analog Input 1 as pressure setpoint.
2	AN2	Use Analog Input 2 as pressure setpoint.

2.8 Speed/flow feedback

Speed feedback is read in parameter ru08 while flow rate monitor is displayed in pq24 and depends on the displacement value (see chapter 0).

Index	Id-Text	Name	Function
0x3968	pq24	flow rate	Flow rate monitor in [l/min] based on pump speed and displacement.

2.9 Speed/flow setpoint

Speed/flow setpoint is defined in pq04 between Analog Input 1, Analog Input 2, Analog Input 3 and PDO. If PDO is selected, the value written in pq07 is considered as speed/flow setpoint. Use pq25 to select if the setpoint is considered as speed or flow. Pq10 is the maximum value corresponding at 100% of analog input, used to scale input. In case of the analog source configuration parameter pq07 reflects the scaled value of the analog input.

Index	Id-Text	Name	Function
0x3954	pq04	speed/flow source PQ	Select speed/flow setpoint source.
0x3957	pq07	speed/flow setpoint PQ	Digital (PDO) speed/flow setpoint expressed in [1/min] or [l/min]. Applied physical unit depends on configuration in parameter pq25. In case of the analog source configuration reflects the scaled value of the analog input.
0x395A	pq10	speed/flow PQ equivalent	Determines the scaling factor of the applied speed/flow analog source. The entered value defines the speed/flow in [1/min] or [l/min] equivalent to 100% of the selected analog input. Applied physical unit depends on configuration in parameter pq25.
0x3969	pq25	speed/flow selector	Selects speed/flow setpoint unit (speed [1/min] or flow [l/min]).

pq04	speed/flow source PQ	0x3954
Value	Configuration	Note
0	Digital [pq07]	Use value written in pq07 as speed/flow set-point.
1	AN1	Use Analog Input 1 as speed/flow setpoint.
2	AN2	Use Analog Input 2 as speed/flow setpoint.
3	AN3	Use Analog Input 3 as speed/flow setpoint.

pq25	speed/flow selector	0x3969
Value	Configuration	Note
0	Speed [1/min]	Use speed unit [1/min] for setpoint.
1	Flow [l/min]	Use flow unit [l/min] for setpoint.

For the need of the servo pump control application, additional analog inputs configuration parameters for Analog Input 3 are introduced. AN3 parameters correspond to the AN1 and AN2 parameters present in the standard firmware, with the difference that AN3 is always configured as voltage input (0.2…10 V). Physical interface of the AN3 is shared together with the Digital Input 1; therefore, it is not possible to use both inputs at the same time.

Index	Id-Text	Name	Function
0x3315	an21	AN3 mean filter	Mean filter for the analog signal.
0x3316	an22	AN3 PT1 filter	PT1 filter for the analog signal.
0x3317	an24	AN3 zero point hysteresis	Zero point hysteresis.
0x3318	an25	AN3 gain	Gain of the analog signal.
0x3319	an26	AN3 offset X	Offset X for the analog signal.
0x331A	an27	AN3 offset Y	Offset Y for the analog signal. Out = gain * (In –OffsetX) + OffsetY
0x331B	an28	AN3 neg limit	Lower limit for the analog setpoint.
0x331C	an29	AN3 pos limit	Upper limit for the analog setpoint.

➢ Analog Input 3 is not available at the S6-K control boards.

2.10 Displacement

Pump displacement is used for speed to flow conversion, for gain calculation during autotuning procedure and for mechanical stop check. Actual displacement depends on the values in pq08, pq32 and the selection done in PQ controller control word (pq01).

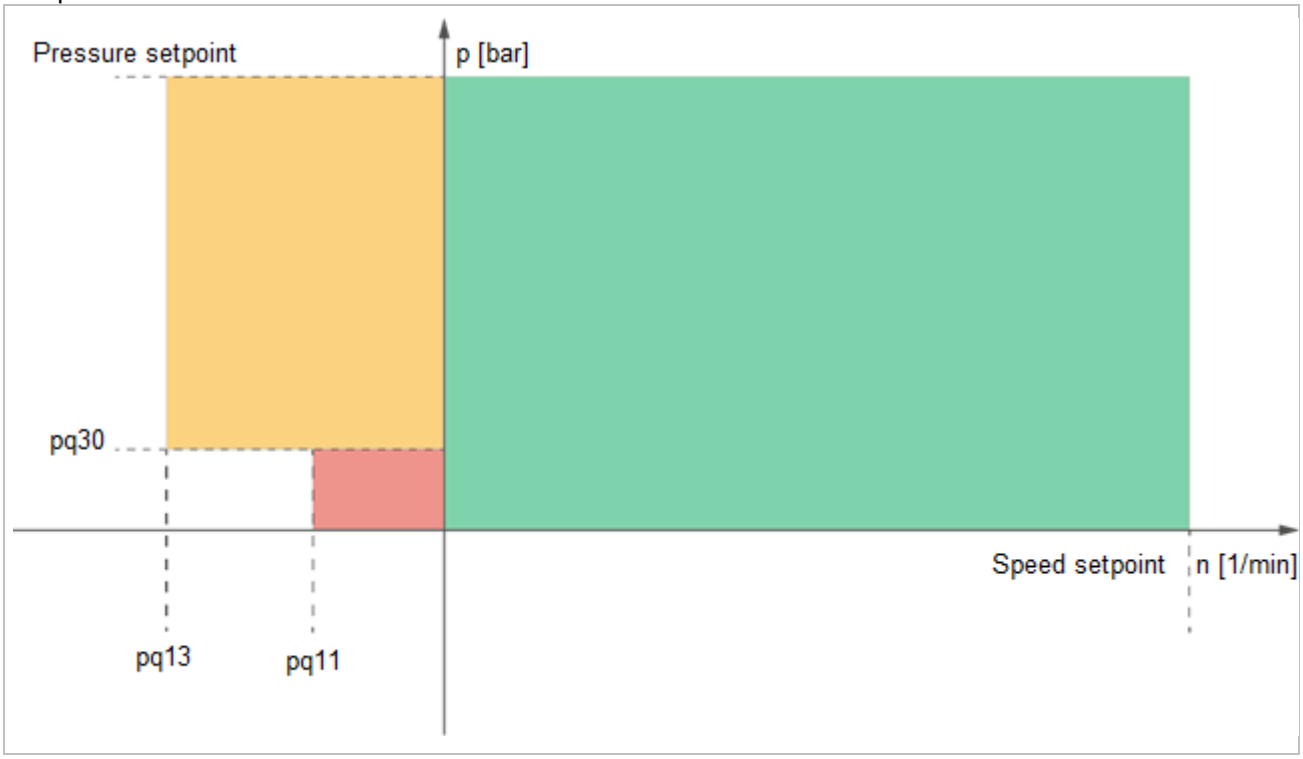
Index	Id-Text	Name	Function
0x3958	pq08	pump displacement [cm3/rev]	Single pump delivery.
0x3970	pq32	multipump displacement [cm3/rev]	Multi pump delivery.

2.11 Reverse speed

In order to protect the pump against cavitation, two protections on reverse speed are implemented.

2.11.1 Reverse speed operation

Pump is allowed to go in negative speed and the maximum negative speed is defined by pq13. This limit is kept as long as pressure feedback is higher than the threshold defined in pq30, otherwise pq11 value will be kept.
In order to provide smoother transition between both negative speeds a parametrized hysteresis (pq42) in the pressure feedback threshold is built in.



Picture 3: Reverse speed protection

Index	Id-Text	Name	Function
0x395B	pq11	min. reverse speed	Negative speed limitation when the actual pressure is lower than those defined in pq30.
0x395D	pq13	max. reverse speed	Negative speed limitation when the actual pressure is higher than those defined in pq30.
0x396E	pq30	lower pressure thr for reverse speed	Pressure threshold given in [bar] for negative speed limitation (pq11/pq13).
0x397A	pq42	lower pressure thr for rev. speed hyst.	Pressure threshold hysteresis given in [bar] for negative speed limitation.

When the negative speed limitation is reached, this will be indicated in the PQ controller status word (pq00) bit 4.

2.11.2 Reverse speed timer

Every time the pump starts to go in negative direction a timer will start. If time defined in pq29 will elapsed, an error will trigger and the pq controller will be disabled.

Index	Id-Text	Name	Function
0x396D	pq29	reverse speed timer	Maximum time for reverse speed operation. If the defined time is exceeded the error condition will be triggered (see the chapter 2.4).

2.12 Controller gain

Pressure controller works like a PI regulator. An array of 8 elements is available in order to store 8 sets of gains/times and change them online using the hydraulic system selector pq12 or the binary value of the digital inputs I2, I3 and I4 depending on the configuration in the parameter pq38 (see chapter 2.5).

Index	Id-Text	Name	Function
0x395C	pq12	hydraulic system selector	Index of applied gains/times set. Directly written or reflects the status in case when digital input selection is configured (pq38).
0x395E	pq14	Tau 1	Zero constant time [ms].
0x395F	pq15	Tau 2	Pole constant time [ms].
0x3960	pq16	integrator gain	Integrator gain [ms^-1].
0x3961	pq17	proportional gain	Proportional gain [rpm/bar].
0x3976	pq38	hydraulic system selector source	Selection of the hydraulic system using the value in pq12 or binary value of the digital inputs I2, I3 and I4.

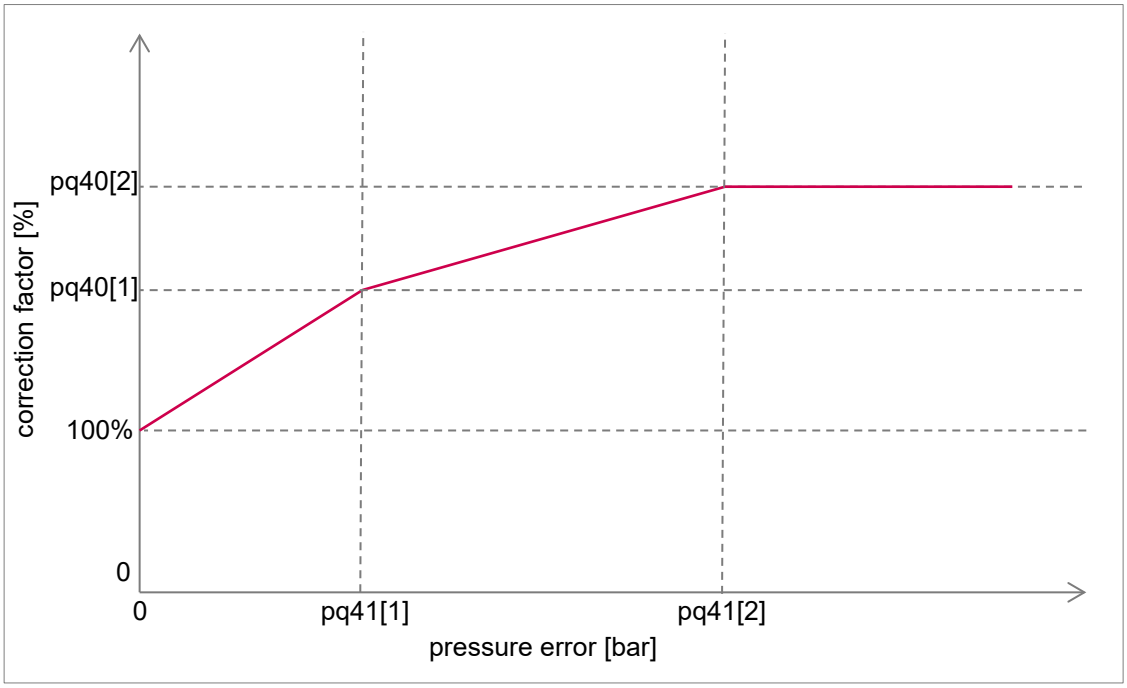
2.12.1 Adaptive proportional gain

The strength of the active proportional gain (selected through the hydraulic system selector pq12) of the PI regulator can be dynamically modified depending on the amount of the actual pressure error: absolute difference between the reference and actual pressure. For calculating the absolute difference the reference pressure is taken from the ramp output and the actual pressure from the band stop filter (if enabled).

Index	Id-Text	Name	Function
0x3978	pq40	variable Kp pressure gain	Array of the correction factor endpoints defining variable proportional gain.
Subidx	Name		Function
1	variable Kp pressure gain		Endpoint of proportional gain correction factor for the first segment given in [%].
2	variable Kp pressure gain		Endpoint of proportional gain correction factor for the second segment given in [%].

Index	Id-Text	Name	Function
0x3979	pq41	press. err. thr for var Kp gain	Array of the pressure error thresholds endpoints defining variable proportional gain.
Subidx	Name		Function
1	press. err. thr for var Kp gain		Endpoint of the pressure error threshold for the first segment given in [bar].
2	press. err. thr for var Kp gain		Endpoint of the proportional gain correction factor for the second segment given in [bar].

Dependency between the pressure error and the correction factor is realized as linear interpolation between the endpoints defined in the parameters pq40 and pq41.



Picture 4: Variable proportional gain parametrisation

The initial point is always considered to be at 0 bar and 100 %, while the correction factor remains constant after the second point.

Example:

For the following settings of the pq40 and pq41:

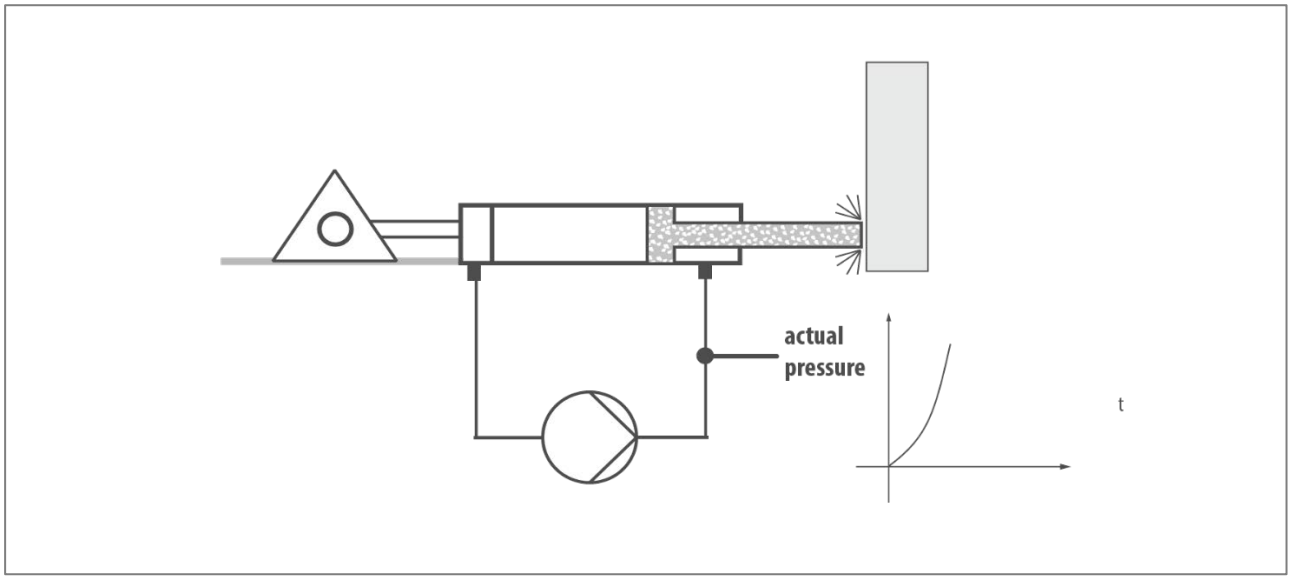
pq40[1] = 200 %
pq40[2] = 300 %
pq41[1] = 5 bar
pq41[2] = 15 bar

In case when the setpoint pressure (calculated from the ramp) is 60 bar while the actual pressure (smoothed with the band stop filter if enabled) is 50 bar, the resulting correction factor is calculated as linear interpolation between the points pq41[1] and pq41[2] since the pressure error is 10bar. This will give the correction factor of 250%.
At the end, if the active proportional gain is set to 15 rpm/bar (pq17 [1] = 15 and pq12 = 1) the resulting proportional gain will be 250% from 15, which is 37.5 rpm/bar.

In order to disable the adaptive proportional gain option it is enough to set both points pq40[1] and pq40[2] to 100%.

2.13 Mechanical stop check

An additional protection is done by mechanical stop check. Here pressure derivative is monitored and compared with the maximum theoretical derivative that can be done with a certain speed.



Picture 5: Mechanical stop check

Index	Id-Text	Name	Function
0x3962	pq18	safe speed	Speed limit in case of mechanical stop recognition [1/min]
0x3963	pq19	min. derivative speed	Minimal speed for mechanical stop calculation. If the actual speed is lower than this threshold, mechanical stop condition is calculated with this speed [1/min].
0x3964	pq20	tauD	Time constant for pressure derivative check filter [ms].
0x3965	pq21	derivative pressure K	Strength factor of mechanical stop check (0.5 is optimal; more than 10 is very week).
0x3967	pq23	hydraulic capacity x10^-7	Minimum hydraulic capacity of the system [m^3/bar]

2.14 Saturation current check

Parameter pq22 defines current amount at which the Current Check condition will be triggered (bit 5 in pq00 status word). Maximal value of this parameter is limited to 90% of the inverter maximal current (de29).

Index	Id-Text	Name	Function
0x3966	pq22	saturation current	Saturation current [A].

2.15 Pressure setpoint ramp

The pressure setpoint built-in ramp generator supports linear and s-curve ramps. The parameterization of the ramp generator corresponds to those described in the standard firmware manual in chapter *Ramp generator,* with the difference in the parameter naming and units. Additional difference in pressure setpoint ramp persist in the absence of the configuration parameters for negative direction of the setpoint, since in this case negative pressure values have no sense, and in option for completely turning off the ramp.
Further, the pressure setpoint ramp mode is extracted from the pressure setpoint ramp settings parameter (pq39) and defined as separate array parameter (pq31) which depends on actual state of the parameter pq12 (see chapter 2.5).

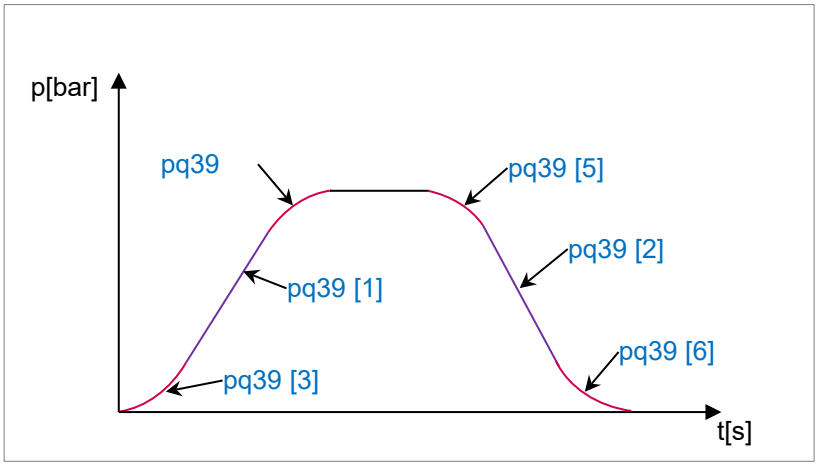
Index	Id-Text	Name	Function
0x395C	pq12	hydraulic system selector	Index of the applied pressure setpoint ramp mode pq31. Directly written or reflects the status in case when digital input selection is configured (pq38).
0x396A	pq26	pressure ramp out	Shows the output from the pressure setpoint ramp generator in units selected by pq44.
0x396F	pq31	pressure setpoint ramp mode	Operational performance for the ramp generator.
0x3976	pq38	hydraulic system selector source	Selection of the hydraulic system using the value in pq12 or binary value of the digital inputs I2, I3 and I4.
0x3977	pq39	pressure setpoint ramp settings	Parameter structure for configuration of the pressure setpoint ramp generator.
0x397C	pq44	pressure unit selection	Selects the pressure unit of the value shown in pq26.

pq31	pressure setpoint ramp mode			0x396F
Bit	Function	Value	Plaintext	Note
0	Ramp type	0	S-curve	S-curves.
		1	lin	Linear ramps.
1	Linear ramp up/down	0	sep. para	Separate settings for speed up and speed down.
		2	speed up para	Speed up parameter (pq39[1]) valid also for speed down (pq39[2]). Only effective if linear ramps selected.
2	S-curve type	0	continuous S-curve	See the explanation in the standard firmware manual.
		4	abort in S-curve	See the explanation in the standard firmware manual.
3	Ramp disable	0	ramp off	Turning off the ramp when bit is set
		8		

As already emphasized before, the selection in pq44 has no influence on the pressure setpoint ramp settings units; they are always referred to bars.

pq39	pressure setpoint ramp settings	0x3977

Subidx	Name	Function
1	speed up [bar/s]	Pressure rising speed in [bar/s].
2	speed down [bar/s]	Pressure decreasing speed in [bar/s].
3	acc low pressure [bar/s^2]	Pressure acceleration at low values in [bar/s^2].
4	acc high pressure [bar/s^2]	Pressure acceleration at high values in [bar/s^2].
5	dec high pressure [bar/s^2]	Pressure deceleration at high values in [bar/s^2].
6	dec low pressure [bar/s^2]	Pressure deceleration at low values in [bar/s^2].



Picture 6: Pressure setpoint ramp generator

2.16 Band-stop filter

A notch filter is implemented in order to suppress a certain range of frequency on pressure feedback signal.

Index	Id-Text	Name	Function
0x3974	pq36	band stop (notch) filter	Parameter structure for configuration of the notch filter.
Subidx	**Name**		**Function**
1	Enable filter		Enable/disable of the filter.
2	Disturbance frequency		Filter center frequency [Hz].
3	Bandwith		Filter bandwidth [Hz].

2.17 Speed stop at minimum pressure

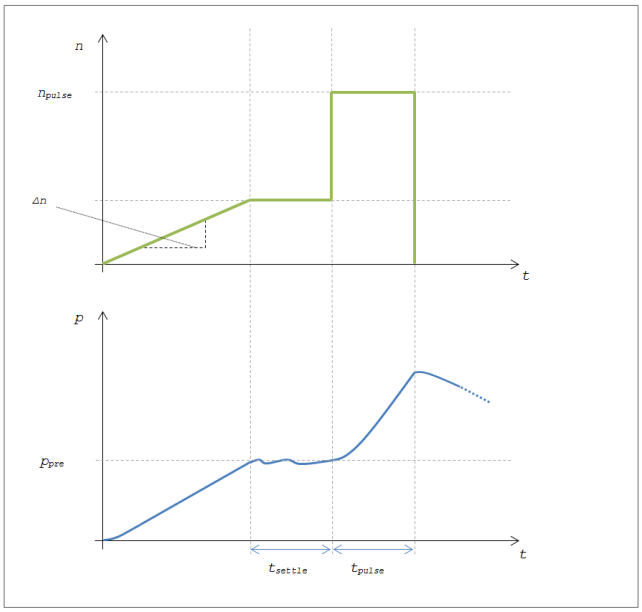
In order to avoid regulation fluctuations at the pressures near zero, there is a possibility to force the output speed to zero in such condition. Both levels defined in the parameters pq27 and pq28 has to be satisfied at the same time for the activation of the speed stop condition.
In order to provide smoother exit from stopped mode a parametrized hysteresis (pq43) in the actual pressure threshold is built in.

Index	Id-Text	Name	Function
0x396B	pq27	low pressure setpoint thr. for operation	Minimal level of the pressure setpoint given

			in [bar] under which the “speed stop” condition will be activated. For the pressure set-point is considered the output from the ramp generator.
0x396C	pq28	low pressure feedback thr. for operation	Minimal level of the actual pressure given in [bar] under which the “speed stop” condition will be activated. For the actual pressure is considered the pressure smoothed with the band stop filter (if activated).
0x397B	pq43	low pressure thr. for operation hyst.	Threshold hysteresis of the actual pressure given in [bar] for the “speed stop” condition.

2.18 PQ controller (hydraulic) autotuning

This structure defines parameter needed for hydraulic autotuning procedure done via wizard. The aim of this procedure is automatically determination of the regulation parameters for the pressure control loop.
The automatic hydraulic autotuning procedure consists from three phases:



Picture 7: PQ controller autotuning procedure

- Phase 1: Speed increment (Δn: pq37 [3]) until the predefined pressure ($p_{pre:}$ pq37 [2]) is reached.
- Phase 2: Settling time. The last speed amount is kept constant for defined time (t_{settle}: pq37 [4]).
- Phase 3: Speed impulse. The set speed is for the defined time (t_{pulse}: pq37 [6]) at the configurable value (n_{pulse}: pq37 [5]) increased, and after that reduced to zero.

Index	Id-Text	Name	Function
0x3975	pq37	pq control autotuning	Parameter structure for configuration of the pressure control loop autotuning.
Subidx	Name		Function
1	status		Status of the autotunig procedure.
2	pre pressure level		Starting pressure for the speed impulse (p_{pre})

		given in [bar].
3	pre pressure speed increment [rpm/s]	Speed slope until the starting pressure is reached (Δn).
4	settle time	Settle time between reaching the starting pressure and beginning the speed impulse (t_{settle}).
5	pulse speed	Amount of the speed impulse (n_{pulse}).
6	pulse time	Duration of the speed impulse (t_{pulse}).
7	auto sequence enable	Activation of the autotuning procedure.

⚠ CAUTION

- The speed slope (pre pressure speed increment [rpm/s]) as well as the amount of the speed impulse (pulse speed) and the duration of the speed impulse (pulse time) should be configured from the user in such way that there is no danger for the system due to too fast pressure increase.

Details about the status of the hydraulic autotuning procedure are shown in pq37[1]:

pq37	status			0x3975
Bit	Function	Value	Plaintext	Note
0...3	Status	0	not started	Autotuning procedure not started yet.
		1	active - incrementing speed for pre pressure	Phase 1.
		2	active - settle time	Phase 2.
		3	active - speed pulse	Phase 3.
		4	finished	Autotunig procedure finished.
		5	error	Error.
		6...15	reserved	Reserved.
4...7	Error code	0	OK	No error.
		16	drive error (ru01)	Some drive error (ru01) occurred during running the autotuning sequence.
		32	configuration error	Autotuning configuration error. (Reserved for future upgrading, not used in this version).
		48	auto sequence error	Error during autotunig sequence, possible causes: - The speed for reaching a starting pressure is already higher than defined amount for speed impulse.

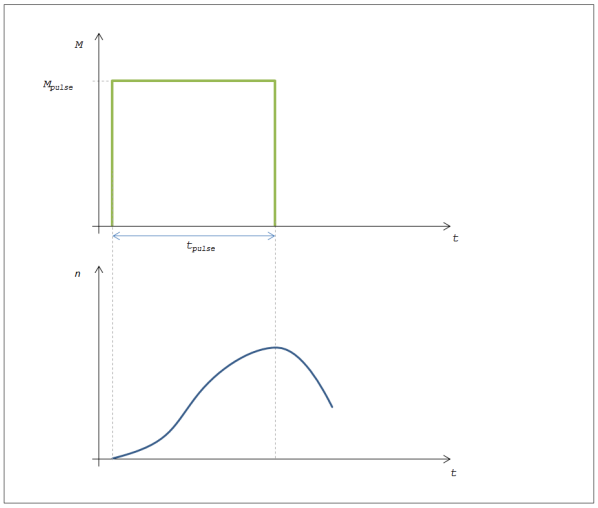
Additionally, the status word (pq00) indicates when the autotuning procedure is active (bit 7).

pq37	auto sequence enable	0x3975
Value	Status	Function
0	disabled	Deactivation of the automatic hydraulic autotuning procedure.
1	enabled	Activation of the automatic hydraulic autotuning procedure. Precondition for starting the procedure is that the velocity mode is

pq37	auto sequence enable	0x3975
Value	Status	Function
		configured (co01), PQ-Controller is activated (pq01) and the state machine status of the drive is “**Operation enabled**”.

2.19 Speed controller autotuning (inertia identification)

This parameter structure is an addition to the cs parameter group of the standard firmware which is used together with the COMBIVIS Wizard for automatically adjustment of the speed control loop regulation parameters. The inertia identification (autotuning) procedure assumes the generation of the torque impulse with predefined amount (cs28 [2]) and duration (cs28 [3]) on the motor shaft.



Picture 8: Speed controller autotuning procedure

Index	Id-Text	Name	Function
0x271C	cs28	inertia identification	Parameter structure for configuration of the speed control loop autotuning.
Subidx	**Name**		**Function**
1	status		Status of the autotunig procedure.
2	pulse torque		Amount on the torque impulse (M_{pulse}) in % of the rated torque (dr09).
3	pulse time		Duration of the torque impulse (t_{pulse}).
4	auto sequence enable		Activation of the autotuning procedure.

cs28	auto sequence enable	0x271C
Value	**Status**	**Function**
0	disabled	Deactivation of the automatic inertia identification autotuning procedure.
1	enabled	Activation of the automatic inertia identification autotuning procedure. Pre-condition for starting the procedure is that the velocity mode is configured (co01) and the state machine status of the drive is “**Operation enabled**”.

cs28	status			0x271C
Bit	Function	Value	Plaintext	Note
0...3	Status	0	not started	Autotuning procedure not started yet.
		1	active	Torque impulse active
		2	finished	Autotunig procedure finished.
		3	error	Error.
		4...6	reserved	Reserved.
4...7	Error code	0	OK	No error.
		16	drive error (ru01)	Some drive error (ru01) occurred during running the autotuning sequence.
		32	configuration error	Autotuning configuration error. (Reserved for future upgrading, not used in this version).
		48	auto sequence error	Error during autotunig sequence, possible causes: - Torque impulse reached maximal allowed value.

2.20 Power display

It is possible to monitor the amount of power and energy consumed by the pump. For energy monitor it is possible to change time base of calculation with pq35. Accuracy of the energy calculation is only slightly affected with the parameter pq35, it should be considered more as refresh rate of the energy display (pq34).

Index	Id-Text	Name	Function
0x3971	pq33	Hydraulic power display	Hydraulic power consumed by the pump [kW].
0x3972	pq34	Hydraulic energy display	Hydraulic energy consumed by the pump [kWh].
0x3973	pq35	time base for energy calculation	Refresh rate for hydraulic energy display.

2.21 Digital Output: Flag Operands

Servo pump control application extends the list of the available parameters for flag operands A and B in do01 and do02 with:

do01	flag operand A		0x2601
do02	flag operand B		0x2602
Value	Plaintext	Note	
2	PQ status (pq00)	PQ controller status word.	
21	pressure feedback value (pq05)	Actual pressure given in units selected by pq44.	
22	pressure setpoint (pq06)	Pressure setpoint in units selected by pq44.	
50	speed/flow setpoint PQ (pq07)	Speed [1/min] or flow [l/min] setpoint.	
51	flow rate monitor (pq24)	Flow rate monitor [l/min].	

2.22 Braking transistor mode

The servo pump control application extends the standard software (which relays on version V2.5) also with the parameter pn33 braking transistor mode. The parameter is used to configure different modes of braking transistor activation/deactivation behavior; detailed description of this parameter can be found in the Programming manual for standard software based on version V2.8.

The breaking transistor function shall be enable also in case of error or when the modulation is released. In this way if the drives goes in error when there is still high pressure on the pump, the back flow on the pump will make the motor run backwards, charging the DC bus but the breaking transistor function will intervene in order to avoid any damage on the capacitor.

For a correct behavior in case of error, all bit of pn33 braking transistor mode must be set to 0.

3 Annex

3.1 Inverter parameters (address / resolution /type)

Abbreviations	RO	ReadOnly		
	PD	available for ProcessDataCommunication		
	CAN	CAN-OPEN type	V	VAR
			ST	Structure
			A	Array

For structures, the name of the structure is entered in the row of subindex 0 (number).

3.1.1 Servo pump specific parameters

pq: pressure flow parameter

Index	Sub-Idx	CAN	Type	IDtxt	Name	Upper Limit	Lower Limit	Default Value	Mult.	Div	Unit	PD	RO
3950h	0	V	UINT16	pq00	Status PQ	---	---	---	1	1	---	X	X
3951h	0	V	UINT8	pq01	PQ controller control word	63	0	0	1	1	---	X	---
3952h	0	A	UINT8	pq02	pressure feedback source	8	8	8	1	1	---	---	X
	1...8		UINT8			2	1	1	1	1	---	X	---
3953h	0	V	UINT8	pq03	pressure setpoint source	2	0	0	1	1	---	X	---
3954h	0	V	UINT8	pq04	speed/flow source PQ	3	0	0	1	1	---	X	---
3955h	0	V	UINT16	pq05	pressure feedback value	---	---	---	1	10	---	X	X
3956h	0	V	UINT16	pq06	pressure setpoint	65535	0	0	1	10	---	X	---
3957h	0	V	UINT16	pq07	speed/flow setpoint PQ	40000	0	0	1	10	---	X	---
3958h	0	V	UINT32	pq08	pump displacement [cm^3/rev]	1000000	0	0	1	100	---	X	---
3959h	0	A	UINT8	pq09	pressure equivalent	2	2	2	1	1	---	---	X
	1...2		UINT16			4096	0	200	1	10	bar	X	---
395Ah	0	V	UINT16	pq10	speed/flow PQ equivalent	4000	0	2000	1	1	---	X	---
395Bh	0	V	INT16	pq11	min. reverse speed	0	-400	-50	1	1	1/min	X	---
395Ch	0	V	UINT8	pq12	hydraulic system selector	8	1	1	1	1	---	X	---
395Dh	0	V	INT16	pq13	max. reverse speed	0	-4000	-1000	1	1	1/min	X	---
395Eh	0	A	UINT8	pq14	Tau 1	8	8	8	1	1	---	---	X
	1...8		UINT16			4000	1	1	1	1	ms	X	---
395Fh	0	A	UINT8	pq15	Tau 2	8	8	8	1	1	---	---	X
	1...8		UINT16			4000	1	1	1	1	ms	X	---
3960h	0	A	UINT8	pq16	integrator gain [ms^-1]	8	8	8	1	1	---	---	X
	1...8		UINT16			100	1	1	1	1000	---	X	---
3961h	0	A	UINT8	pq17	proportional gain [rpm/bar]	8	8	8	1	1	---	---	X
	1...8		UINT16			20000	0	100	1	100	---	X	---
3962h	0	V	UINT16	pq18	safe speed	4000	0	300	1	1	1/min	X	---
3963h	0	V	UINT16	pq19	min. derivative speed	4000	0	200	1	1	1/min	X	---
3964h	0	V	UINT16	pq20	tauD	4000	1	10	1	1	ms	X	---

pq: pressure flow parameter													
Index	**Sub-Idx**	**CAN**	**Type**	**IDtxt**	**Name**	**Upper Limit**	**Lower Limit**	**Default Value**	**Mult.**	**Div**	**Unit**	**PD**	**RO**
3965h	0	V	UINT16	pq21	derivative pressure K	1000	1	10	1	10	---	X	---
3966h	0	V	UINT32	pq22	saturation current	1932735282	0	0	1	100	A	X	---
3967h	0	V	UINT16	pq23	hydraulic capacity x 10^-7 [m^3/bar]	10000	1	100	1	100	---	X	---
3968h	0	V	INT16	pq24	flow rate [l/min]	---	---	---	1	10	---	X	X
3969h	0	V	UINT8	pq25	speed/flow selector	1	0	0	1	1	---	X	---
396Ah	0	V	UINT16	pq26	pressure ramp out	---	---	---	1	10	---	X	X
396Bh	0	V	UINT16	pq27	low pressure setpoint thr. for operation	500	0	0	1	10	bar	X	---
396Ch	0	V	UINT16	pq28	low pressure feedback thr. for operation	500	0	0	1	10	bar	X	---
396Dh	0	V	UINT16	pq29	reverse speed timer	10000	0	500	1	1	ms	X	---
396Eh	0	V	UINT8	pq30	lower pressure thr for reverse speed	100	5	10	1	1	bar	X	---
396Fh	0	A	UINT8	pq31	pressure setpoint ramp mode	8	8	8	1	1	---	---	X
	1...8		UINT8			15	0	0	1	1	---	X	---
3970h	0	V	UINT32	pq32	multipump displacement [cm^3/rev]	1000000	0	0	1	100	---	X	---
3971h	0	V	UINT32	pq33	Hydraulic power display	---	---	---	1	1000	kW	X	X
3972h	0	V	UINT32	pq34	Hydraulic energy display	4294967295	0	0	1	1000	KWh	X	---
3973h	0	V	UINT16	pq35	time base for energy calculation	36000	1	10	1	10	s	X	---
3974h	0	ST	UINT8	pq36	band-stop (notch) filter	---	---	---	1	1	---	X	X
	1		UINT8		Enable filter	1	0	0	1	1	---	X	---
	2		UINT16		Disturbance frequency	2000	1	10	1	10	Hz	X	---
	3		UINT16		Bandwith	1000	1	100	1	10	Hz	X	---
3975h	0	ST	UINT8	pq37	pq control autotuning	---	---	---	1	1	---	X	X
	1		UINT8		status	---	---	---	1	1	---	X	X
	2		UINT16		pre pressure level	4096	1	10	1	10	bar	X	---
	3		UINT16		pre pressure speed increment [rpm/s]	1000	1	1	1	1	---	X	---
	4		UINT16		settle time	65535	0	100	1	1	ms	X	---
	5		UINT32		pulse speed	128000	1	100	1	1	1/min	X	---
	6		UINT16		pulse time	65535	1	50	1	1	ms	X	---
	7		UINT8		auto sequence enable	1	0	0	1	1	---	X	---
3976h	0	V	UINT8	pq38	hydraulic system selector source	1	0	0	1	1	---	X	---
3977h	0	ST	UINT8	pq39	pressure setpoint ramp settings	---	---	---	1	1	---	X	X
	1		INT32		speed up [bar/s]	429496704	1	2000	1	100	---	X	---
	2		INT32		speed down [bar/s]	429496704	1	2000	1	100	---	X	---
	3		INT32		acc low pressure [bar/s^2]	13094412	1	10000	1	100	---	X	---
	4		INT32		acc high pressure [bar/s^2]	13094412	1	10000	1	100	---	X	---
	5		INT32		dec high pressure [bar/s^2]	13094412	1	10000	1	100	---	X	---
	6		INT32		dec low pressure [bar/s^2]	13094412	1	10000	1	100	---	X	---
3978h	0	A	UINT8	pq40	variable Kp pressure gain	2	2	2	1	1	---	---	X

pq: pressure flow parameter													
Index	**Sub-Idx**	**CAN**	**Type**	**IDtxt**	**Name**	**Upper Limit**	**Lower Limit**	**Default Value**	**Mult.**	**Div**	**Unit**	**PD**	**RO**
	1...2		UINT16			1000	100	100	1	1	%	X	---
3979h	0	A	UINT8	pq41	press. err. thr. for var. Kp gain	2	2	2	1	1	---	---	X
	1...2		UINT8			200	0	10	1	1	bar	X	---
397Ah	0	V	UINT8	pq42	lower pressure thr. rev. speed hyst.	255	0	0	1	10	bar	X	---
397Bh	0	V	UINT8	pq43	low pressure thr. for operation hyst.	255	0	0	1	10	bar	X	---
397Ch	0	V	UINT8	pq44	pressure unit selection	2	0	0	1	1	---	X	---

cs: control speed parameter													
Index	**Sub-Idx**	**CAN**	**Type**	**IDtxt**	**Name**	**Upper Limit**	**Lower Limit**	**Default Value**	**Mult.**	**Div**	**Unit**	**PD**	**RO**
271Ch	0	ST	UINT8	cs28	inertia identification	---	---	---	1	1	---	X	X
	1		UINT8		status	---	---	---	1	1	---	X	X
	2		UINT16		pulse torque	5000	0	200	1	10	%	X	---
	3		UINT16		pulse time	65535	1	50	1	1	ms	X	---
	4		UINT8		auto sequence enable	1	0	0	1	1	---	X	---

an: analog input output parameter													
Index	**Sub-Idx**	**CAN**	**Type**	**IDtxt**	**Name**	**Upper Limit**	**Lower Limit**	**Default Value.**	**Mult.**	**Div**	**Unit**	**PD**	**RO**
3315h	0	V	UINT8	an21	AN3 mean filter	15	0	4	1	4	ms	X	---
3316h	0	V	UINT16	an22	AN3 PT1 filter	65535	0	1000	1	1000	ms	X	---
3317h	0	V	UINT16	an24	AN3 zero point hysteresis	1000	0	82	100	4096	%	X	---
3318h	0	V	INT16	an25	AN3 gain	20000	-20000	1000	1	1000	---	X	---
3319h	0	V	INT16	an26	AN3 offset X	4096	-4096	0	100	4096	%	X	---
331Ah	0	V	INT16	an27	AN3 offset Y	4096	-4096	0	100	4096	%	X	---
331Bh	0	V	INT16	an28	AN3 neg limit	16384	-16384	-16384	100	4096	%	X	---
331Ch	0	V	INT16	an29	AN3 pos limit	16384	-16384	16384	100	4096	%	X	---

3.2 History of changes

From revision	Chapter	Change
05/2020		Application Note – Servo Pump Control
	2.2	Extend the control word with the “enable wire break monitor” bit.
	2.3	Extend the status word with the “PQ stop” bit.
	2.4	Extend the Servo pump specific exception with “ERROR PQ-Controller pressure feedback wire break” error code.
	2.6	Description of wire break monitor functionality added.
	2.12.1	Description of adaptive proportional gain functionality added.

	2.17	Description of speed stop at minimum pressure functionality added.
	3.1.1	Servo Pump specific parameters tables.
07/2021	3.1.1	Change the limits for the parameter pq24.
	2.22	Chapter added.
08/2021	2.11.1	pd00 bit 5 changed to bit 4.
	2.18	pd00 bit 6 changed to bit 7 .
09/2022	2.5	Chapter added.
	2.9	Correct the description of the parameter pq10. Add info block for the S6-K control boards.
	2.2	Update of the control word bits (bit 5 and caution symbol are added).
	2.3	Update of the status word bits (bit 8 is added).
	3.1	Update abbreviations table description.
	3.1.1	Update parameter description.
	2.6	Update pressure feedback behaviour.
	2.7	Update pressure setpoint behaviour.
	2.11.1	Update reverse speed operation behaviour.
	2.12	Simplify the description of the controller gain.
	2.15	Update pressure setpoint ramp behaviour.
	2.17	Update stopped mode behaviour.
	2.21	Update the flags operands description.
	2.13	Add picture reference.
09/2023	2.9	Input voltage of AN3 corrected to 0…10 V.

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KEB Automation KG Südstsraße 38 32683 Barntrup Tel. +49 5263 401-0 E-Mail: info@keb.de