PowerXL™

DG1 Variable Frequency Drives
Torque Control

Level 3	1 – Fundamental – No previous experience necessary 2 – Basic – Basic knowledge recommended 3 – Advanced – Reasonable knowledge required 4 – Expert – Good experience recommended

Powering Business Worldwide

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Contents

Danger! - Dangerous electrical voltage!

- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally restarted.
- Verify isolation from the supply.
- Cover or enclose any adjacent live components.
- Follow the engineering instructions (AWA/IL) for the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.
- Before installation and before touching the device ensure that you are free of electrostatic charge.
- The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization. The system installer is responsible for implementing this connection.
- Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions.
- Suitable safety hardware and software measures should be implemented for the I/O interface so that an open circuit on the signal side does not result in undefined states.
- Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the specification, otherwise this may cause malfunction and/or dangerous operation.
- Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatching of the emergency-stop devices must not cause a restart.
- Devices that are designed for mounting in housings or control cabinets must only be operated and controlled after they have been properly installed and with the housing closed.
- Wherever faults may cause injury or material damage, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, mechanical interlocks etc.).
- Frequency inverters may have hot surfaces during and immediately after operation.
- Removal of the required covers, improper installation or incorrect operation of motor or frequency inverter may destroy the device and may lead to serious injury or damage.
- The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live frequency inverters.
- The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g. with regard to cable cross sections, fuses, PE).
- Transport, installation, commissioning and maintenance work must be carried out only by qualified personnel (IEC 60364, HD 384 and national occupational safety regulations).
- Installations containing frequency inverters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the frequency inverters using the operating software are permitted.
- All covers and doors must be kept closed during operation.
- To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the frequency inverter (increased motor speed or sudden standstill of motor). These measures include: – Other independent devices for monitoring safety related variables (speed, travel, end positions etc.).
    - Electrical or non-electrical system-wide measures (electrical or mechanical interlocks).
- Never touch live parts or cable connections of the frequency inverter after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs.

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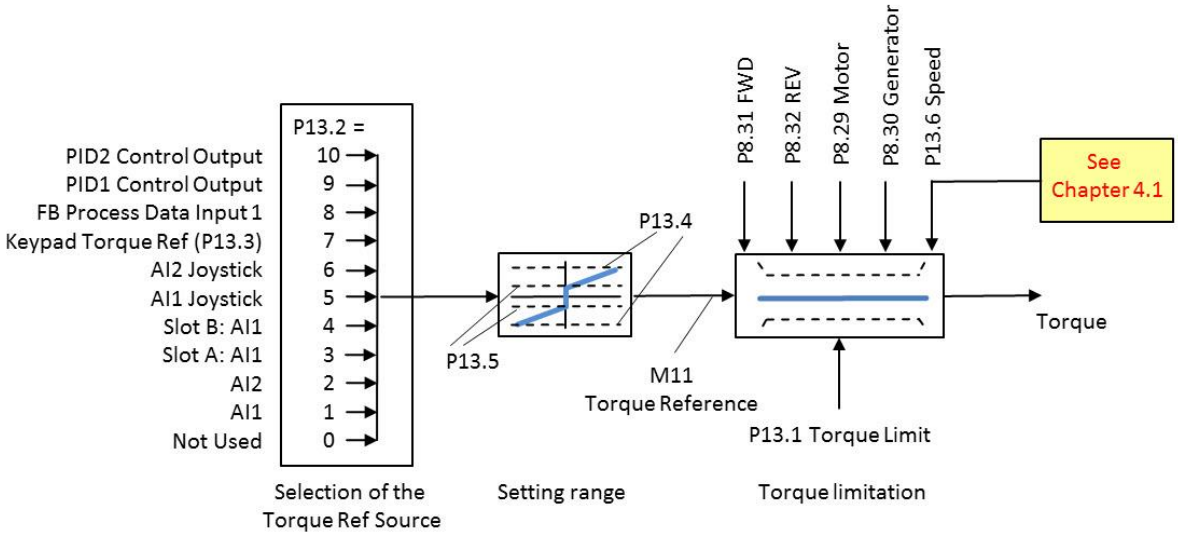
1 General

The variable frequency drives of the series **PowerXL™ DG1** offer the possibility to control the torque of the connected motor. To use this feature the motor control mode has to be set accordingly. (See 2).

When the torque of a motor is controlled, the speed depends on the load. This means, that the speed is the one, where the motor torque corresponds to the load torque. Torque as well as speed can be limited to prevent unwanted situations of the machine.



The functions described here, refer to an application software version 1.02.xxxx and above (see parameter P21.2.3).

2 Selection of the Motor Control Mode

The motor control mode is set with P8.1 „Motor Control Mode". The setting "Open Loop Torque Control (6)" must be selected. In this mode no external torque feedback signal is necessary (open loop).

The torque is calculated out of the motor data. All operating conditions, e.g. field weakening, are taken into account.

In torque mode the drive works in vector control. Therefore it is of utmost importance to set the right motor data and/or to perform a motor identification run (P8.14 "Identification"), when torque control is used.

Parameter	Name	Range	Default
P8.1	Motor Control Mode	Freq Control (0) Speed Control (1) Open Loop Speed Control (5) Open Loop Torque Control (6)	Freq Control (0)

3 Torque reference

The setting of the torque reference is done in percent of the motor rated torque, which is calculated from the motor data. The direction is determined by

- the control signals FWD and REV in case of a unipolar reference signal
- the sign in applications with a bipolar reference signal or when a joystick is used.

FWD respectively sign +:	positive torque = motoring cw respectively generating ccw
REV respectively sign -:	negative torque = motoring ccw respectively generating cw

3.1 Torque reference source

The torque reference source is selected with P13.2 „Torque Ref Select“, see also picture in chapter 1.

P13.2 „Torque Ref Select“

Not Used (0)	
AI1 (1)[1)]	The torque reference comes from analog input AI1 (terminals 2 and 3).
AI2 (2) [1)]	The torque reference comes from analog input AI2 (terminals 4 and 5).
Slot A: AI1 (3) [1)]	The torque reference comes from analog input AI1 on DXG-EXT-1AI2AO in Slot A.
Slot B: AI1 (4) [1)]	The torque reference comes from analog input AI1 on DXG-EXT-1AI2AO in Slot B.
AI1 Joystick (5) [1)]	The torque reference comes from analog input AI1 (terminals 2 and 3). Torque = 0 corresponds to the middle of the range. Example for a signal 0 … 10 V: 0 V = - P13.4 „Torque Ref Max“ 5 V = 0 % 10 V = + P13.4 „Torque Ref Max“
AI2 Joystick (6) [1)]	The torque reference comes from analog input AI2 (terminals 4 and 5). Torque = 0 corresponds to the middle of the range. Example see “AI1 Joystick”.
Keypad Torque Ref (7)	The torque reference is determined by the parameter P13.3 „Keypad Torque Ref“.
FB Process Data Input (8)	The torque reference comes from a connected fieldbus.
PID1 Control Output (9)	The torque reference comes from the output of controller PID1.
PID2 Control Output (10)	The torque reference comes from the output of controller PID2.

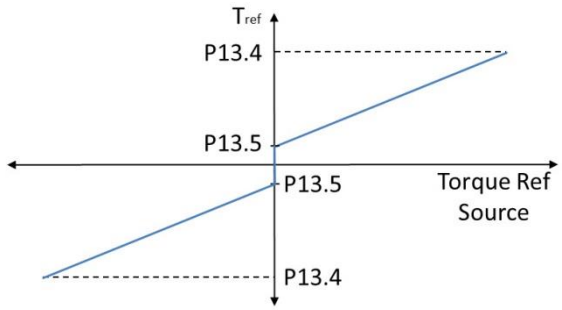
[1)] In torque control the signals from the analog inputs are taken 1:1. Parameters P2.2.3 up to P2.2.10 respectively P2.3.3 up to P2.3.10 (scaling, offset …) are not effective. The same is true for the parameters related to the inputs on DXG-EXT-1AI2AO.

With P13.11 „Torque Reference Filter TC“ a filter time can be set.

Parameter	Name	Range	Default
P13.2	Torque Ref Select	Not Used (0) AI1 (1) AI2 (2) Slot A: AI1 (3) Slot B: AI1 (4) AI1 Joystick (5) AI2 Joystick (6) Keypad Torque Ref (7) FB Process Data Input (8) PID1 Control Output (9) PID2 Copntrol Output (10)	Not Used (0)
P13.3	Keypad Torque Ref	-300.0 % … + 300.0 %	0.0 %
P13.11	Torque Reference Filter TC	0 … 32000 ms	0 ms

3.2 Torque reference setting range

The permitted setting range of the torque reference is determined by the parameters P13.4 „Torque Ref Max“ and P13.5 “Torque Ref Min”. These values are valid for both torque directions.



When, for example, an analog signal 0 … 10 V is used as torque reference, 0 V corresponds to the value set with P13.5 and +10 V to the one set with P13.4.

In case a torque in both directions is needed, P13.5 = 0 % should be set to prevent a skip at minimum reference signal.

Parameter	Name	Range	Default
P13.4	Torque Ref Max	0 … 300.0 %	100.0 %
P13.5	Torque Ref Min	0 … 300.0 %	0.0 %

4 Torque limitation

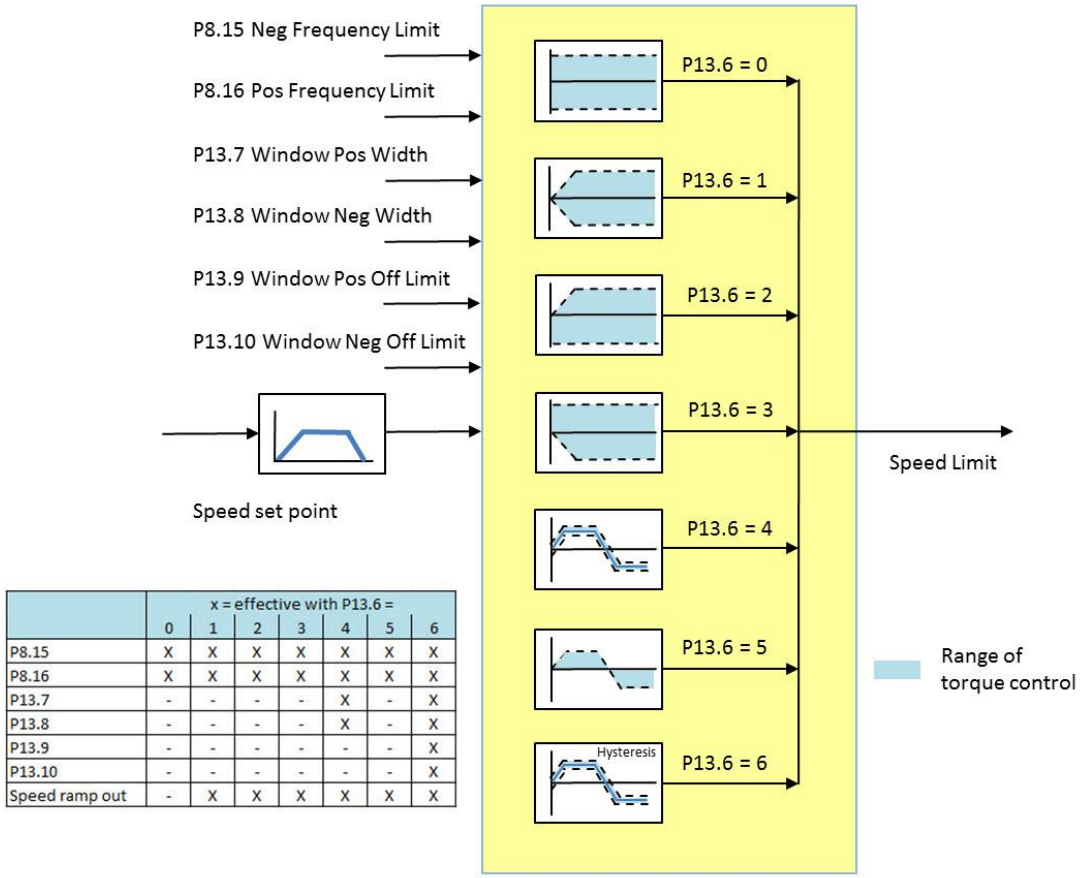
The torque of the motor can be limited depending on different measurements.

- General limit (P13.1 „Torque Limit“)
- Limit in motor mode (P8.29 „Motoring Torque Limit“)
- Limit in generator mode (P8.30 „Generator Torque Limit“)
- Limit in forward direction (cw) (P8.31 „Torque Limit Forward“)
- Limit in reverse direction (ccw) (P8.32 „Torque Limit Reverse“)
- Speed dependent limitation (P13.6 „Speed Limiter Mode“)
- Stall prevention (P13.12 „Pull Out Torque“) = break down torque / full load operating torque

These limits can be active simultaneously if required by the application,. The limit with the lowest setting is effective first, when this value is reached. See also picture in chapter 1.

Parameter	Name	Range	Default
P13.1	Torque Limit	0 … 400 %	400 %
P13.6	Speed Limiter Mode	See Chapter 4.1	
P13.12	Pull Out Torque	0 … 1000 %	250 %
P8.29	Motoring Torque Limit	0 … 300 %	300 %
P8.30	Generator Torque Limit	0 … 300 %	300 %
P8.31	Max Torque FWD	0 … 300 %	300 %
P8.32	Max Torque REV	0 … 300 %	300 %

4.1 Speed dependent limitation

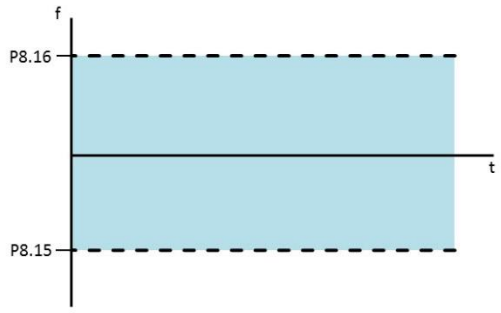
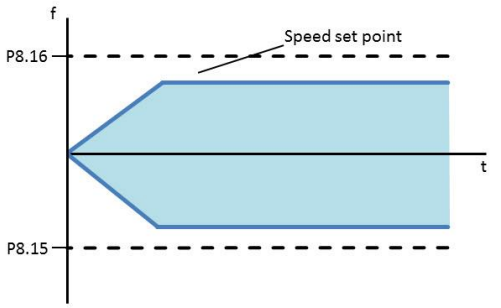


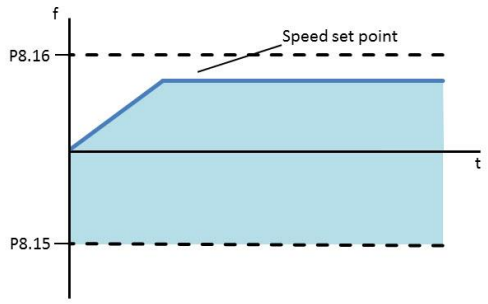
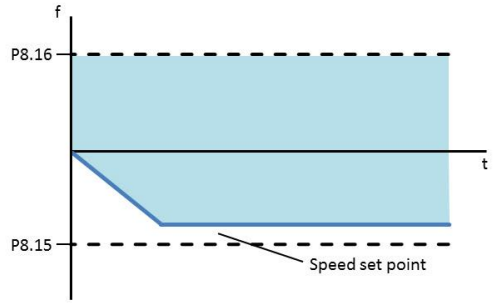
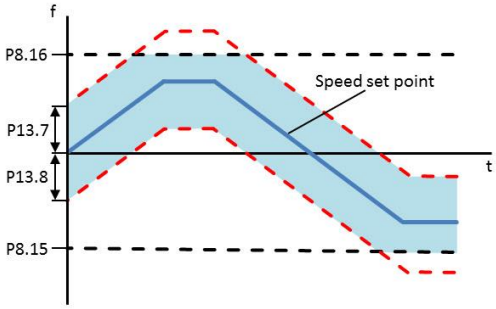
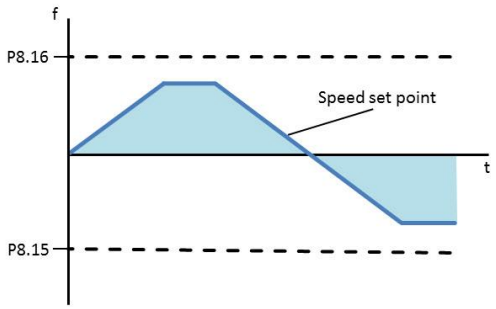
	x = effective with P13.6 =						
	0	1	2	3	4	5	6
P8.15	X	X	X	X	X	X	X
P8.16	X	X	X	X	X	X	X
P13.7	-	-	-	-	X	-	X
P13.8	-	-	-	-	X	-	X
P13.9	-	-	-	-	-	-	X
P13.10	-	-	-	-	-	-	X
Speed ramp out	-	X	X	X	X	X	X

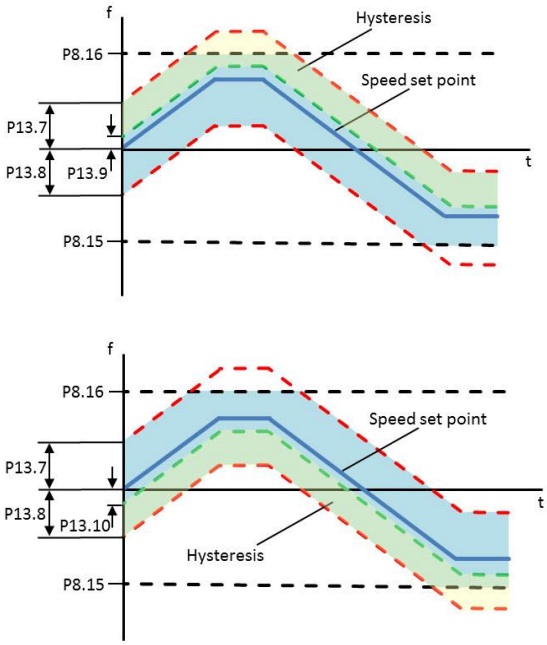
The setting of parameter P13.6 „Speed Limiter Mode“ determines the speed range, inside which torque control can be performed. The pictures have to be understood in a way, that speed control is possible inside the blue shaded areas. In case the speed limit is reached, the drive remains at this speed. For details of the setting possibilities see below.

With the settings P13.6 = 1 to P13.6 = 6 the limit is not a constant value, but depending on the speed reference at the output of the ramp. In most cases a limitation depending on a speed controlled drive is required. One example is a torque controlled drive, which generates a certain tension on a material, which suddenly ruptures. Without monitoring the speed, the drive would accelerate until its speed limit. Because one doesn't want that kind of reaction, the speed has to be limited to line speed +x %. It is necessary, that the torque controlled drive gets the information about the line speed. This is achieved by applying the same speed reference to the speed controlled drive and to the torque controlled one, where also the same ramp times (P1.3 “Accel Time 1” and P1.4 “Decel Time 1”) have to be set. Alternatively the actual speed of the speed controlled drive can be used as a reference. In this case the ramp times of the torque controlled drive have to be set to their minumum value (see example 2 in chapter 6.2).

With all settings of P13.6 “Speed Limiter Mode” the speed is always limited by P1.2 “Max Frequency”, P8.15 “NegFrequency Limit” and P8.16 “Pos Frequency Limit”. P1.2 “Max Frequency” has the highest priority.

P13.6 = NegFreqMax … PosFreqMax (0) 	The speed range, inside which a torque control can take place, is bounded by the parameters P8.15 “Neg Frequency Limit” and P8.16 “Pos Frequency Limit”. • P8.15 is effective in reverse direction • P8.16 is effective in forward direction
P13.6 = -|FreqRampOut| … +|FreqRampOut| (1) 	Torque control is performed between standstill and the speed, which corresponds to the speed reference at the output of the ramp. The sense of rotation is not of importance. In case the speed of the torque controlled drive corresponds to the speed reference at the output of the ramp, the drive runs speed controlled instead of torque controlled. When the speed drops, a commutation back to torque control takes place automatically.

P13.6 = NegFreqMax … FreqRampout(MIN) (2) 	In forward direction torque control is performed between standstill and the speed, which corresponds to the speed reference at the output of the ramp. In case the speed of the torque controlled drive corresponds to the speed reference at the output of the ramp, the drive runs speed controlled instead of torque controlled. When the speed drops, a commutation back to torque control takes place automatically. In reverse direction torque control is possible up to the speed defined with P8.15.
P13.6 = FreqRampOut … PosFreqMax (MAX) (3) 	In reverse direction torque control is performed between standstill and the speed, which corresponds to the speed reference at the output of the ramp. In case the speed of the torque controlled drive corresponds to the speed reference at the output of the ramp, the drive runs speed controlled instead of torque controlled. When the speed drops, a commutation back to torque control takes place automatically. In forward direction torque control is possible up to the speed defined with P8.16.
P13.6 = FreqRampOut ± WindowPosNegWidth(4) 	When the speed of the torque controlled drive is inside the tolerance band around the speed reference at the output of the ramp, torque control is performed. The permissible deviation is bounded above by P13.7 “Window Pos Width” and below by P13.8 “Window Neg Width”. In case the red dashed line is reached, the drive runs speed controlled. When the speed comes back into the tolerance band a commutation back to torque control takes place automatically. The maximum possible speed is defined by the parameters P8.15 and P8.16.
P13.6 = 0…FreqRampOut(pos or neg direction)(5) 	In both directions torque control is performed between standstill and the speed, which corresponds to the speed reference at the output of the ramp. In case the speed of the torque controlled drive corresponds to the speed reference at the output of the ramp, the drive runs speed controlled instead of torque controlled. When the speed drops, a commutation back to torque control takes place automatically.

P13.6 = FreqRamp ± Window/Pos/Neg/PosOff/NegOff (6) 	When the speed of the torque controlled drive is inside the tolerance band around the speed reference at the output of the ramp, torque control is performed. The permissible deviation is bounded above by P13.7 “Window Pos Width” and below by P13.8 “Window Neg Width”. In case the red dashed line is reached, the drive runs speed controlled. When the speed comes back into the tolerance band a commutation back to torque control takes place automatically. Thereby a hysteresis is effective (green shaded area). When deviating in the upper direction, the speed must undercut the threshold defined with P13.9 “Window Pos Off Limit” first, before it changes back to torque control. The same is true for deviations in the lower direction, where the threshold for reactivating torque control is defined with P13.10 “Window Neg Off Limit”. The hysteresis prevents, that a drive which operates close to the red dashed line commutes between torque control and speed control permanently, which can lead to oscillations inside the application. The maximum possible speed is defined by the parameters P8.15 and P8.16.

Parameter	Name	Range	Default
P13.7	Window Pos Width	0.00 … 50.00 Hz	2.00 Hz
P13.8	Window Neg Width	0.00 … 50.00 Hz	2.00 Hz
P13.9	Window Pos Off Limit	0.00 … 2.00 Hz	0.00 Hz
P13.10	Window Neg Off Limit	0.00 … 2.00 Hz	0.00 Hz

5 Torque threshold signalling

Exceeding or undercutting a set torque value can be signalled by a digital output respectively a relay. “Torque Limit Superv (20)” has to be assigned to the respective output (P5.1 … P5.6).

The switching threshold is defined with P5.12 „Torque Limit Superv Val“ in percent of the motor rated torque. To prevent a continuous commutation when operating close to the threshold, a hysteresis can be set with P5.52 “Torque Limit Superv Hyst”.

P5.11 “Torque Limit Superv” determines, if an exceeding or an undercutting of the threshold is signalled.

- P5.11 = 0 → No Limit
  - Function is not active
- P5.11 = 1 → Low Limit Superv
  - The relay contact is closed respectively the digital output is active, when the value, set with P5.12, is undercut.
- P5.11 = 2 → High Limit Superv
  - The relay contact is closed respectively the digital output is active, when the value, set with P5.12, is exceeded.
- P5.11 = 3 → Brake-off Control
  - This setting is used with hoists, where a certain torque must be present, before a mechanical brake is deactivated.

Parameter	Name	Range	Default
P5.1 or P5.2 or P5.3 or P5.4 or P5.5 or P5.6	DO1 Function RO1 Function RO2 Function RO3 Function Virtual RO1 Function Virtual RO2 Function	Not used (0) … Torque Limit Superv (20) … Run Bypass/Drive (60)	
P5.11	Torque Limit Superv	No Limit (0) Low Limit Superv (1) High Limit Superv (2) Brake-off Control (3)	0
P5.12	Torque Limit Superv Val		100 %
P5.52	Torque Limit Superv Hyst	1 … 5 %	1 %

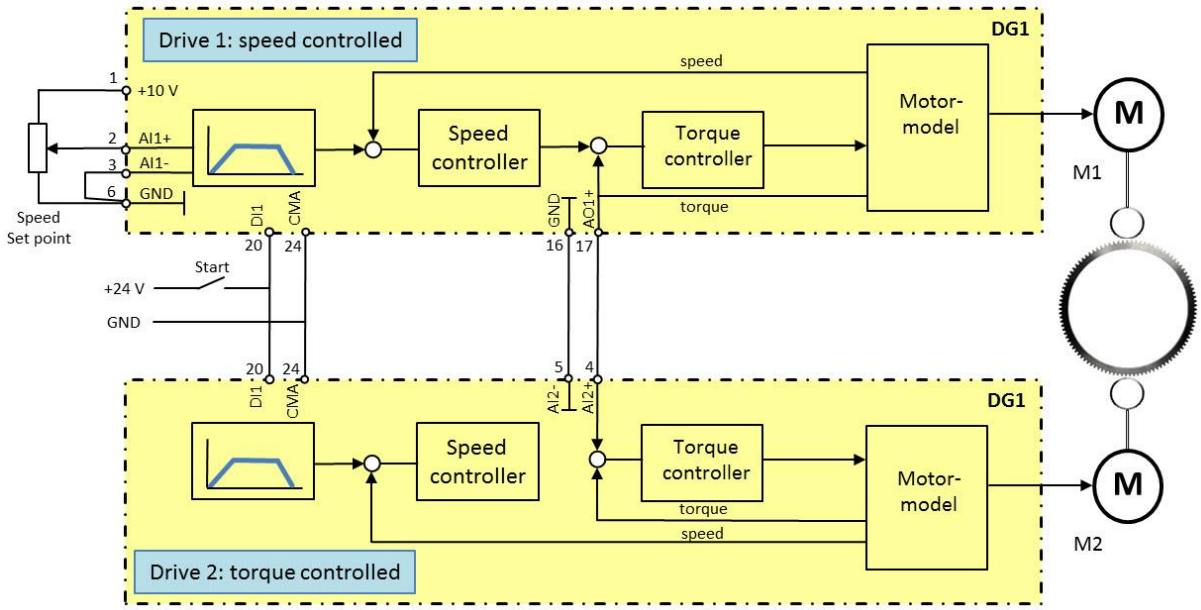
6 Examples

In the examples below only the application specific parameters are mentioned. The general configuration of the drive, e.g. enable signals … must be considered in addition.

In general it is of utmost importance to use the right and complete motor data. In addition a motor identification run (P8.14) must be performed to enable the internal motor model to calculate the right values for the motor torque.

6.1 Examples 1: Equal load sharing between two coupled motors

Two drives of the same power rating are mechanically coupled with a geared ring. The ring shall be controlled with variable speed and the load shared equally between the motors M1 and M2.



Motor M1 is speed controlled. The speed set point is defined by a potentiometer, which is connected to analog input AI1. The torque reference of drive 1 is also used as torque reference for drive 2, using analog output AO1 of drive 1 and analog input AI2 of drive 2. Ramp and speed controller of drive 2 are not used. Because the two motors are coupled mechanically, no speed supervision for drive 2 is necessary.

Variant A:

The ring operates in one direction only; braking and an additional starting torque are not necessary.

Application dependent setting of the parameters:

	Drive 1	Drive 2
Motor Control Mode	P8.1 = Open Loop Speed Control (5)	P8.1 = Open Loop Torque Control (6)
Torque reference = analog signal	Analog output AO1 is used (terminal 17). Increased starting torque is not necessary ➞ P4.1 „AO1 Mode“ = 0 – 10 V (1) P4.2 „AO1 Function“ = Motor Torque (0 – Nom) (5)	To connect the torque reference signal 0 … 10 V, analog input AI2 is used. ➞ P2.3.1 „AI2 Mode“ = 0 – 10 V (1) P2.3.2 „AI2 Signal Range“ = 0 – 100 % (0) Attention! Scaling and min/max limitation for AI2 are not effective here.
Reference source selection		P13.2 = AI2 (2)
Setting range of the reference		The signal 0 … 10 V corresponds to 0 … 100 % torque ➞ P13.4 „Torque Ref Max“ = 100.0 % P13.5 „Torque Ref Min“ = 0.0 %

Variant B:

The ring operates in two directions.

	Drive 1	Drive 2
Motor Control Mode	P8.1 = Open Loop Speed Control (5)	P8.1 = Open Loop Torque Control (6)
Torque reference = analog signal	Analog output AO1 is used (terminal 17). Both torque directions are possible ➞ P4.1 „AO1 Mode“ = 0 – 10 V (1) P4.2 „AO1 Function“ = Motor Torque (-2 - +2N) (20) (0 V = -200 % / 5 V = 0 % / 10 V = +200 %)	To connect the torque reference signal 0 … 10 V, analog input AI2 is used. ➞ P2.3.1 „AI2 Mode“ = 0 – 10 V (1) P2.3.2 „AI2 Signal Range“ = 0 – 100 % (0) Attention! Scaling and min/max limitation for AI2 are not effective here.
Reference source selection		5 V of the analog signal corresponds to 0.0 % torque. P13.2 = AI2 Joystick (6)
Setting range of the reference		The signal 0 … 10 V corresponds to -200 … +200 % torque ➞ P13.4 „Torque Ref Max“ = 200.0 % P13.5 „Torque Ref Min“ = 0.0 % The settings of P13.4 and P13.5 apply to both directions of torque.

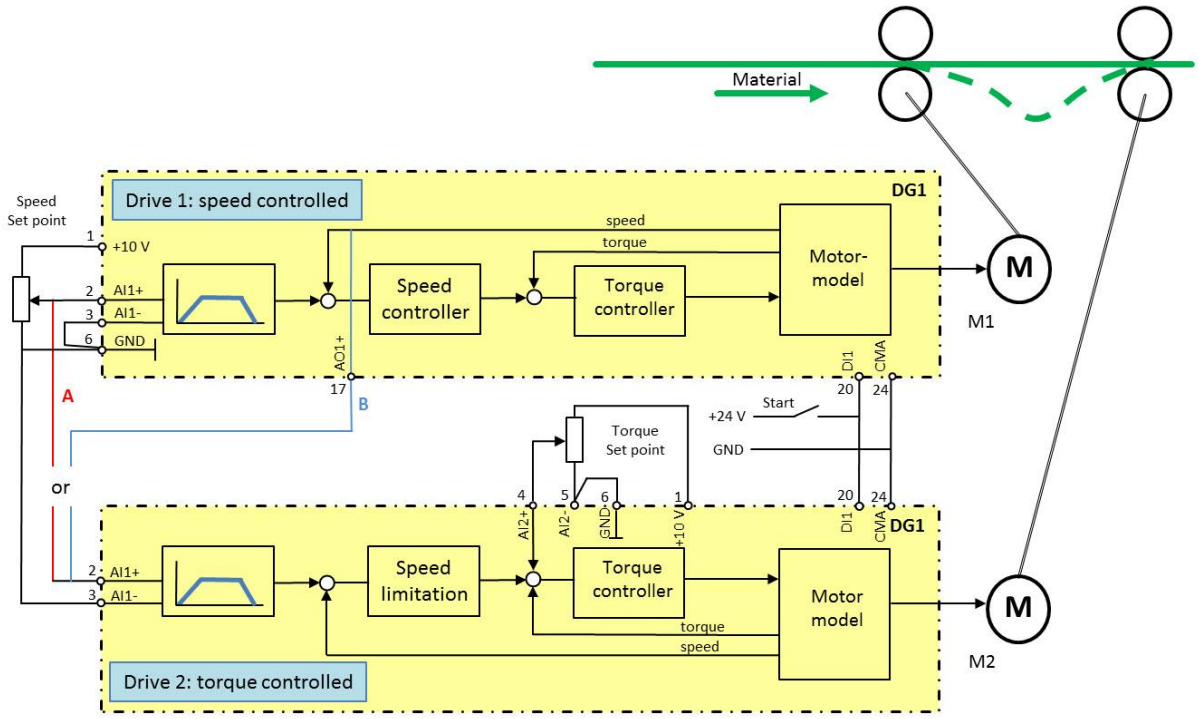
6.2 Example 2: Tension control of a calender

Two calenders, mounted in series, are transporting material. The speed and the tension of the material shall be adjustable. The setting range of the torque is required to be 10 … 100 % of the rated torque. This is necessary to compensate the friction inside the calender system. The tension is assumed to be 10 % across the complete speed range.

In case the rolls are opened respectively the material slips, the peripheral speed of the torque controlled calender may deviate 5 Hz from the line speed at the maximum. The mechanics of both calenders are assumed to be identical.

It can happen, that the material is not tightened at the point of start.

Because the material has to be preserved during acceleration and deceleration, ramp times must be set relatively long. A braking by the motors is therefore not necessary.



Motor M1 determines the line speed. The speed set point comes from a potentiometer and is connected to analog input AI1. Motor M2 is torque controlled and defines the tension of the material. In case the torque (tension) is set too high, it is possible than motor 2 tries to accelerate motor 1, which must be able to brake in this situation.

In this case of application it is of advantage to connect the d.c. bus of the two drives in parallel. For this the terminals R+ of both drives must be connected as well as the DC- ones. Both devices must be supplied simultaneously (terminals L1 / L2 / L3). The energy, which is possibly fed back by drive 1 into the d.c. bus when braking, is consumed by drive 2. Therefore no trip because of overvoltage occurs and no brake chopper is necessary.

The material tension is adjusted with the potentiometer for the torque set point. 10 % of rated motor torque is required at the very left position of the pot to compensate frictions inside the system. This is achieved in setting P13.5 “Torque Ref Min” to 10 %.

A torque controlled motor always tries to transfer the set torque (or tension in linear movements) to the load. When this is not possible, the torque is used to accelerate and the torque controlled drive accelerates until its maximum limit. In this case of application it is required, that the speed may deviate from the line speed 5 Hz maximum. When this boundary is reached, the speed is limitetd and the drive changes from torque control to speed control. For this the speed dependent torque limitation must be activated → P13.6 = 4. The band width can be set with P13.7 and P13.8 to 5 Hz.

To detect the actual line speed for comparing it with the speed of the torque controlled drive M2, the signal at the output of the ramp is used. This means that the torque controlled drive M2 must “know” the line speed. There are two possibilities (A and B).

In Case A the speed reference inputs of the drives M1 and M2 are connected in parallel. It is also necessary to set the ramp times of both drives (P1.3 “Accel Time 1” and P1.4 “Decel Time 1”) equally to prevent deviations during speed changes. Advantage is to have the information about a speed reference change simultaneously at both drives, not to have an offset in reaction time. Disadvantage is, that a possible drop in line speed (M1), e.g. because of overload, is not realized by the torque controlled drive M2.

In Case B one uses the actual speed of drive 1 instead of the speed reference. Now there is a possibility to realize also speed deviations of drive 1. Disadvantage is, that the two drives do not react simultaneously, because Motor 1 has to turn first, before drive 2 gets its reference for the speed limitation. This should play no role in most applications and is compensated by the tolerance band (here: 5 Hz). In this case the ramp times of drive 2 must be set to their minimum value, because the reference (Actual speed of drive 1) follows the ramp of drive 1 already.

When there is a material loop (green dashed line in the picture above), it is picked up by the torque controlled drive, because it increases the speed by 5 Hz, until the torque (tension) can be transferred to the material. Depending on the application, multiple measures are possible and it has to be decided on a case by case basis, which one will be used. This starts from a pickup of the loop by operating drive 2 manually up to an automatic detection and pickup. At this place only the basic principle is described.

	Drive 1	Drive 2
Motor Control Mode	P8.1 = Open Loop Speed Control (5)	P8.1 = Open Loop Torque Control (6)
Speed reference = analog signal	Analog input AI1 is used (terminals 2 + 3). 0 … 10 V ➞ P2.2.1 „AI1 Mode“ = 0 – 10 V (1) P2.2.2 „AI1 Signal Range“ = 0 – 100 % (0) Case B: Analog output AO1 is used for the actual line speed (terminal 17) ➞ P4.1 „AO1 Mode“ = 0 – 10 V (1) P4.2 „AO1 Function“ = Motor Speed (3)	Analog input AI1 is used (terminals 2 + 3). 0 … 10 V ➞ P2.2.1 „AI1 Mode“ = 0 – 10 V (1) P2.2.2 „AI1 Signal Range“ = 0 – 100 % (0) Case A: P1.3 and P1.4 of the torque controlled drive must have the same settings as the ones of the speed controlled drive. Case B: P1.3 and P1.4 must be set to their minimum values
Torque reference = analog signal		To connect the torque reference signal 0 … 10 V, coming from a potentiometer, analog input AI2 is used. ➞ P2.3.1 „AI2 Mode“ = 0 – 10 V (1) P2.3.2 „AI2 Signal Range“ = 0 – 100 % (0) Attention! Scaling and min/max limitation for AI2 are not effective here.
Reference source selection		P13.2 = AI2 (2)
Setting range of the reference		The signal 0 … 10 V corresponds to 10 … 100 % torque ➞ P13.4 „Torque Ref Max“ = 100.0 % P13.5 „Torque Ref Min“=10.0 %
Speed limitation		P13.6 „Speed Limiter Mode“= 4 P13.7 „Window Pos Width“ = 5 Hz P13.8 “Window Neg Width” = 5 Hz