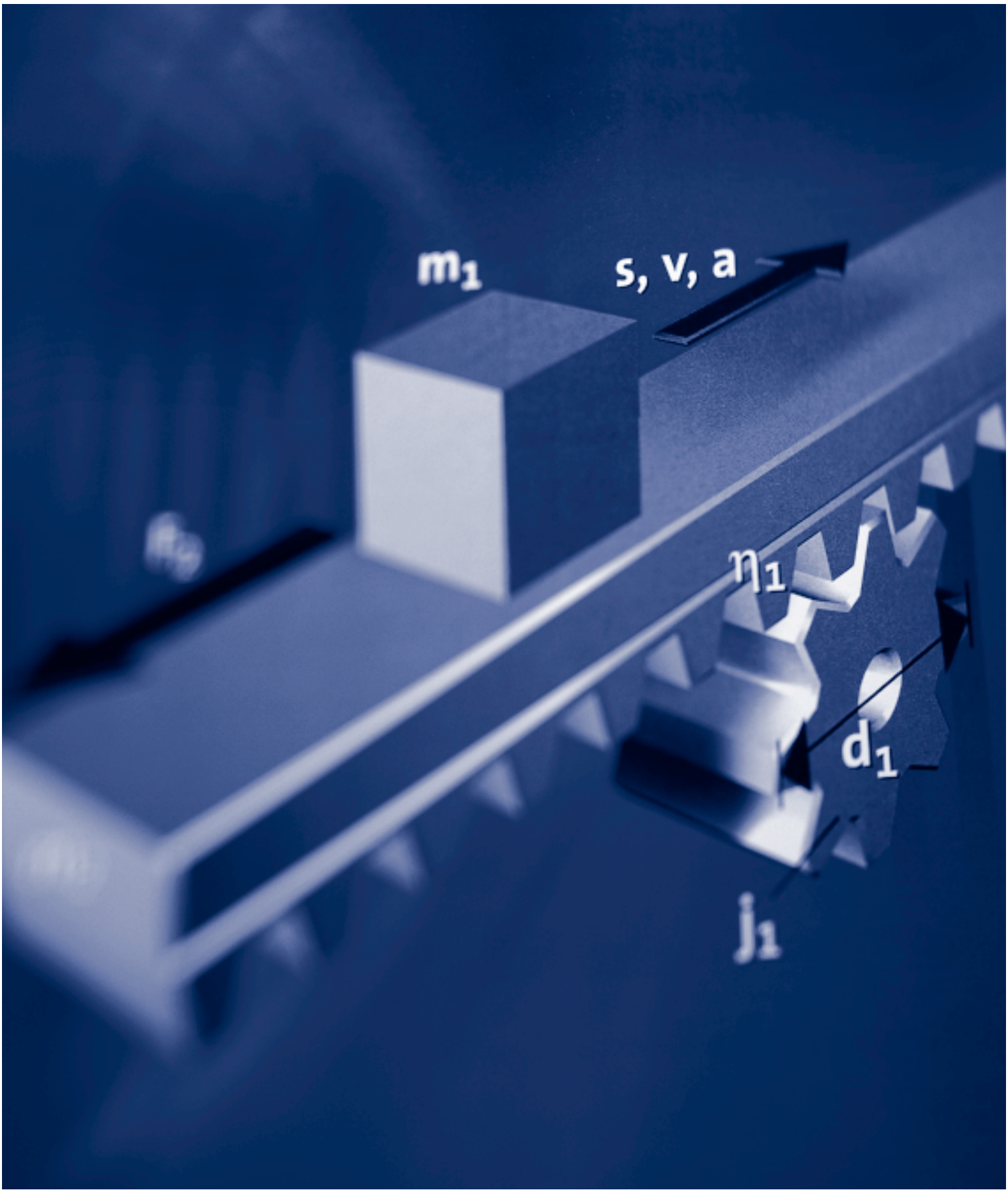
Geared servo motor selection



Lenze

Geared servo motor selection

General information
The selection of drives with geared servo motors is explained below.

The target of the rating
is to select the best-fit geared servo motor which reliably meets the requirements of the application.
The specific application conditions are taken into account:

- Ambient temperature, installation height
- mounting conditions
- load profile

For the sake of simplicity, the rating for standard duty cycles and for general load profiles is shown:

- constant load, duty cycle **S1 ***
- short-time duty **S2**
- intermittent duty **S3**
- continuous operation **S6 ***
- load profiles for an **application-specific load-collective**

***** For the sake of a long life, Lenze recommends to use motors with low rated speed for the duty cycles S1 and S6.

The **rating includes 3 elements**:

- Fulfillment of the **drive function** → is the selected drive able to perform the speeds, torques, accelerations required?
- **mechanical strength** → is the drive able to mechanically transmit the occurring torques and forces?
- **thermal rating** → does the operating temperature stay within the permissible limits to avoid early ageing?

Drive function
Based on the process requirements values, a drive with all operating points being within the speed-torque-limiting characteristics is selected. As a result, a gearbox with a suitable ratio with a motor with suitable speed with a controller with sufficient max. current is selected. Further limits (Max. speed, installation height) are shown in the tables.

Mechanical strength
Based on the forces and torques occurring, a drive is selected by means of the service factor and the gearbox torque, which features sufficient mechanical strength (fatigue strength of the gearing for the periodically occurring torques and time strength for the sporadically occurring torques).

Thermal rating
The thermal rating for the **controller** is made by means of continuous controller current and/or by means of the obtainable continuous torque of the combination from motor and controller.
The thermal rating for the **motor** is made by means of the average speed and the r.m.s.torque.
The thermal rating for the **gearbox** is made by means of the average speed and the continous torque of the combination from motor and gearbox. The average speed indicated should be understood as a recommendation. The speed of the drive should not exceed the values specified.

3-step rating
Geared servo motors are selected in 3 steps which are broken down into the a.m. duty cycles (S1, S2, S3, S6, profile):

Determination of the input parameters, such as:
- Load torque, load speed, acceleration (for speed profiles several operating points with periods)
- max. torque
- mounting position
- force load
- type of torque transmission

Calculation of the process requirement values, such as
- Total torques from load torque and acceleration
- max. load torque
- r.m.s. torque
- average speed
- max. speed

Selection of the geared servo motor and examination of the selection for fulfillment of requirements such as:
- Calculation of the total torque on motor side (r.m.s. torque, max. torque)
- thermal check of motor by means of r.m.s. torque and average speed
- thermal check of gearbox by means of average speed and r.m.s. torque
- Max. gearbox torque examination by means of periodically occurring torques and sporadically occurring max. torques
- Examination motor-controller-combination by means of max. torques
- Examination of load equilization
- Examination of the axial and radial force of the gearbox

Special attention should be given to the selection and **examination of the drive** to obtain a **reliable selection**. The individual elements of selection and examination are explicitly explained in the following. The observance of the limits of the geared servo motor drive is given priority (functional limits, thermal limits, mechanical limits).

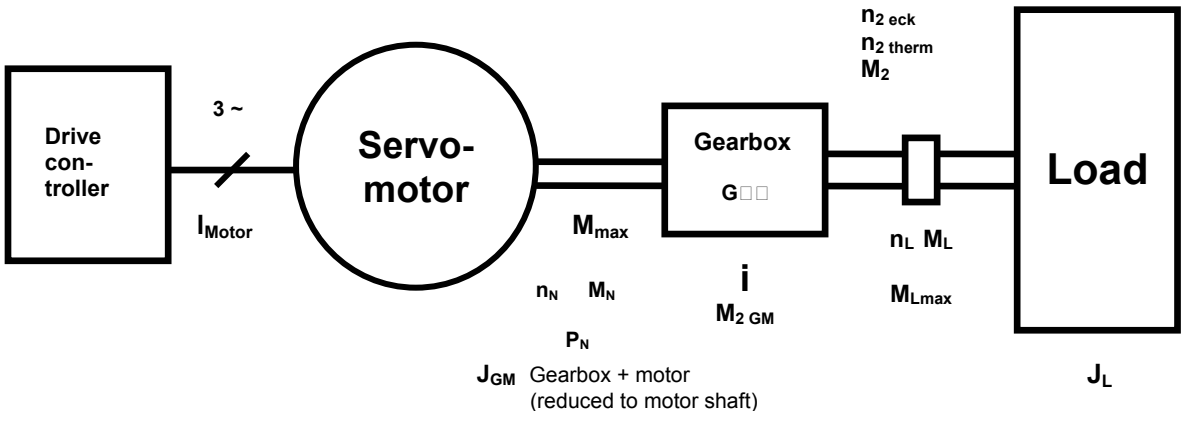
Select a geared servo motor for kinematics profiles, operating modes S1, S2, S3, S6, speed profile

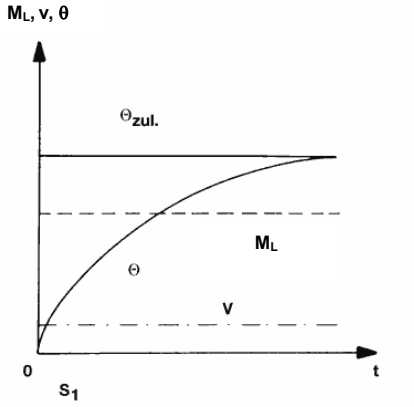
Suitable for simple linear speed profiles, not for S-curves etc. For complex selections or rating at max. load please contact your nearest Lenze representative.

Standard operating conditions
- 1-shift operation 8 h/day, 240 days/year
- Ambient temperature up to 30°C
- 70% on-time every day
- Average speed 80% of the rated speed
- Mounting position A
- Installation height up to 1000m

Considered	Not considered
- Rated mains voltage AC 400 V, 3 phases - Installation height max. 1000 m, Ambient temperature 30°C max. - Selection with speed-torque-charcteristics 9300 and ECS with mains voltages 400 V, 3 phases - Process requirements - Preselection of the motor - Load capacity of the gearbox - Specified gearbox ratio - Max. permissible gearbox input speed - Axial and radial loads of the gearbox output shaft - Total reduced inertia - Load equilization of the inertias	- Accurate consideration of the motoring / dynamic efficiency - Accessories such as brake chopper, brake resistors, Feedback systems, mains filter - Current derating of 9300 Servo at low speeds - Special ambient conditions such as special mains properties, increased temperatures / installation heights, contaminations, outdoor area Explosion protection - maximum standstill current - Inhibit the controller for thermal discharge of the drive

Graph of a driving axle



Select a geared servo motor for operating mode S1 (EN 60034)		
With the S1 duty, the drive is constantly on load, change of the rotational direction, alternating load where necessary. Requirement: constant power loss of the starting-up sequence (constant rise of temperature)		
		
Input parameters required		
Operating time / day		_____ [h]
Daily on-time		_____ [%]
average speed per day from n_L		_____ [%]
Ambient temperature		T_u =_____ [°C]
Radial force		F_r =_____ [N]
Axial force		F_a =_____ [N
Transmission element at gearbox	Gears, sprocket wheels …	_____
Load torque		M_L =_____ [Nm]
Load speed		n_L =_____ [min^{-1}]
Short-time max. torque	Emergency stop, quick-action stop … occasional heavy starting	$M_{L,max}$ =_____ Nm]
Running time at max. torque		t_L =_____ [%]
Select gearbox design and design of servo motor		
Type of gearbox	GST, GFL, GKR, GKS, GSS, GPA	=_____
Mounting position	A, B, C , D, E, F	=_____
Output designs	Shaft design: hollow shaft, solid shaft …	=_____
	flange	=_____
Design of drive	**A** (asynchronous) / **S** (synchronous)	=_____
Ventilation	self ventilation / forced ventilation	=_____
⇨ **Product key** **Geared motor designs**		

Determine the size of gearbox by means of forces

Determination of the axial and radial forces acting on the gearbox shaft

	Calculation	Check
Transmission element	f_z = _____	
Radial force (from input parameter or from transmission element)	$F_r = 2000 \cdot \frac{M_{max} \cdot f_z}{d_w [mm]}$	$F_r \le F_{r,zul} = f_w \cdot f_\alpha \cdot F_{r,Tab} \le f_w \cdot F_{r,max}$
Axial force	F_a = _____	$F_a \le F_{a,zul} = F_{a,Tab}$ bei $F_r = 0$

⇨ f_z → Page 17

$f_w, f_\alpha, F_{r,Tab}, F_{a,Tab}$ → permissible radial and axial forces → technical data depending on type of gearbox

Determination of the speed reduction factor

Ambient temperature	k_{n1} =_____
Mounting position	k_{n2} =_____
average daily speed (in % from n_L) and daily on-time ED	k_{n3} =_____

⇨ k_{n1}, k_{n2} k_{n3} → Page 16

$$k_n = k_{n1} \cdot k_{n2} \cdot k_{n3}$$

Select and check combination geared servo motor / inverter

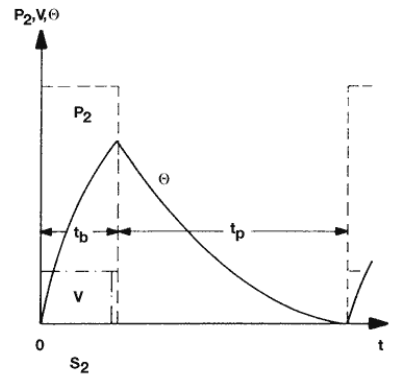
	Check	Selection
Output torque	$M_2 \ge M_L$	M_2 = _____ [Nm]
Output speed	$n_{2therm} \ge \frac{n_L}{k_n}$ (Recommendation)	n_{2therm} = _____ [min $^{-1}$]
	$n_{2Eck} \ge n_L$	n_{2Eck} = _____ [min $^{-1}$]
No alternating load	$M_{2GN} \ge M_{L,max}$	M_{2GN} = _____ [Nm]
At alternating load	$M_{2GN} \ge M_{L,max} \cdot 1{,}4$	
Short-time max. torque	$M_{2,max} \ge M_{L,max}$	$M_{2,max}$ = _____ [Nm]
Ratio		i =_____
Servo inverter	Suitable controllers for S1 duty are shown in the selection tables; where necessary, select larger controller for $M_{L,max}$ a	Type = E_____ ____ [kHz]

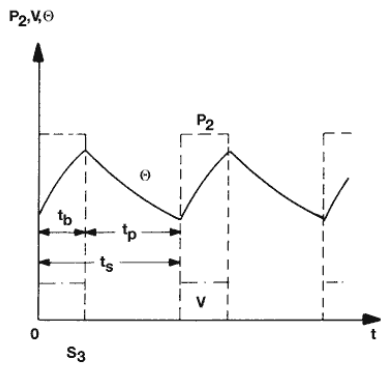
⇨ **M_2, n_{2therm}, n_{2Eck}, M_{2GN}, $M_{2,max}$, i, servo- inverter** → Selection tables according to type of gearbox

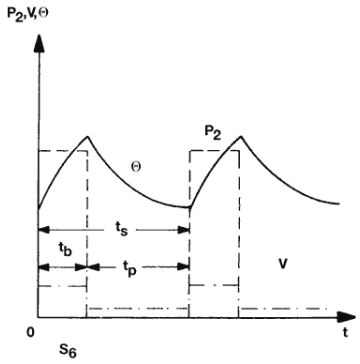
Determination of the required gearbox load capacity		
Intensity	$k_I = \frac{M_{L,max}}{M_2}$	k_I = _____
Operating factor		k = _____
⇨	***k*** → Page 17/18	
	Check	**Selection**
Load capacity	$c \geq k$	c =_____
⇨	***c***→ Selection tables according to type of gearbox	
Determination of the combination geared servo motor / inverter		
⇨	see fax orders	
Selection of further accessories, such as brake chopper for generating operation, mains filter, etc.		
⇨	see product catalog servo inverters	

Select a geared servo motor for S2, S3 and S6 operation modes (EN 60034)

S2 duty: Running the drive for a short time, with a subsequent “long” rest period
Periodic intermittent duty S3: Periodic alternation of the drive between on and off (max. cycle time 10 min)
Periodic intermittent load S6: The motor runs constantly while the load changes between on and off (max. cycle time 10 min)
The acceleration process is not considered. For dynamic use, the selection should be made according to the profile.







Input parameters required

Operating time / day		_____ [h]
Daily on-time		_____ [%]
Average speed per day from n_L		_____ [%]
Duty	S2	*ED* = _____[min]
	S3, S6	*ED* = _____[%]
Ambient temperature		T_u =_____ [°C]
Radial force		F_r =_____ [N]
Axial force		F_a =_____ [N
Transmission element at gearbox	Gears, sprocket wheels …	_____
Load torque		M_L =_____ [Nm]
Load speed		n_L =_____ [min^{-1}]
Short-time max. torque	Emergency stop, quick-action stop, occasional heavy starting	M_{Lmax} =_____ Nm]
Running time at max. torque		t_L =_____ [%]

Determine the design of gearbox and servo motor		
Type of gearbox	GST, GFL, GKR, GKS, GSS, GPA	=___ _____
Mounting position	A, B, C , D, E, F	=_____
Output side designs	Shaft design: hollow shaft, solid shaft …	=_____
	flange	=_____
Drive design	**A** (asynchronous) / **S** (synchronous)	=_____
Ventilation:	self-ventilation / forced ventilation	=_____

⇨ **Product key**
Geared motor designs

Determine the size of gearbox by means of forces

Determination of the axial and radial forces acting on the gearbox shaft

	Calculation	Check
Transmission element	f_z = _____	
Radial force (from input parameter or from transmission element)	$F_r = 2000 \cdot \frac{M_{max} \cdot f_z}{d_w\,[mm]}$	$F_r \le F_{r,zul} = f_w \cdot f_\alpha \cdot F_{r,Tab} \le f_w \cdot F_{r,max}$
Axial force	F_a = _____	$F_a \le F_{a,zul} = F_{a,Tab}$ bei $F_r = 0$

⇨ f_z → Page 17
$f_w, f_\alpha, F_{r,Tab}, F_{a,Tab}$ → permissible radial and axial forces → Technical data depending on type of gearbox

Determination of the speed reduction factor

Ambient temperature	k_{n1} =_____
Mounting position	k_{n2} =_____
average daily speed (in % von n_L) and daily on-time ED	k_{n3} =_____

⇨ k_{n1}, k_{n2}, k_{n3} → Page 16

Speed correction factor average speed k_m

Duty cycle S2		Duty cycle S3		Duty cycle S6	
ED [min]	k_m	*ED* [%]	k_m	*ED* [%]	k_m
10	0,16	15	0,15	15	1,00
30	0,50	25	0,25	25	
60	1,00	40	0,40	40	
90	1,00	60	0,60	60	

$$k_n = \frac{k_{n1} \cdot k_{n2} \cdot k_{n3}}{k_m}$$

Determination of the overload factor k_L (guiding values) depending on the application / kinematics

S2		S3		S6	
ED [min]	k_L	ED [%]	k_L	ED [%]	k_L
10	1,4-1,5	15	1,4-1,5	15	1,5-1,6
30	1,15-1,2	25	1,3-1,4	25	1,4-1,5
60	1,07-1,1	40	1,15-1,2	40	1,3-1,4
90	1,0-1,05	60	1,05-1,1	60	1,15-1,2

k_L =_____

Select and check combination geared servo motor - inverter

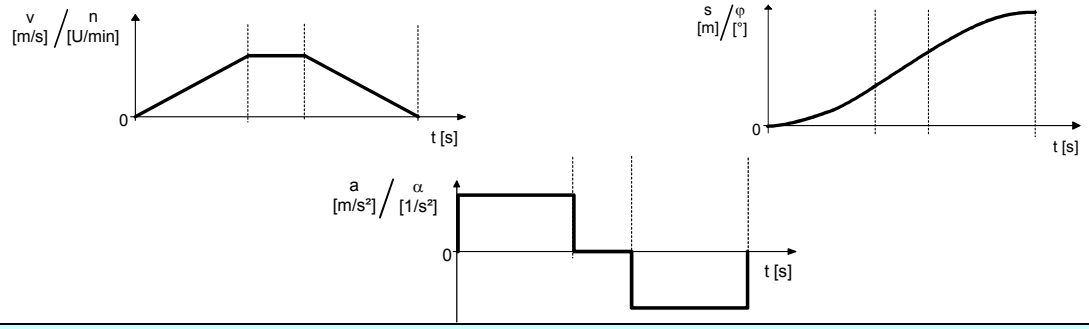
	Check	**Selection**
Output torque	$M_2 \geq \frac{M_L}{k_L}$	M_2 = _____ [Nm]
Output speed	$n_{2therm} \geq \frac{n_L}{k_n}$	n_{2therm} = _____ [min $^{-1}$]
	$n_{2Eck} \geq n_L$	n_{2Eck} = _____ [min $^{-1}$]
no alternating load	$M_{2GN} \geq M_{L,max}$	M_{2GN} = _____ [Nm]
at alternating load	$M_{2GN} \geq M_{L,max} \cdot 1{,}4$	
Short-time max. torque	$M_{2,max} \geq M_{L,max}$	$M_{2,max}$ = _____ [Nm]
Ratio		i =_____
Thermally effective operating point	$(i \cdot k_m \cdot n_L \ , \ \frac{M_L}{k_L \cdot i \cdot \eta_G})$	below the S1-torque characteristic of the servo motor
all operating points	$(i \cdot n_L \ , \ \frac{M_L}{i \cdot \eta_G})$	below the max. torque characteristic of the combination servo motor - inverter
Servo inverter		Type = E_____ ____ [kHz]

⇨ ***M*$_2$, *n*$_{2therm}$, *n*$_{2Eck}$, *M*$_{2GN}$, *M*$_{2,max}$, *i*, Servo inverter** → Selection tables acc. to type of gearbox
Torque characteristic → Technical data servo motors

Determination of the required gearbox load capacity		
Intensity	$k_I = \frac{M_{L,max}}{M_2}$	k_I = _____
Operating factor		k = _____
⇨	***k*** → Page 17/18	
	Check	**Selection**
Load capacity	$c \geq k$	c =_____
⇨	***c***→ Selection tables according to the type of gearbox	
Determination of the combination geared servo motor / inverter		
⇨	see fax orders	
Selection of further accessories, such as brake chopper for generating operations, mains filter, etc.		
⇨	see product catalog servo inverters	

Select a geared servo motor with speed profiles, cycle time / load cycle time ≤ 1 min

The profiles as exemplified below should be determined. A thumbsketch of the motion to be implemented may help with the following calculations.



Input parameters required

Operating time / day		_____ [h]
Daily on-time		_____ [%]
average speed per day from n_L		_____ [%]
Ambient temperature		T_u =_____ [°C]
Radial force		F_r =_____ [N]
Axial force		F_a =_____ [N
Transmission element at gearbox	Gears, sprocket wheels …	_____
Mass moment of interia		J_L =_____ [kgm^2]

Time response of the load for the individual periods z

Load torque		$M_{L,z}$ =_____ [Nm]
Load speed		$\Delta n_{L,z}$ =_____ [min^{-1}]
Individual periods		Δt_z =_____ [s]
Load cycle time	$T = \sum \Delta t_z$	T =_____ [s]
Shorttime max. torque	Emergency stop, quick-action stop…. occasional heavy starting	$M_{L,max}$ =_____ Nm]
Running time at max. torque		t_L =_____ [%]

Select gearbox design and design of servo motor		
Type of gearbox	GST, GFL, GKR, GKS, GSS, GPA	=_____
Mounting position	A, B, C , D, E, F	=_____
Output designs	Shaft design: hollow shaft, solid shaft …	=_____
	flange	=_____
Drive design	**A** (asynchronous) / **S** (synchronous)	=_____
Ventilation	self ventilation / forced ventilation	=_____

⇨ **Product key**
Geared motor designs

Determine the size of gearbox by means of forces

Determination of the axial and radial forces acting on the gearbox shaft

	Calculation	Check
Transmission element	f_z = _____	
Radial force (from input parameter or from transmission element)	$F_r = 2000 \cdot \frac{M_{max} \cdot f_z}{d_w [mm]}$	$F_r \le F_{r,zul} = f_w \cdot f_\alpha \cdot F_{r,Tab} \le f_w \cdot F_{r,max}$
Axial force	F_a = _____	$F_a \le F_{a,zul} = F_{a,Tab}$ bei $F_r = 0$

⇨ f_z → Page 17
$f_w, f_\alpha, F_{r,Tab}, F_{a,Tab}$ → permissible radical and axial forces → technical data depending on type of gearbox

Determination of the speed reduction factor

Ambient temperature	k_{n1} =_____
Mounting position	k_{n2} =_____
average daily speed (in % of n_L) and daily on-time ED	k_{n3} =_____

⇨ k_{n1}, k_{n2}, k_{n3} →Page 16

$$k_n = k_{n1} \cdot k_{n2} \cdot k_{n3}$$

Calculation of the process requirements values		
Output torque	$M_z = M_{L,z} + J_L \cdot \frac{2\pi\ \Delta n_{L,z}}{\Delta t_z} = M_{L,z} + 0{,}105 \cdot \frac{\Delta n_{L,z}}{\Delta t_z} \cdot J_L$	
Max. torque	$M_{P,\max} = \max(M_z)$	
RMS torque	$M_{eff} = \sqrt{\frac{1}{T}\sum_z M_z^2 \cdot \Delta t_z}, T \le 1\text{min}$	
average speed	$n_m = \overline{\lvert n_{L,z} \rvert} = mean - value\left(\lvert n_{L,z} \rvert\right) = \frac{1}{T}\sum_z n_{L,z} \cdot \Delta t_z$	
Max. speed	$n_{\max} = \max(n_{L,z})$	
	Check	**Preselection**
Output torque	$M_2 > M_{eff}$	M_2 = _____ [Nm]
Output speed	$n_{2therm} \ge \frac{n_m}{k_n}$ (recommendation)	n_{2therm} = _____ [min $^{-1}$]
	$n_{2Eck} \ge n_{\max}$	n_{2Eck} = _____ [min $^{-1}$]
Max. speed	$n_{1,\max} \le n_{\max} \cdot i$	$n_{1,\max}$ = _____ [min^{-1}]
No alternating load	$M_{2GN} \ge M_{P,\max}$	M_{2GN} = _____ [Nm]
At alternating load	$M_{2GN} \ge M_{P,\max} \cdot 1{,}4$	
Ratio		i = _____
Load equilization factor for optimum dynamics response/closed-loop performance	Requirement k_J = 0,5…10 Optimum k_J = 1	$k_J = \frac{J_L}{i^2 \cdot (J_{GM} + J_B)}$
	Check of the motor torques	
Acceleration torque	$M_{S,z} = M_z + (J_{GM} + J_B) \cdot \frac{2\ \pi\ \Delta n_{L,z}}{\Delta t_z} \cdot i^2$	(with consideration of the inertia of masses of the gearbox, motor and brake)
RMS torque	$M_{S,eff} = \sqrt{\frac{1}{T}\sum_z M_{S,z}^2 \cdot \Delta t_z}$	
⇨	***M_2, n_{2therm}, n_{2Eck}, M_{2GN}, i, J_{GM}*** → Selection tables according to the type of gearbox ***$n_{1,max}$*** → Page 16	
Thermally effective operating point	$\left(i \cdot n_m, \frac{M_{S,eff}}{i \cdot \eta_G}\right)$	below the S1-torque characteristic of the servo motor
All operating points	$\left(i \cdot n_{L,z}, \frac{M_{S,z}}{i \cdot \eta_G}\right)$	below the max. torque characteristic of the servo motor inverter combination
Servo inverter	Type = E_____ ____ [kHz]	
⇨	**Torque characteristics** → Technical data servo motors	

Determination of the required gearbox load capacity		
Intensity	$k_I = \frac{M_{L,max}}{M_2}$	k_I = _____
Operating factor		k = _____
⇨	***k*** → Page 17/18	
	Check	**Selection**
Load capacity	$c \geq k$	c =_____
⇨	***c***→ Selection tables according to type of gearbox	
Determination of the combination geared servo motor - inverter		
⇨	see fax orders	
Selection of further accessories, such as brake chopper for generating operation, mains filter, etc.		
⇨	see product catalog servo inverters	

Maximum gearbox input speeds

Max. input speeds which may in no case be exceeded.

Motor type	Input speed $n_{1,max}$ [min $^{-1}$]	Motor type	Input speed $n_{1,max}$ [min $^{-1}$]
MCA10	5000	**MCS06**	5000
MCA13	5000	**MCS09**	5000
MCA14	5000	**MCS12**	5000
MCA17	5000	**MCS14**	5000
MCA19	4000	**MCS19**	4000
MCA21	4000		

Speed correction factors

Ambient temperature

T_u [°C]	k_{n1} [-]
20	1,1
30	1,0
40	0,85

Mounting positions

Type of gearbox	Mounting position factor k_{n2}					
	A	**B**	**C**	**D**	**E**	**F**
GST	1,0	0,8	0,8	0,7*	1,0	1,0
GFL	1,0	0,8	0,85	0,7*	0,9	0,8
GKS	1,0	0,8	0,8	0,7*	0,8	0,8
GKR	1,0	0,9	0,8	0,8*	0,95	0,95
GSS	1,0	0,9	0,8	0,8*	0,95	0,95

* the average input speed n_1 should not exceed 1500 min^{-1}

Daily operating time and average speed

Daily operating time	average daily speed referring to load speed n_L				
	100%	**80%**	**60%**	**50%**	**25%**
ED	Correction factor k_{n3}				
15%	1,25	1,29	1,35	1,38	1,52
25%	1,15	1,20	1,25	1,29	1,42
40%	1,06	1,11	1,16	1,20	1,33
60%	0,99	1,03	1,08	1,12	1,25
70%	0,96	1,00	1,05	1,09	1,22
100%	0,89	0,93	0,99	1,02	1,15

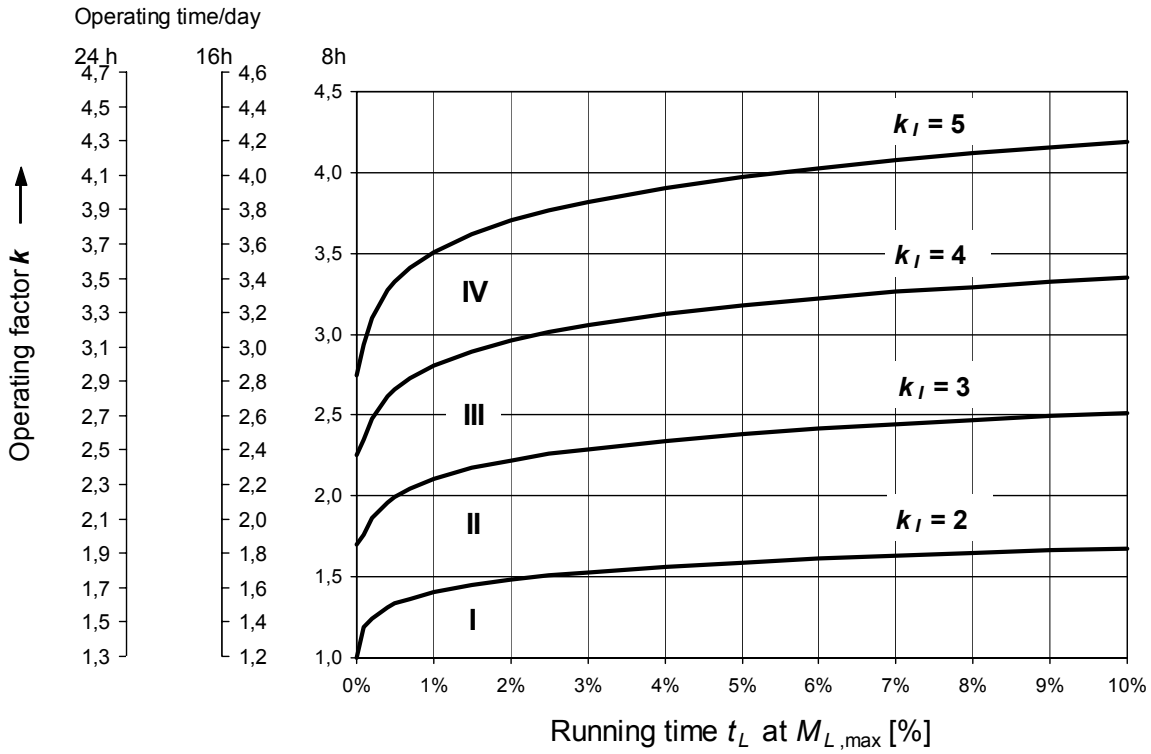
Radial force coefficient of the transmission elements

Transmission element	f_z
Gears	1,12
Sprocket wheels	1,25... 1,4
Crown gears	1,5
Small V-belt pulleys according to prestress	1,5...2,0

GST, GFL, GKS, GKR, GSS

Operating factors

Determine operating factor ***k*** of the machine by means of the diagram
Interpolation between the graphs is admitted.
For running times >10% $M_{L,\,max}$ is considered as M_L



GPA

Intensity and load class

Intensity k_I	Load class
$k_I \leq 1{,}1$	I
$1{,}1 < k_I \leq 1{,}25$	II
$1{,}25 < k_I \leq 2$	III

Operating factors

Determine operating factor ***k*** of the machine by means of the diagram
Interpolation between the graphs is admitted.