Motors

Configuration

Motor selection

The motor is selected on the basis of the required torque, which is defined by the application, e.g. traveling drives, hoisting drives, test stands, centrifuges, paper and rolling mill drives, feed drives or main spindle drives. Gear units for movement conversion or for adapting the motor speed and motor torque to the load conditions must also be considered.

As well as the load torque, which is determined by the application, the following mechanical data are among those required to calculate the torque to be provided by the motor:

- Masses to be moved
- Diameter of the drive wheel/diameter
- Leadscrew pitch, gear ratios
- Frictional resistance data
- Mechanical efficiency
- Traversing paths
- Maximum velocity
- Maximum acceleration and maximum deceleration
- Cycle time

You must decide whether synchronous or asynchronous motors (induction motors) are to be used.

Synchronous motors should be selected for compact construction volume, low rotor moment of inertia and therefore maximum dynamic response.

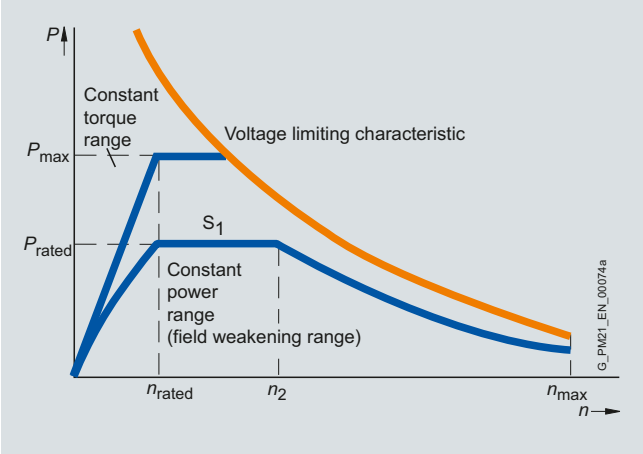
Asynchronous motors can be used to increase maximum speeds in the field-weakening range. Asynchronous motors (induction motors) for higher power ratings are also available.

The following factors are of prime importance during configuration:

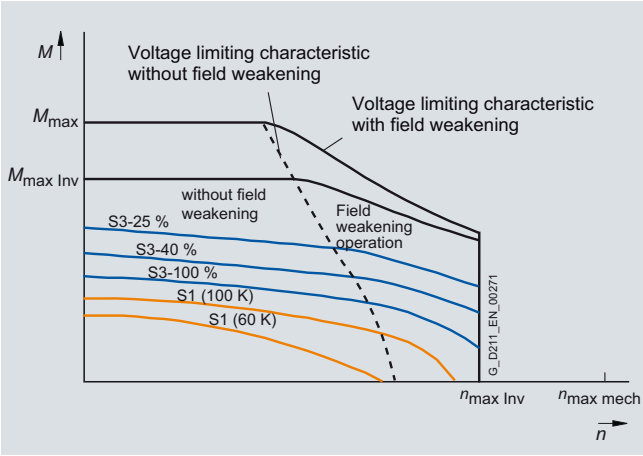
- The line supply configuration, when using specific types of motor and/or line filters on IT systems (non-grounded systems)
- The ambient temperatures and the installation altitude of the motors and drive components

The motor-specific limiting characteristics provide the basis for defining the motors.

These define the torque or power characteristic over speed and take into account the motor limits based on the DC-link voltage of the Power Module or Motor Module. The DC-link voltage in turn is dependent on the line voltage and, with multi-motor drives, on the type of Line Module.



Typical speed/power graph for asynchronous motors



Torque characteristics of synchronous motors

For detail engineering information, please refer to the motor configuration manuals.

An updated overview of configuration manuals is available in a number of languages on the Internet at:
www.siemens.com/motioncontrol

Follow menu items
Support > Technical Documentation > Ordering Documentation > Printed Documentation or download at:
Support > Technical Documentation > Download Documentation > DOConWEB.

The SIZER for Siemens Drives engineering tool is available to support engineering.

SINAMICS S120 Control Units

Overview

Simple technological tasks can be carried out by the SINAMICS S120 Control Unit itself. The CU320-2 Control Unit is available for multi-axis applications and the CU310-2 Control Unit for single drives.

Sophisticated Motion Control tasks are best supported by the powerful SIMOTION D Control Units (D410-2, D425-2, D435-2, D445-2, D455-2) with graded performance.

Each of these Control Units is based on an object-oriented SINAMICS S120 standard firmware which contains all the most popular *V/f* control modes and closed-loop control variants, that can be scaled to meet even the most advanced performance requirements.

The following are ready-to-configure drive objects (drive controls):

- The control for a line infeed: Infeed Control
- The control for the broad scope of rugged asynchronous (induction) motors and torque motors, including sensorless: Vector Control
- The control for permanent magnet synchronous and servo asynchronous motors with demanding dynamic requirements: Servo Control

All these control variants are based on the principle of field-oriented, closed-loop vector control.

The most commonly used *V/f* control modes are stored in the Vector Control drive object and are ideal for implementing even simple applications such as, for example, group drives with SIEMOSYN motors.

Guide to selecting a closed-loop control variant

The two tables below titled "Closed-loop control characteristics" and "Performance characteristics" are provided to help users select the "right" type of closed-loop control.

The drive control functions integrated in the SIMOTION D410-2, D4x5-2 and CX32-2 Control Units are based on the drive control of the SINAMICS S120 Control Units (firmware version V4.x), although there is a slight difference in functionality. For example, the basic positioner (EPos) and the Basic Operator Panel BOP20 are not supported.

- SIMOTION D410-2 is based on the output control of a SINAMICS S120 Control Unit CU310-2 (62.5 µs current controller clock cycle is not supported by SIMOTION D410-2)
- SIMOTION D4x5-2/CX32-2 is based on the output control of a SINAMICS S120 Control Unit CU320-2

For further information, see the SIMOTION and SINAMICS documentation.

Closed-loop control characteristics SINAMICS S

Criteria for assessing control quality	Explanations, definitions
Rise time	The rise time is the period which elapses between an abrupt change in a setpoint and the moment the actual value first reaches the tolerance band (2 %) around the setpoint. The dead time is the period which elapses between the abrupt change in the setpoint and the moment the actual value begins to increase. The dead time is partially determined by the read-in, processing and output cycles of the digital closed-loop control. Where the dead time constitutes a significant proportion of the rise time, it must be separately identified.
Characteristic angular frequency -3 dB	The limit frequency is a measure of the dynamic response of a closed-loop control. A pure sinusoidal setpoint is input to calculate the limit frequency; no part of the control loop must reach the limit. The actual value is measured under steady-state conditions and the ratio between the amplitudes of actual value and setpoint is recorded. -3 dB limit frequency: Frequency at which the absolute value of the actual value drops by 3 dB (to 71 %) for the first time. The closed-loop control can manage frequencies up to this value and remain stable.
Ripple	The ripple is the undesirable characteristic of the actual value which is superimposed on the mean value (useful signal). Oscillating torque is another term used in relation to torque. Typical oscillating torques are caused by motor slot grids, by limited encoder resolution or by the limited resolution of the voltage control of the IGBT power unit. The torque ripple is also reflected in the speed ripple as being indirectly proportional to the mass inertia of the drive.
Accuracy	Accuracy is a measure of the magnitude of the average, repeatable deviation between the actual value and setpoint under nominal conditions. Deviations between the actual value and setpoint are caused by internal inaccuracies in the measuring and control systems. External disturbances, such as temperature or speed, are not included in the accuracy assessment. The closed-loop and open-loop controls should be optimized with respect to the relevant variable.

Configuration

Performance characteristics SINAMICS S

Features	Servo Control	Vector Control	*V/f* Control	Notes
Typical application	• Drives with highly dynamic motion control • Angular-locked synchronism with isochronous PROFIBUS/ PROFINET in conjunction with SIMOTION • For use in machine tools and clocked production machines	• Speed-controlled drives with high speed and torque stability in general mechanical engineering systems • Particularly suitable for asynchronous motors	• Drives with low requirements on dynamic response and accuracy • Highly synchronized group drives, e.g. on textile machines with SIEMOSYN motors	Mixed operation of Servo Control and Vector Control is not possible on CU320-2. Mixed operation for the *V/f* Control modes is possible.
Dynamic response	Very high	High	Low	Highest dynamic response with 1FK7 High Dynamic synchronous motors and Servo Control.
Control modes with encoder	Position control/ Speed control/ Torque control	Position control/ Speed control/ Torque control	None	SIMOTION D with Servo Control is standard for motion control.
Control modes without encoder	Speed control	Speed control/ Torque control	All *V/f* control modes	With Servo for asynchronous motors only. With *V/f* Control the speed can be kept constant by means of selectable slip compensation.
Asynchronous motor	Yes	Yes	Yes	*V/f* Control (textiles) is recommended for SIEMOSYN motors.
Synchronous motor	Yes	No	No	
Torque motor	Yes	Yes	No	
Linear motor	Yes	No	No	
Permissible ratio of motor rated current to rated current of Motor Module	1:1 to 1:4	1.3:1 to 1:4	1:1 to 1:12	Maximum control quality in the case of Servo Control and Vector Control up to 1:4. Between 1:4 and 1:8 increasing restrictions as regards torque and rotational accuracy. *V/f* Control is recommended for <1:8.
Maximum number of parallel-connected motors per Motor Module	4	8	Unlimited in theory	Motors connected in parallel must be asynchronous (induction) motors with identical power ratings. With *V/f* Control, the motors can have different power ratings.
Setpoint resolution position controller	31 bit + sign	31 bit + sign	–	
Setpoint resolution Speed/frequency	31 bit + sign	31 bit + sign	0.001 Hz	
Setpoint resolution Torque	31 bit + sign	31 bit + sign	–	
Maximum output frequency				
• For current controller clock cycle/pulse frequency	660 Hz at 125 µs/4 kHz	330 Hz at 250 µs/4 kHz	400 Hz at 250 µs/4 kHz	Note limit voltage (2 kV) and use of VPM Module with synchronous motors.
• With current controller clock cycle/pulse frequency (chassis frame sizes FX and GX)	330 Hz at 250 µs/2 kHz	160 Hz at 250 µs/2 kHz	200 Hz at 250 µs/2 kHz	For asynchronous motors only: When using edge modulation, 600 Hz are possible at 4 kHz, or 300 Hz at 2 kHz and 200 Hz at 1.25 kHz.
• With current controller clock cycle/pulse frequency (chassis frame sizes HX and JX)	Not permitted	100 Hz at 400 µs/1.25 kHz	100 Hz at 400 µs/1.25 kHz	
Maximum field weakening				
• For asynchronous motors	5 ×	5 ×	4 ×	With Servo Control combined with encoder and appropriate special motors, field weakening up to 16 times the field-weakening threshold speed is possible.
• For synchronous motors	2 ×	2 ×	–	These values refer to 1FT7/1FK7 synchronous motors. Note limit voltage (kE factor) with non-Siemens motors.

SINAMICS S120 Control Units

Configuration

Fundamental closed-loop control characteristics of SINAMICS S

- Booksize format, pulse frequency 4 kHz, closed-loop torque control

	Servo Control		Vector Control		Notes
Synchronous motor	**1FK7 with R14DQ [1)]**	**1FT7**	Vector Control is not designed as an operating mode for 1FK7/1FT7 synchronous motors.		
Controller cycle	125 µs	125 µs			
Rise time (without delay)	0.7 ms	0.5 ms			At a speed operating range from 50 rpm for resolver.
Characteristic angular frequency -3 dB	650 Hz	900 Hz			In this case, the dynamic response is determined primarily by the encoder system.
Torque ripple	3 % of M_0	0.6 % of M_0			With speed operating range of 20 rpm up to rated speed. A ripple of < 1 % is possible with an absolute encoder ≤ 1 rpm. Not possible with resolver.
Torque accuracy	±1.5 % of M_0	±1.5 % of M_0			Measured value averaged over 3 s. With motor identification and friction compensation. In torque operating range up to ± M_0. Speed operating range 1:10 up to rated speed. Caution: External influences such as motor temperature can cause an additional long-time inaccuracy (constancy) of about ± 2.5 %. Approx. ±1 % less accuracy in field-weakening range.
Asynchronous motor	**1PH8 without encoder**	**1PH8 with incremental encoder 1024 S/R**	**1PH8 without encoder**	**1PH8 with incremental encoder 1024 S/R**	
Controller cycle	125 µs	125 µs	250 µs	250 µs	
Total rise time (without delay)	–	0.8 ms	2 ms	1.2 ms	With encoderless operation in speed operating range 1:10, with encoder 50 rpm and above up to rated speed.
Characteristic angular frequency -3 dB	–	600 Hz	250 Hz	400 Hz	With encoderless operation in speed operating range 1:10. The dynamic response is enhanced by an encoder feedback.
Torque ripple	–	1.5 % of M_{rated}	2 % of M_{rated}	2 % of M_{rated}	With encoderless operation in speed operating range 1:20, with encoder 20 rpm and above up to rated speed.
Torque accuracy	–	±3.5 % of M_{rated}	±2 % of M_{rated}	±1.5 % of M_{rated}	Measured value averaged over 3 s. With motor identification and friction compensation, temperature effects compensated by KTY84 and mass model. In torque operating range up to ±M_{rated}. Approx. additional inaccuracy of ±2.5 % in field-weakening range. Servo: Speed operating range 1:10 referred to rated speed. Vector: Speed operating range 1:50 referred to rated speed.

[1)] R14DQ: Resolver 14 bit (resolution 16384, internal 2-pole).

Configuration

- Booksize format, pulse frequency 4 kHz, closed-loop speed control

	Servo Control		Vector Control		Notes
Synchronous motor	**1FK7 with R14DQ [1)]**	**1FT7**	Vector Control is not designed as an operating mode for 1FK7/1FT7 synchronous motors.		
Controller cycle	125 µs	125 µs			
Total rise time (without delay)	3.5 ms	2.3 ms			With encoderless operation in speed operating range 1:10, with encoder 50 rpm and above up to rated speed.
Characteristic angular frequency -3 dB	140 Hz	250 Hz			In this case, the dynamic response is determined primarily by the encoder system.
Speed ripple	See note	See note			Determined primarily by the total mass moment of inertia, the torque ripple and especially the mechanical configuration. It is therefore not possible to specify a generally applicable value.
Speed accuracy	≤ 0.001 % of n_{rated}	≤ 0.001 % of n_{rated}			Determined primarily by the resolution of the control deviation and encoder evaluation in the converter. This is implemented on a 32 bit basis for SINAMICS.
Asynchronous motor	**1PH8 without encoder**	**1PH8 with incremental encoder 1024 S/R**	**1PH8 without encoder**	**1PH8 with incremental encoder 1024 S/R**	
Controller cycle	125 µs	125 µs	250 µs	250 µs	
Total rise time (without delay)	12 ms	5 ms	20 ms	10 ms	With encoderless operation in speed operating range 1:10, with encoder 50 rpm and above up to rated speed.
Characteristic angular frequency -3 dB	40 Hz	120 Hz	50 Hz	80 Hz	With encoderless operation in speed operating range 1:10. The dynamic response is enhanced by an encoder feedback. Servo with encoder is slightly more favorable than Vector with encoder, as the speed controller cycle with Servo is quicker.
Speed ripple	See note	See note	See note	See note	Determined primarily by the total mass moment of inertia, the torque ripple and especially the mechanical configuration. It is therefore not possible to specify a generally applicable value.
Speed accuracy	0.1 × f_{slip}	≤ 0.001 % of n_{rated}	0.05 × f_{slip}	≤ 0.001 % of n_{rated}	Without encoder: Determined primarily by the accuracy of the calculation model for the torque-producing current and rated slip of the asynchronous motor (see table "Typical slip values"). With speed operating range 1:50 (Vector) or 1:10 (Servo) and with activated temperature evaluation.

[1)] R14DQ: Resolver 14 bit (resolution 16384, internal 2-pole).

SINAMICS S120 Control Units

Configuration

- Blocksize, booksize compact, booksize and chassis, pulse frequency 4 kHz, position control

	Servo Control		Vector Control		Notes
Synchronous motor	**1FT7**	**1FK7**	Vector Control is not designed as an operating mode for 1FT7/1FK7 synchronous motors.		
Position controller cycle	1 ms	1 ms			
Resolution	4.19×10^6 incr./rev.	16384 incr./rev.			Correspondingly better with multi-pole resolver.
Attainable positioning accuracy	10^5 ... 10^6 incr./rev.	4096 incr./rev.			In practice, the resolution must be higher than the required positioning accuracy by a factor of 4 to 10. These values are approximate nominal values only.
• In relation to the motor shaft, approx.	0.00072 °	0.1 °			
Asynchronous motor	**1PH8 with AM22DQ [1)]**	**1PH8 with incremental encoder 1024 S/R**	**1PH8 with AM22DQ [1)]**	**1PH8 with incremental encoder 1024 S/R**	
Position controller cycle	1 ms	1 ms	2 ms	2 ms	
Resolution	4.19×10^6 incr./rev.	4096 incr./rev.	4.19×10^6 incr./rev.	4096 incr./rev.	
Attainable positioning accuracy	10^5 ... 10^6 incr./rev.	1024 incr./rev.	10^5 ... 10^6 incr./rev.	512 incr./rev.	In practice, the resolution must be higher than the required positioning accuracy by a factor of 4 to 10. These values are approximate nominal values only. Vector is less accurate than Servo by a factor of approximately 2.
• In relation to the motor shaft, approx.	0.00072 °	0.35 °	0.00072 °	0.7 °	

[1)] AM22DQ: Absolute encoder 22 bit single-turn (resolution 4194304, encoder-internal 2048 S/R) + 12 bit multi-turn (traversing range 4096 revolutions).

Configuration

- Chassis format, pulse frequency 2 kHz, closed-loop torque control

	Servo Control		Vector Control		Notes
Synchronous motor	**1FT7 without encoder**	**1FT7 with AM22DQ [1]**	Vector Control is not designed as an operating mode for 1FT7 synchronous motors.		
Controller cycle	250 µs	250 µs			
Total rise time (without delay)	–	1.2 ms			
Characteristic angular frequency -3 dB	–	400 Hz			In this case, the dynamic response is determined primarily by the encoder system.
Torque ripple	–	1.3 % of M_0			A ripple of < 1 % is possible with an absolute encoder ≤ 1 rpm. Not possible with resolver.
Torque accuracy	–	±1.5 % of M_0			Measured value averaged over 3 s. With motor identification and friction compensation. In torque operating range up to ±M_0. Speed operating range 1:10 up to rated speed. Caution: External influences such as motor temperature can cause an additional long-time inaccuracy (constancy) of about ±2.5 %. Approx. ±1 % less accuracy in field-weakening range.
Asynchronous motor	**1PH8 without encoder**	**1PH8 with incremental encoder 1024 S/R**	**1PH8 without encoder**	**1PH8 with incremental encoder 1024 S/R**	
Controller cycle	250 µs	250 µs	250 µs	250 µs	
Total rise time (without delay)	–	1.6 ms	2.5 ms	1.6 ms	With encoderless operation in speed operating range 1:10, with encoder 50 rpm and above up to rated speed.
Characteristic angular frequency -3 dB	–	350 Hz	200 Hz	300 Hz	With encoderless operation in speed operating range 1:10. The dynamic response is enhanced by an encoder feedback.
Torque ripple	–	2 % of M_{rated}	2.5 % of M_{rated}	2 % of M_{rated}	With encoderless operation in speed operating range 1:20, with encoder 20 rpm and above up to rated speed.
Torque accuracy	–	±3.5 % of M_{rated}	±2 % of M_{rated}	±1.5 % of M_{rated}	Measured value averaged over 3 s. With motor identification and friction compensation, temperature effects compensated by KTY84 and mass model. In torque operating range up to ±M_{rated}. Approx. additional inaccuracy of ±2.5 % in field-weakening range. Servo: Speed operating range 1:10 referred to rated speed. Vector: Speed operating range 1:50 referred to rated speed.

[1] AM22DQ: Absolute encoder 22 bit single-turn (resolution 4194304, encoder-internal 2048 S/R) + 12 bit multi-turn (traversing range 4096 revolutions).

SINAMICS S120 Control Units

Configuration

- Chassis format, pulse frequency 2 kHz, closed-loop speed control

	Servo Control		Vector Control		Notes
Synchronous motor	**1FT7 without encoder**	**1FT7 with AM22DQ [1]**	Vector Control is not designed as an operating mode for 1FT7 synchronous motors.		
Controller cycle	250 µs	250 µs			
Total rise time (without delay)	–	5 ms			With encoderless operation in speed operating range 1:10, with encoder 50 rpm and above up to rated speed.
Characteristic angular frequency -3 dB	–	100 Hz			In this case, the dynamic response is determined primarily by the encoder system.
Speed ripple	–	See note			Determined primarily by the total mass moment of inertia, the torque ripple and especially the mechanical configuration. It is therefore not possible to specify a generally applicable value.
Speed accuracy	–	≤ 0.001 % of n_{rated}			Determined primarily by the resolution of the control deviation and encoder evaluation in the converter. This is implemented on a 32 bit basis for SINAMICS.
Asynchronous motor	**1PH8 without encoder**	**1PH8 with incremental encoder 1024 S/R**	**1PH8 without encoder**	**1PH8 with incremental encoder 1024 S/R**	
Controller cycle	250 µs	250 µs	250 µs	250 µs	
Total rise time (without delay)	21 ms	8 ms	20 ms	12 ms	With encoderless operation in speed operating range 1:10, with encoder 50 rpm and above up to rated speed.
Characteristic angular frequency -3 dB	25 Hz	80 Hz	35 Hz	60 Hz	With encoderless operation in speed operating range 1:10. The dynamic response is enhanced by an encoder feedback. Servo with encoder is slightly more favorable than Vector with encoder, as the speed controller cycle with Servo is quicker.
Speed ripple	See note	See note	See note	See note	Determined primarily by the total mass moment of inertia, the torque ripple and especially the mechanical configuration. It is therefore not possible to specify a generally applicable value.
Speed accuracy	0.1 × f_{slip}	≤ 0.001 % of n_{rated}	0.05 × f_{slip}	≤ 0.001 % of n_{rated}	Without encoder: Determined primarily by the accuracy of the calculation model for the torque-producing current and rated slip of the asynchronous motor (see table "Typical slip values"). With speed operating range 1: 50 (Vector) or 1:10 (Servo) and with active temperature evaluation.

[1] AM22DQ: Absolute encoder 22 bit single-turn (resolution 4194304, encoder-internal 2048 S/R) + 12 bit multi-turn (traversing range 4096 revolutions).

Configuration

Typical slip values for standard asynchronous motors (induction motors)

Motor power	Slip values	Notes
< 1 kW	6 % of n_{rated} e.g. motor with 1500 rpm: 90 rpm	The slip values of 1PH asynchronous motors are very similar to those of standard motors
< 10 kW	3 % of n_{rated} e.g. motor with 1500 rpm: 45 rpm	
< 30 kW	2 % of n_{rated} e.g. motor with 1500 rpm: 30 rpm	
< 100 kW	1 % of n_{rated} e.g. motor with 1500 rpm: 15 rpm	
> 500 kW	0.5 % of n_{rated} e.g. motor with 1500 rpm: 7.5 rpm	