Technical notes

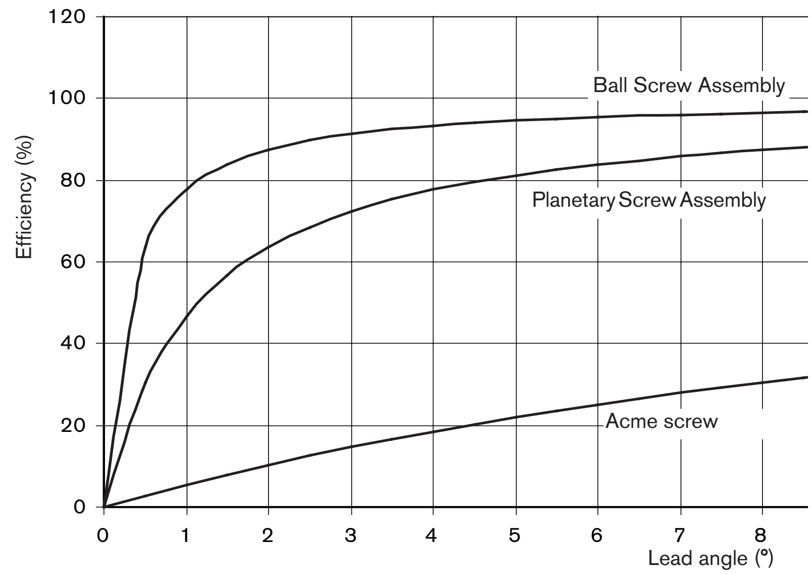
ISO 3408-1 defines a Ball Screw Assembly as follows:

A ball screw drive (BASA) is a unit consisting of a ball screw shaft, ball nut, and balls that is able to convert rotary motion into linear motion, and vice versa.

Advantages over the Acme screw drive
- The maximum mechanical efficiency of an Acme screw drive is 50%, whereas a Planetary Screw Assembly can achieve 90%, and a Ball Screw Assembly 98%.
- Higher life expectancy due to negligible wear during operation
- Less drive power required
- No stick-slip effect
- More precise positioning
- Higher travel speed
- Less heat-up

Due to the high level of effectivity (low friction level between the screw and the nut), ball screw drives are not self-locking.

⚠ **Safety information**
If installing in a non-horizontal position, customers should check whether separate protection against falling loads is necessary, e.g. an arrestor nut. With particularly critical applications in vertical operation, we recommend installing arrestor nuts.
Please consult us.



Selection criteria for ball screw drives

The factors below are significant when rating a ball screw drive:
- Degree of accuracy required (lead deviation)
- Load
- Service life
- critical speed
- buckling load
- rigidity/permissible clearance or desired preload
- characteristic speed (max. permissible linear speed)

The following points should be taken into consideration when selecting a PLSA that is to be both cost-efficient and optimally designed:
- The lead is a crucial factor in the load-bearing capacity (conditional on the maximum possible ball diameter) and the drive torque.
- The calculation of the service life should be based on average loads and average speeds, not on maximum values.
- In order for us to provide you with a customized solution, installation drawings or sketches of the nut environment should be enclosed.

⚠ **Note**
Radial and eccentric forces relative to the screw must be avoided, as they can negatively affect the ball screw drive's performance and shorten its service life.

Where special conditions of use are involved, please consult us.

Load ratings and service life
The calculations for the load capacities and service lives are based on ISO 3408-5. The dynamic load capacities in the tables are above the ISO 3408-5 values. These values have been confirmed in tests.

Static load rating C_0
The static load rating is an axial, concentrically acting force that induces a permanent deformation of 0.0001 x the ball diameter between the ball and the ball track.

Dynamic load rating C
The dynamic load rating is an axial, concentrically acting force of constant magnitude and direction under which 90% of a sufficiently large number of identical BASAs can achieve a nominal service life of one million revolutions.

Correction factor for tolerance grades
The static load rating C_0 and the dynamic load rating C must be multiplied by the correction factor f_{ac} as appropriate for the specific tolerance grade of the screw.

Tolerance grade T	3	5	7	9
f_{ac}	1	1	0,9	0,8

Service life
The nominal service life is expressed by the number of revolutions (or number of operating hours at constant speed) that will be attained or exceeded by 90% of a representative sample of identical BASAs before the first signs of material fatigue become evident. The nominal life is designated as L or L_h h, depending on whether it is specified in revolutions or hours.

Short stroke
Short stroke applications = stroke ≤ nut length
Lubrication:
During a short stroke, the planets do not make a real turn. It is therefore impossible for an adequate lubricating film to form. This may result in premature wear.
To avoid this, it is sufficient to perform longer strokes at regular intervals with simultaneous relubrication as "lubricating strokes".
Please consult our regional centers regarding short stroke applications.
You can find your local contact person at: www.boschrexroth.com/contact

Load rating:
Short stroke applications will increase the number of times a rolling load passes over each point within the load zone.
This reduces the load rating.

Critical speed and buckling load
The critical speed and buckling load can be checked using the corresponding charts.
For precise calculations
see formula 12 15 , in the section "Design Calculations3."

Characteristic speed $d_0 \cdot n$
Due to their structural design, Rexroth Ball Screw Assemblies can be operated at very high speeds. Characteristic speeds of up to 150,000 are possible depending on the nut type.

$d_0 \cdot n$	≤	**150,000**	
d_0	=	**nominal diameter**	**(mm)**
n	=	**speed**	**(rpm)**

The theoretically possible maximum linear speed v_{max} (m/min) is specified on the page featuring the relevant nut. Actually attainable speeds are heavily dependent among other factors on preload and duty cycle. They are generally restricted by the critical speed. (See "Design Calculations").

Material, hardness
BASAs are made of high-quality, heat-treatable steel, carbon chrome alloy steels or case-hardened steels. The screw and nut raceways have a minimum Rockwell hardness of HRC 58.
Ball screw drives made from stainless steel (DIN EN 10088) are available on request.
Normally, the screw ends are not hardened.

Sealing
Ball screw drives need protection from contamination. Flat protective covers, bellows-type dust boots, or the AGK drive unit are particularly suitable for this. Since there are many applications in which these methods do not provide sufficient protection, we have developed a gapless lip-type seal which ensures an optimal sealing effect and maintains high efficiency due to the low friction level. This means that the standard versions of our ball screw drives are supplied with seals. At the customer's request, the seals can be omitted entirely or special seals are used. For applications where it appears that it is not possible to avoid severe contamination of the screw, we have developed a reinforced variant of the standard seal. The sealing effect has been enhanced even further by increasing the preload. You should note the considerably higher frictional torque (see the technical data) compared to standard seals which leads to greater heat generation. You can easily recognize the reinforced seal by its dark-green color.

Permissible operating temperatures
Ball screw drives permit operation at continuous temperatures of up to 80 °C with temporary peaks of 100 °C (measurements taken on the outer shell of the nut in each case).

Permissible operating temperatures:
$-10\ °C \leq T_{operation} \leq 80\ °C$

Permissible storage temperature
$-15\ °C \leq T_{bearing} \leq 80\ °C$

Bearing
When calculating the life expectancy of the overall system, the end bearings must be considered separately.

Acceptance Conditions and Tolerance Grades

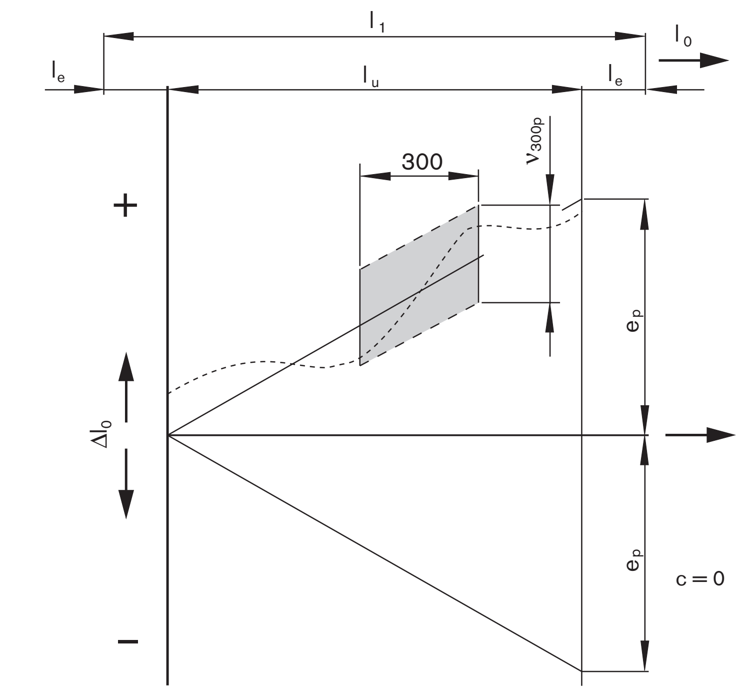
Permissible travel deviation

According to ISO 3408-3

Symbol definitions:
(excerpt)

l_0 = nominal travel
l_1 = thread length
Δl_0 = travel deviation
l_u = Useful travel
l_e = excess travel (the closer tolerances for travel and hardness do not apply here)
c = travel compensation (target travel deviation) (standard: c = 0)
e_p = tolerance mean target travel deviation
ν_{300p} = permissible travel deviation within 300 mm travel
a = actual
p = permissible

T **Ball Screw Assembly with precision screw**



Tolerance grades of precision screws

Tolerance grade			
3	**5**	**7**	**9**

Permissible travel deviation within 300 mm travel

ν_{300p} (µm) Tolerance grade			
3	**5**	**7**	**9**
12	23	52	130

Permissible target travel deviation

Useful travel l_u		Tolerance for target travel e_p (µm) Tolerance grade			
>	≤	**3**	**5**	**7**	**9**
0	100	8	18	44	110
100	200	10	20	48	120
200	315	12	23	52	130
315		$e_p = \frac{l_u}{300} \cdot \nu_{300p}$			

Non-usable length l_e
(Excess travel)
Modified compared to ISO 3408-3

d_0 (mm)	l_e (mm)
6, 8	15
12, 16	20
20, 25, 32, 40	40
50, 63, 80	50

Minimum number of measurements within 300 mm (measuring interval) and excess travel to be taken into consideration.

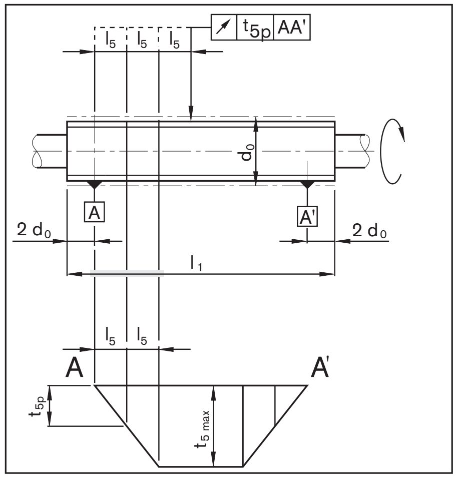
Lead P (mm)	Minimum number of measurements for tolerance grade			
	3	**5**	**7**	**9**
1	10	6	3	2
2	10	6	3	2
2.5	10	6	3	2
5	10	6	3	2
10	5	3	1	1
12	5	3	1	1
16	5	3	1	1
20	4	3	1	1
25	4	3	1	1
30	3	2	1	1
32	3	2	1	1
40	2	1	1	1
64	2	1	1	1

Acceptance Conditions and Tolerance Grades

Run-outs and location deviations

Based on DIN ISO 3408-3

Radial run-out $\mathbf{t_5}$ of the outer diameter of the screw over the length $\mathbf{l_5}$ used to determine the straightness relative to AA'.

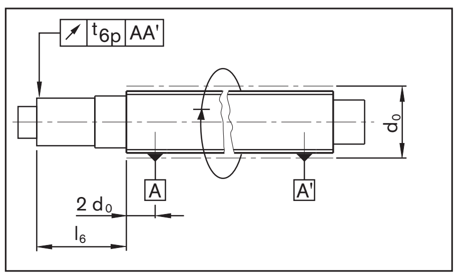


d_0		l_5	t_{5p} in µm for l_5 for tolerance grade			
Over	Up to		3	5	7	9
= 6	12	80	25	32	40	60
12	25	160				
25	50	315				
50	100	630				

l_1/d_0		t_{5max} in µm for $l_1 \geq 4\ l_5$ Tolerance grade			
Over	Up to	3	5	7	9
	40	50	64	80	120
40	60	75	96	120	180
60	80	125	160	200	300
80	100	200	256	320	480

Coaxial deviation t_6 of the bearing journal in relation to AA' where $\mathbf{l_6} \leq \mathbf{l}$.
Table value $\mathbf{t_{6p}}$ applies if $\mathbf{l_6} \leq$ reference length **l**.

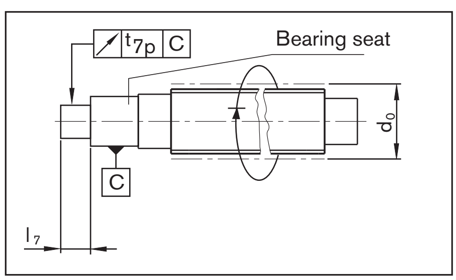
Where $l_6 > l$, then $t_{6a} \leq t_{6p} \cdot \frac{l_{6a}}{l}$



Nominal diameter d_0		Reference length l	t_{6p} in µm for $l_6 \leq l$ Tolerance grade			
Over	Up to		3	5	7	9
= 6	20	80	12	20	40	50
20	50	125	16	25	50	63
50	125	200	20	32	63	80

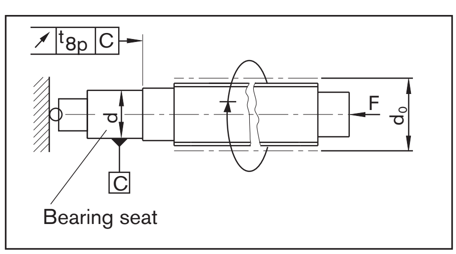
Radial run-out $\mathbf{t_7}$ of the journal diameter of the ball screw shaft relative to the bearing diameter for $\mathbf{l_7} \leq \mathbf{l}$.
Table value $\mathbf{t_{7p}}$ applies if $\mathbf{l_7} \leq$ reference length **l**.

Where $l_7 > l$, then $t_{7a} \leq t_{7p} \cdot \frac{l_{7a}}{l}$



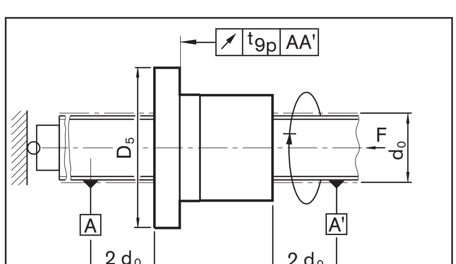
Nominal diameter d_0		Reference length l	t_{7p} in µm for $l_7 \leq l$ Tolerance grade			
Over	Up to		3	5	7	9
= 6	20	80	6	8	12	14
20	50	125	8	10	16	18
50	125	200	10	12	20	23

Axial run-out $\mathbf{t_8}$ of the shaft (bearing) face of the ball screw shaft relative to the bearing diameter.



Nominal diameter d_0		t_{8p} in µm for tolerance grade			
Over	Up to	3	5	7	9
= 6	63	4	5	6	8
63	125	5	6	8	10

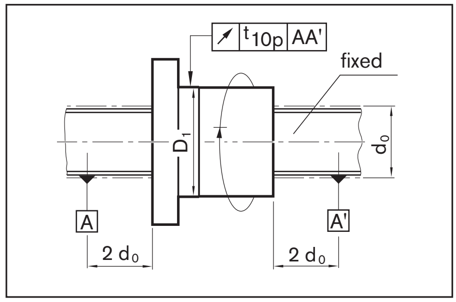
Axial run-out $\mathbf{t_9}$ of the ball nut location face in relation to **A** and **A'** (for preloaded ball nuts only).



Flange diameter D_5		t_{9p} in µm for tolerance grade			
Over	Up to	3	5	7	9
16	32	12	16	20	–
32	63	16	20	25	–
63	125	20	25	32	–
125	250	25	32	40	–

Technical data

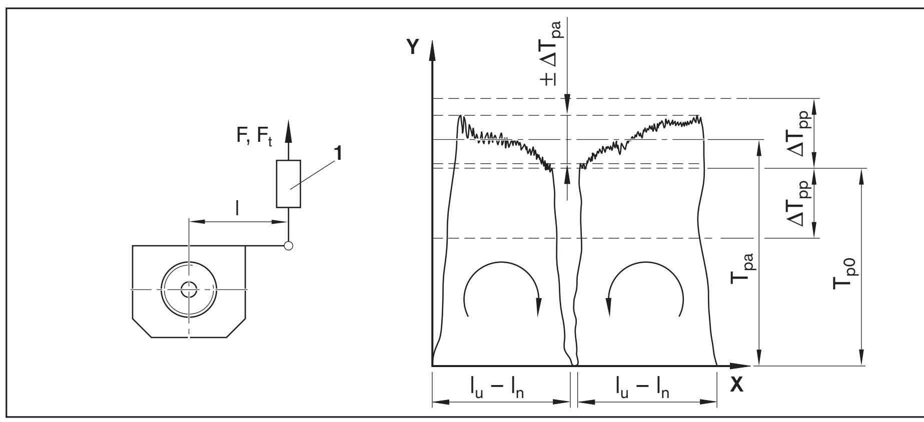
Radial run-out t_{10} of the outer diameter D_1 of the ball nut relative to **A** and **A'** (for preloaded and rotating ball nuts only). When measuring, fix the ball screw shaft to prevent rotation.



Outer diameter D_1		t_{10p} in µm for tolerance grade			
Over	**Up to**	**3**	**5**	**7**	**9**
16	**32**	12	16	20	–
32	**63**	16	20	25	–
63	**125**	20	25	32	–
125	**250**	25	32	40	–

Please contact us for the permissible axial and radial run-out with a driven nut

Limiting deviation ΔT_{pp} for the dynamic drag torque T_{p0} resulting from preloading (for preloaded ball nuts only)



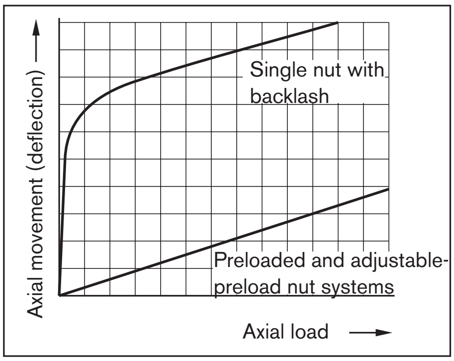
Symbol definitions:
X = travel
Y = Dynamic drag torque with preload
1 = Dynamometer
T_p = $F \cdot l$ without wiper
T_t = $F_t \cdot l$ with wiper
l_n = Length of ball nut

l_u / d_0 applies to	T_{p0} (Nm)		Tolerance grade							
			3	**5**	**7**	**9**	**3**	**5**	**7**	**9**
	>	≤	ΔT_{pp} (% of T_{p0}); $l_u \le$ 4000 mm				ΔT_{pp} (% of T_{p0}); $l_u >$ 4000 mm			
≤ 40	**0**	**0.4**	40	50	50	–	60	60	70	–
	0.4	**0.6**	35	40	40	–	50	50	60	–
	0.6	**1.0**	30	35	40	–	40	45	50	–
	1.0	**2.5**	25	30	35	–	35	40	45	–
	2.5	**6.3**	20	25	30	–	30	35	40	–
	6.3	**10.0**	15	20	30	–	25	30	35	–
	10.0		15	20	30	–	25	30	35	–
> 40	**0**	**0.4**	50	60	60	–	60	60	70	–
	0.4	**0.6**	40	45	45	–	50	50	60	–
	0.6	**1.0**	35	40	45	–	40	45	50	–
	1.0	**2.5**	30	35	40	–	35	40	45	–
	2.5	**6.3**	25	30	35	–	30	35	40	–
	6.3	**10.0**	20	25	35	–	25	30	35	–
	10.0		20	25	35	–	25	30	35	–

Preload and rigidity

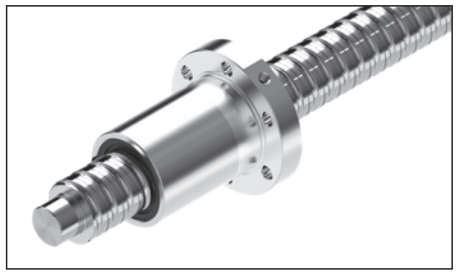
Nut system preload

In addition to single nuts with reduced backlash, Rexroth supplies preloaded or adjustable-preload nut systems.

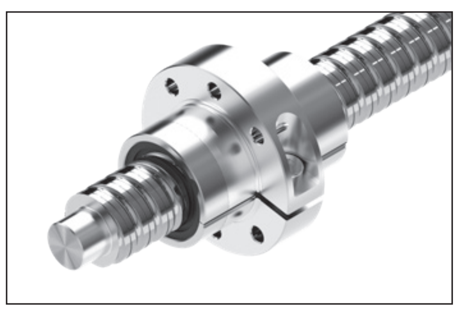


With the same preload, the rigidity behavior of these different Rexroth nut systems is virtually identical. The reason: Installation of adjustable-preload single nuts and preloaded single nuts is much more compact. The screw is typically far less rigid than the nut unit (for details see "Overall axial rigidity...").

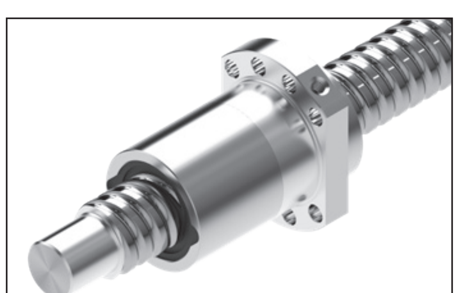
Preloaded single nut
Single nuts can be preloaded in an optimum way with preload classes C1, C2 or C3 by means of ball size selection.



Adjustable-preload single nut
Using adjustable-preload single nuts, the design process can be more favorably priced for many applications.
You set the zero backlash or the preloading radially by means of a slot that is approximately 0.1 mm wide; refer to the section entitled "Installation".
Depending on the application, we preload the nut system with preload classes C1, C2 or C3. The maximum preload is preload class C3.

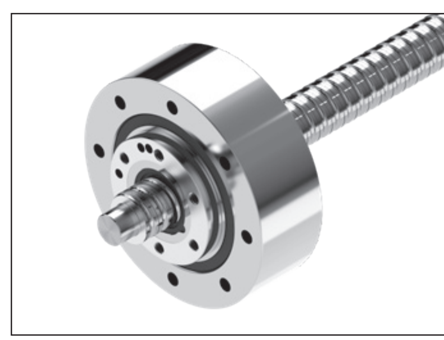


Single nut with flange FED
The HP series single nut with flange is preloaded in an optimum way with preload classes C1 or C2 by means of ball size selection.



Double nut
Bracing two single nuts eliminates the axial play due to production-related issues and increases rigidity, which improves positioning accuracy.
To prevent the service life from being shortened, the preload should not amount to $^{1}/_{3}$ of the average operating load. Depending on the application, we preload the nut system with preload classes C4 or C5.

Driven nut FAR
You can preload Series HP driven nuts like a single nut using
preload classes C1, C2 or C3 by means of ball size selection.



Rigidity

The rigidity of a Ball Screw Assembly is also affected by all adjoining parts such as bearings, housing bores, nut housings, etc.

Overall axial rigidity R_{bs} of the Ball Screw Assembly

The overall axial rigidity $\mathbf{R_{bs}}$ is made up of the component rigidity of the bearing $\mathbf{R_{fb}}$, the screw $\mathbf{R_S}$ and the nut unit $\mathbf{R_{nu}}$.

$$\frac{1}{R_{bs}} = \frac{1}{R_{fb}} + \frac{1}{R_S} + \frac{1}{R_{nu}} \quad (16)$$

Note:

Please note that in most cases the rigidity $\mathbf{R_S}$ of the screw will be significantly lower than the rigidity $\mathbf{R_{nu}}$ of the nut unit. With size 40 x 10, for example, the rigidity $\mathbf{R_{nu}}$ of the nut unit is two to three times greater than the rigidity $\mathbf{R_S}$ of a 500 mm-long screw.

Rigidity of the bearing R_{fb}

The rigidity of the bearings corresponds to the values in the bearing manufacturer's catalog.
See the dimension tables in this catalog for the rigidity values of the bearings that Rexroth can provide.

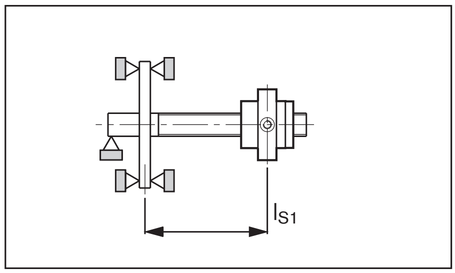
Rigidity in the area of the nut unit R_{nu}

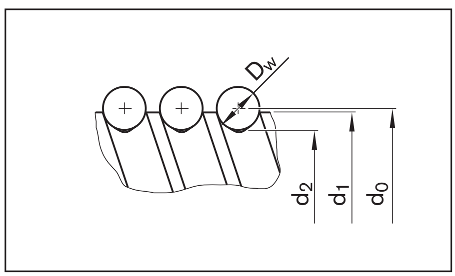
The rigidity in the area of the preloaded nut unit is calculated on the basis of ISO 3408-4.
See the corresponding tables for rigidity values.

Rigidity of the screw R_S

The rigidity of the screw $\mathbf{R_S}$ depends on the type of bearing used.
See the corresponding tables for rigidity values.

1 Fixed bearing of the ball screw shaft on one end.

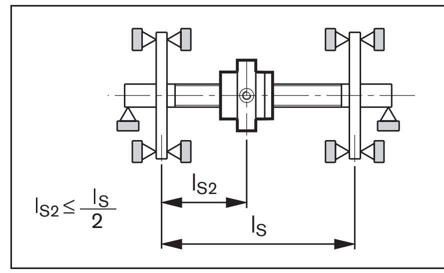




$$R_{S1} = 165 \cdot \frac{(d_0 - 0{,}71 \cdot D_w)^2}{l_{S1}} \ \text{(N/µm)} \quad (17)$$

$\mathbf{R_{S1}}$	=	rigidity of the screw	(N/µm)
$\mathbf{d_0}$	=	nominal diameter	(mm)
$\mathbf{D_w}$	=	ball diameter	(mm)
$\mathbf{l_{S1}}$	=	Bearing - nut distance	(mm)

2 Fixed bearing of the ball screw shaft on both ends.



$$R_{S2} = 165 \cdot \frac{(d_0 - 0{,}71 \cdot D_w)^2}{l_{S2}} \cdot \frac{l_S}{l_S - l_{S2}} \ \text{(N/µm)} \quad (18)$$

The lowest screw rigidity occurs at the center of the screw $\mathbf{R_{S2min}}$ ($l_{S2} = l_S/2$) and thus equals:

$$R_{S2min} = 660 \cdot \frac{(d_0 - 0{,}71 \cdot D_w)^2}{l_S} \ \text{(N/µm)} \quad (19)$$

$\mathbf{R_{S2}}$	=	rigidity of the screw	(N/µm)
$\mathbf{d_0}$	=	nominal diameter	(mm)
$\mathbf{D_w}$	=	ball diameter	(mm)
$\mathbf{l_S}$	=	distance between bearing and bearing	(mm)
$\mathbf{l_{S2}}$	=	distance between bearing and nut	(mm)