PHASE
MOTION CONTROL

U3 ServoMotors

LEADING THE INNOVATION

in High Dynamic and Torque and position control for automation

Catalogue

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Release 2.0

SUMM

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The ULTRACT III series of high performance servo motors, produced in the new Phase Motion Control plant specialized in high performance servo motors, is based on the last generation of rare earth magnets and embodies the patented Phase surface magnet assembly technology, which endows the motors with the highest torque density.

Standard shaft technology To avoid the traditional dichotomy between key–smooth shaft applications, Phase Motion Control releases the new standard shaft in which a key seat is filled with an insert and the whole set is ground to shaft tolerance. The shaft is therefore round and ready for clamping with conical hubs (recommended). If a key is required (and the corresponding reduced servo performance is accepted) the insert can be removed and a standard key inserted. All shafts are balanced with the insert so that simple rotating parts (e.g. pulleys, gears) need not to be balanced.

Safety brake All motors have an internal cavity where the PM safety brake can be mounted. The brakes are all rare earth permanent magnet type. This new high power density brake operates without brake pads. As a consequence, the problem of pollution of the motor cavity when the brake is operated incorrectly is avoided.

Additional inertia An extra flywheel can be introduced in the brake cavity to compensate for poor mechanical linkages between the motor and the load.
Single piece extruded frame, smooth, with O-rings on all couplings and IP 65 protection to allow flushing and sterilization in food and chemical applications
Standard circular connectors, turnable 270 degrees, standard high flexibility cables available;
Oversized front bearings improves bearing life by 70%; 28 mm shaft available on request
Peak speed 4000 rpm on standard type
Standard supply: new Heidenhain absolute magnetic encoders, single or multi turn (4096 turns), with electronic nameplate and AUTOSET function (with PMC drives), accuracy 280”, resolution 19 bit/turn, ENDAT full digital serial interface. The motor can also be equipped with sinusoidal optical encoders (Heidenhain ERN 1385, accuracy 20”, interpolated resolution 24 bit/rev, or resolver (accuracy 10’) for low cost, low performance applications.
KTY 84 linear thermal probe for continuous motor temperature sensing
Standard lip seal on shaft accessible from outside for maintenance/replacement
Flange and shaft manufactured to Grade R (reduced tolerance IEC 72)

U303 MOTOR

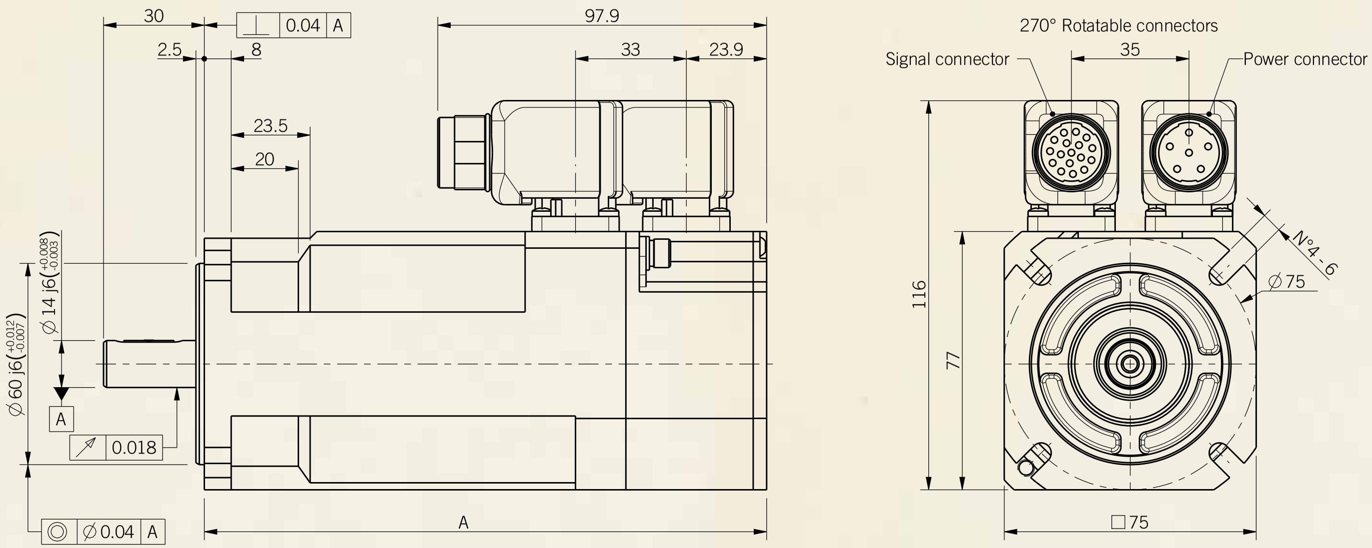
Natural Convection Cooling / For Inverter rated Voltage 380Vac to 480Vac

Motor Type U3			0301	0302	0304
Rated Speed	nM	[rpm]	3000	3000	3000
Stall Torque 2)	Md0	[Nm]	1,08	2,1	3,7
Current @ Stall Torque 2)	Id0	[A]	0,76	2,4	2,3
Number of Poles	2p			8	
Nominal Rating					
Rated Torque 2)	MdN	[Nm]	0,94	1,7	2,7
Rated Current 2)	IdN	[A]	0,67	2,1	1,68
Rated Power 2)	PdN	[kW]	0,30	0,53	0,85
Voltage Constant 3)	Ke	[V/1000rpm]	92,4	55,9	105,5
Torque Constant 3)	Kt	[Nm/A]	1,53	0,92	1,74
Torque Constant @ 130°C 3)	Kt100	[Nm/A]	1,41	0,85	1,61
Winding Resistance @ 20°C 3)	Ru-v	[Ω]	65,7	8,5	11,3
Winding Inductance 3)	Lu-v	[mH]	81	14,55	24
Derating Temp. Coeff. Of Back EMF	Dke/Dt	[%/°C]		-0,11	
Nominal Voltage	Vn	[V]	321	186	336
Minimum Flow Rate	Flow	[L/min]		n.a.	
Losses	Loss	[KW]	0,082	0,106	0,129
Efficiency	Eff	[%]	78	83	87
Knee Speed @ 380Vac	nknee1	[rpm]	3626	6402	3415
Knee Speed @ 480Vac	nknee2	[rpm]	4685	8157	4354
Knee Speed 380Vac and Mmax	nknee3	[rpm]	1553	3515	1771
Knee Speed 480Vac and Mmax	nknee4	[rpm]	2217	4618	2384
Maximum Values					
Max. Torque	Mmax	[Nm]	5	10	20
Max. Current (peak value)	Imax	[A]	4,1	13,5	14,3
Max. Saturation Speed @ 380Vac	nmax1	[rpm]	4113	6798	3602
Max. Saturation Speed @ 480Vac	nmax2	[rpm]	5195	8587	4550
Max. Mechanical Speed	nmax	[rpm]		6000	
Mechanical Data					
Inertia	Jm	[Kgcm²]	0,6	0,89	1,7
Mass	M	[Kg]	2	3	4
Total Length	A	[mm]	141,4	167,4	223
Shaft dimension 7)	ØDxL	[mm]		14j6 x 30	
Technical Data of the holding brake					
Holding Torque	MBr	[Nm]		3,8	
Rated Voltage (±10%)	UBr	[Vdc]		24	
Rated Current 2)	IBr	[A]		0,54	
Mass	MBr	[Kg]		0,55	
Inertia	JBr	[Kgcm²]		0,42	
Addditional motor lenght	Lenght	[mm]		30	

Test Condition

1) Motor tested in horizontal position in free still air, ambient temperature 30°C; 2) Motor flanged on heatsink 300x300x20; 3) Typical data tolerance +/- 5%; 4) Treshold of built in PTC 130°C; 5) KTY84-130; 6) Chopper frequency 8kHz; 7) DIN748-1 - Simultaneous transmission of a torque and a corresponding known bending moment (column b)

Technical Drawing



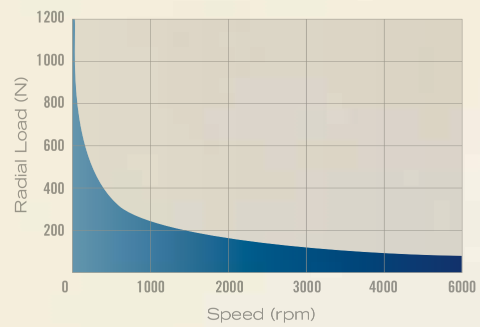
Total Lenght

Type	A (mm)
0301	141,4
0302	167,4
0304	223

Note: exit shaft dimensions to be defined according to the key options

Max. Radial Load

applicable in the middle of the shaft extension



Ref. To Performances Curves pag 40

U305 MOTOR

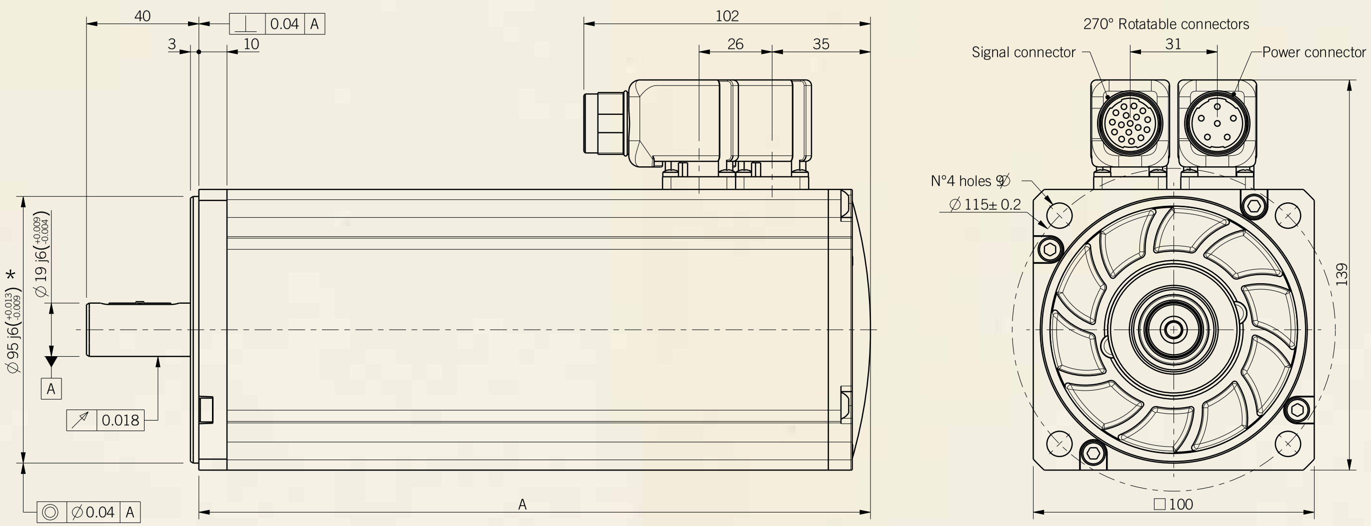
Natural Convection Cooling / For Inverter rated Voltage 380Vac to 480Vac

Motor Type U3			0503		0506		0509		0512	
Rated Speed	nM	[rpm]	1500	3000	1500	3000	1500	3000	1500	3000
Stall Torque 2)	Md0	[Nm]	3,6		7,2		10,5		14	
Current @ Stall Torque 2)	Id0	[A]	1,3	2,6	2,6	5,2	3,9	7,4	5,0	9,6
Number of Poles	2p									
Nominal Rating										
Rated Torque 2)	MdN	[Nm]	3,5	3,1	7,9	6	10	8,6	13,2	11,4
Rated Current 2)	IdN	[A]	1,3	2,3	2,9	4,3	3,7	6,0	4,7	7,8
Rated Power 2)	PdN	[kW]	0,55	0,97	1,24	1,88	1,57	2,70	2,07	3,58
Voltage Constant 3)	Ke	[V/1000rpm]	177	90	180	92	177	94	184	96
Torque Constant 3)	Kt	[Nm/A]	2,93	1,49	2,98	1,52	2,93	1,55	3,04	1,59
Torque Constant @ 130°C 3)	Kt100	[Nm/A]	2,68	1,36	2,73	1,39	2,68	1,42	2,79	1,45
Winding Resistance 3)	Ru-v	[Ω]	30,00	8,50	12,50	3,20	7,00	2,00	5,30	1,45
Winding Inductance 3)	Lu-v	[mH]	50,26	26,00	39,70	10,33	25,40	7,20	20,65	5,60
Derating Temp. Coeff. Of Back EMF	Dke/Dt	[%/°C]	-0,09							
Nominal Voltage	Vn	[V]	302	294	308	292	293	296	302	302
Minimum Flow Rate	Flow	[L/min]	n.a.		n.a.		n.a.		n.a.	
Losses	Loss	[kW]	0,12	0,13	0,19	0,18	0,23	0,23	0,29	0,29
Efficiency	Eff	[%]	82	88	87	91	87	92	88	93
Knee Speed @ 380Vac	nknee1	[rpm]	1939	3931	1891	3943	1984	3879	1914	3805
Knee Speed @ 480Vac	nknee2	[rpm]	2499	5012	2432	5013	2539	4928	2448	4833
Knee Speed 380Vac and Mmax	nknee3	[rpm]	1191	2279	1162	2645	1241	2617	1176	2538
Knee Speed 480Vac and Mmax	nknee4	[rpm]	1672	2979	1567	3438	1654	3393	1566	3287
Maximum Values										
Max. Torque	Mmax	[Nm]	14		28		42		58	
Max. Current (peak value)	Imax	[A]	6,0	11,8	11,8	23,0	17,9	33,8	23,8	45,7
Max. Saturation Speed @ 380Vac	nmax1	[rpm]	2147	4222	2111	4130	2147	4043	2065	3958
Max. Saturation Speed @ 480Vac	nmax2	[rpm]	2712	5333	2667	5217	2712	5106	2609	5000
Max. Mechanical Speed	nmax	[rpm]	6000							
Mechanical Data 3)										
Inertia	Jm	[Kgcm²]	1,1		1,8		2,5		3,2	
Mass	M	[Kg]	5		7		9		11	
Total Length	A	[mm]	195		239		283		327	
Shaft dimension 7)	ØDxL	[mm]	19j6 x 40 (28)							
Shaft dimension 8)	ØDxL	[mm]	19j6 x 40 (28)						24j6 x 50 (36)	
Technical Data of the holding brake										
Holding Torque	MBr	[Nm]	10							
Rated Voltage (±10%)	UBr	[Vdc]	24							
Rated Current	IBr	[A]	0,65							
Mass	MBr	[Kg]	0,7							
Inertia	JBr	[Kgcm²]	1,07							
Addditional motor lenght	Lenght	[mm]	33							

Test Condition

1) Motor tested in horizontal position in free still air, ambient temperature 30°C; 2) Motor flanged on heatsink 300x300x20; 3) Typical data tolerance +/- 10%; 4) Treshold of built in PTC 130°C; 5) KTY84-130; 6) Chopper frequency 8kHz; 7) DIN748-1 - Simultaneous transmission of a torque and a corresponding known bending moment (column b); 8) DIN748-1 - Simultaneous transmission of torque and an unknown bending moment (column c)

Technical Drawing



Total Lenght

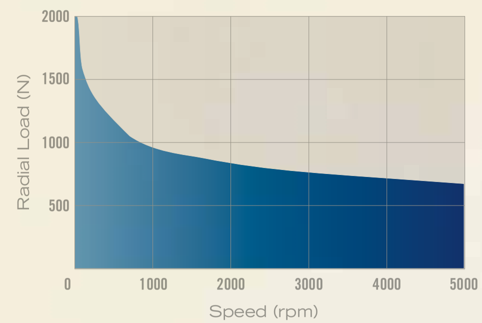
Type	A (mm)
0503	195
0506	239
0509	283
0512	327

Note: exit shaft dimensions to be defined according to the key options

Ref. To Performances Curves pag 40

Max. Radial Load

applicable in the middle of the shaft extension



U307 MOTOR

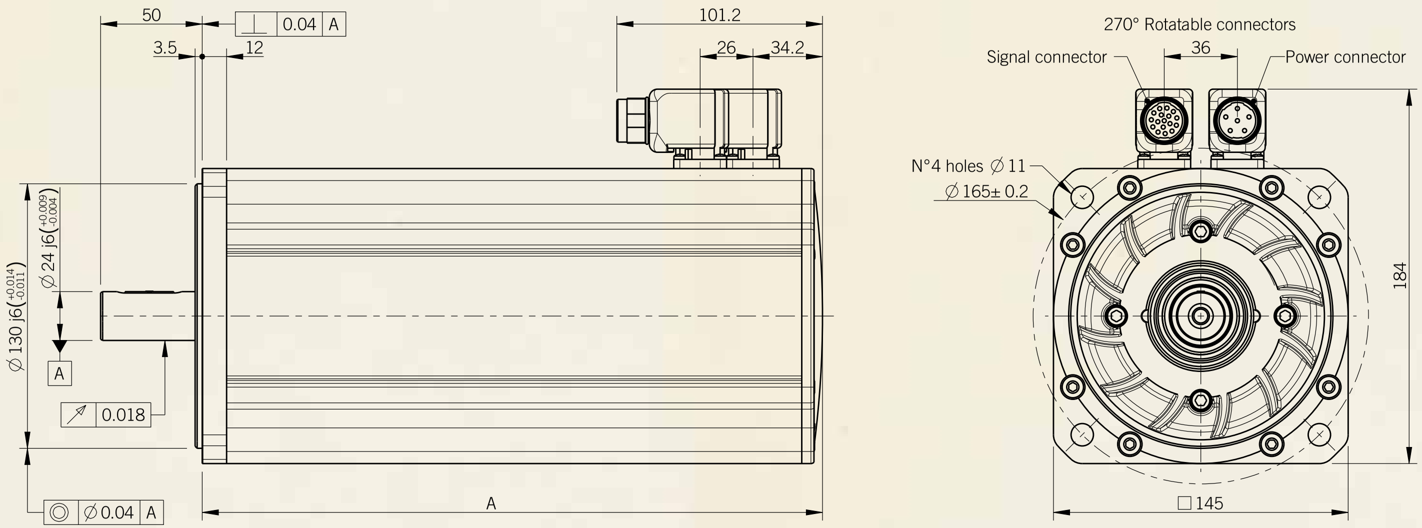
Natural Convection Cooling / For Inverter rated Voltage 380Vac to 480Vac

Motor Type U3			0710			0720			0730			0740		
Rated Speed	nM	[rpm]	1500	2000	3000	1500	2000	3000	1500	2000	3000	1500	2000	3000
Stall Torque 2)	Md0	[Nm]	10			19			27			35		
Current @ Stall Torque 2)	Id0	[A]	3,4	4,2	6,1	6,0	7,8	11,7	8,3	11,1	19,9	10,7	12,1	24,0
Number of Poles	2p		8											
Nominal Rating														
Rated Torque 2)	MdN	[Nm]	9,1	9	8,5	17	16	11	24	23	18	33	32	26
Rated Current 2)	IdN	[A]	3,1	3,8	5,2	5,4	6,5	6,7	7,4	9,4	13,3	10,1	11,0	17,9
Rated Power 2)	PdN	[kW]	1,4	1,9	2,7	2,7	3,3	3,5	3,8	4,8	5,7	5,2	6,7	8,2
Voltage Constant 3)	Ke	[V/1000rpm]	202	162	112	218	168	112	224	167,6	93	224	199	100
Torque Constant 3)	Kt	[Nm/A]	3,34	2,68	1,85	3,61	2,78	1,85	3,70	2,77	1,54	3,70	3,29	1,65
Torque Constant @ 130°C 3)	Kt100	[Nm/A]	2,94	2,36	1,63	3,17	2,45	1,63	3,26	2,44	1,35	3,26	2,90	1,46
Winding Resistance 3)	Ru-v	[Ω]	9,13	5,84	2,8	3,85	2,3	1,01	2,348	1,32	0,41	1,63	1,3	0,33
Winding Inductance 3)	Lu-v	[mH]	38,4	24,91	12,46	22,7	13,9	8,4	16,3	9,6	3,65	12,5	10	3,2
Derating Temp. Coeff. Of Back EMF	Dke/Dt	[%/°C]	-0,09											
Nominal Voltage	Vn	[V]	334	350	356	351	355	347	357	352	289	357	418	311
Minimum Flow Rate	Flow	[L/min]	n.a.			n.a.			n.a.			n.a.		
Losses	Loss	[kW]	0,23	0,23	0,23	0,30	0,30	0,30	0,35	0,35	0,35	0,41	0,41	0,41
Efficiency	Eff	[%]	86	89	92	90	92	92	92	93	94	93	94	95
Knee Speed @ 380Vac	nknee1	[rpm]	1724	2180	3212	1630	2145	3286	1601	2163	3966	1601	1812	3672
Knee Speed @ 480Vac	nknee2	[rpm]	2208	2784	4086	2079	2729	4164	2039	2749	5022	2038	2305	4651
Knee Speed 380Vac and Mmax	nknee3	[rpm]	1152	1503	2257	1128	1504	2038	1096	1491	2539	1114	1265	2383
Knee Speed 480Vac and Mmax	nknee4	[rpm]	1529	1971	2921	1477	1952	2611	1429	1926	3242	1448	1639	3042
Maximum Values														
Max. Torque	Mmax	[Nm]	33			65			100			130		
Max. Current (peak value)	Imax	[A]	12	15	22	23	29	44	34	45	81	44	49	98
Max. Saturation Speed @ 380Vac	nmax1	[rpm]	1881	2346	3393	1743	2262	3393	1696	2267	4086	1696	1910	3800
Max. Saturation Speed @ 480Vac	nmax2	[rpm]	2376	2963	4286	2202	2857	4286	2143	2864	5161	2143	2412	4800
Max. Mechanical Speed	nmax	[rpm]	6000											
Mechanical Data														
Inertia	Jm	[Kgcm²]	7,3			13			19			24		
Mass	M	[Kg]	8,5			12			15			19		
Total Length	A	[mm]	208,2			257,2			307,2			358,2		
Shaft dimension 7)	ØDxL	[mm]	24j6 x 36 (50)											
Shaft dimension 8)	ØDxL	[mm]	***						28j6 x 42 (60)					
Technical Data of the holding brake														
Holding Torque	MBr	[Nm]	32											
Rated Voltage (±10%)	UBr	[Vdc]	24											
Rated Current 2)	IBr	[A]	0,93											
Mass	MBr	[Kg]	2,4											
Inertia	JBr	[Kgcm²]	13,5											
Addditional motor lenght	Lenght	[mm]	50											

Test Condition

1) Motor tested in horizontal position in free still air, ambient temperature 30°C; 2) Motor flanged (Tflange = 30°C or heatsinker 500x500x20); 3) Typical data tolerance +/- 10%; 4) Treshold of built in PTC 130°C; 5) KTY84-130; 6) Chopper frequency 8kHz; 7) DIN748-1 - Simultaneous transmission of a torque and a corresponding known bending moment (column b); 8) DIN748-1 - Simultaneous transmission of torque and an unknown bending moment (column c)

Technical Drawing



Total Lenght

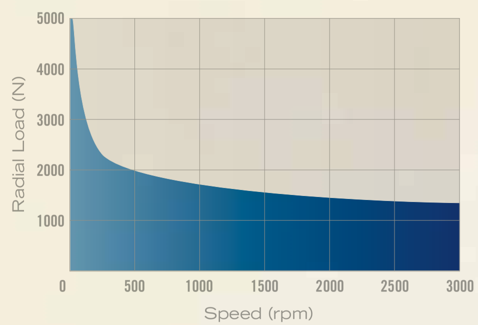
Type	A (mm)
0710	208,2
0720	257,2
0730	307,2
0740	358,2

Note: exit shaft dimensions to be defined according to the key options

Ref. To Performances Curves pag 40

Max. Radial Load

applicable in the middle of the shaft extension



U307C MOTOR

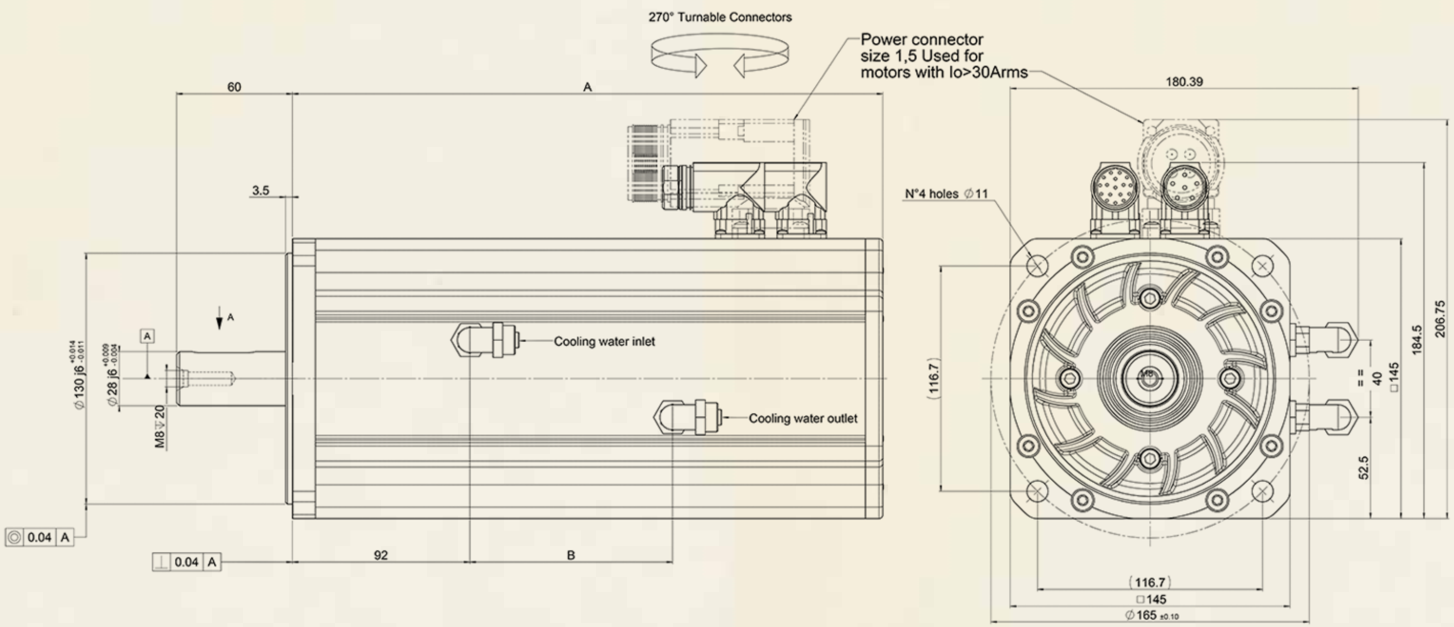
Water Cooling type C / For Inverter rated Voltage 380Vac to 480Vac

Motor Type			0720C		0730C		0740C	
Rated Speed	nM	[rpm]	1500	3000	1500	3000	1500	3000
Stall Torque 2)	Md0	[Nm]	35		58		80	
Current @ Stall Torque 2)	Id0	[A]	11	24	19	36	28	55
Number of Poles	2p							
Nominal Rating								
Rated Torque 2)	MdN	[Nm]	33	30	53	50	78	70
Rated Current 2)	IdN	[A]	10	21	18	31	27	48
Rated Power 2)	PdN	[kW]	5	9	8	16	12	22
Voltage Constant 3)	Ke	[V/1000rpm]	218	100	205	112	199	100
Torque Constant 3)	Kt	[Nm/A]	3,61	1,65	3,39	1,85	3,29	1,65
Torque Constant @ 130°C 3)	Kt100	[Nm/A]	3,17	1,46	2,98	1,63	2,90	1,46
Winding Resistance 3)	Ru-v	[Ω]	5,16	1,09	2,7	0,805	1,74	0,44
Winding Inductance 3)	Lu-v	[mH]	21,7	4,5	12,84	3,82	9,1	2,3
Derating Temp. Coeff. Of Back EMF	Dke/Dt	[%/°C]	-0,09					
Nominal Voltage	Vn	[V]	393	335	370	379	364	340
Minimum Flow Rate	Flow	[L/min]	2		3		5	
Losses	Loss	[kW]	1,36	1,36	2,20	2,20	2,87	2,87
Efficiency	Eff	[%]	79	87	79	88	81	88
Knee Speed @ 380Vac	nknee1	[rpm]	1445	3427	1545	3005	1573	3369
Knee Speed @ 480Vac	nknee2	[rpm]	1874	4375	1997	3840	2032	4297
Knee Speed 380Vac and Mmax	nknee3	[rpm]	1074	2682	1174	2357	1254	2715
Knee Speed 480Vac and Mmax	nknee4	[rpm]	1430	3462	1548	3042	1642	3488
Maximum Values								
Max. Torque	Mmax	[Nm]	65		100		130	
Max. Current (peak value)	Imax	[A]	23	49	37	67	49	98
Max. Saturation Speed @ 380Vac	nmax1	[rpm]	1743	3800	1854	3393	1910	3800
Max. Saturation Speed @ 480Vac	nmax2	[rpm]	2202	4800	2341	4286	2412	4800
Max. Mechanical Speed	nmax	[rpm]	6000					
Mechanical Data								
Inertia	Jm	[Kgcm²]	13		19		24	
Mass	M	[Kg]	12		15		19	
Total Length	A	[mm]	257,2		307,2		358,2	
Shaft dimension 7)	ØDxL	[mm]	28j6 x 42 (60)					
Shaft dimension 8)	ØDxL	[mm]	32k6 x 58 (80)					
Technical Data of the holding brake								
Holding Torque	MBr	[Nm]	32					
Rated Voltage (±10%)	UBr	[Vdc]	24					
Rated Current 2)	IBr	[A]	93,00					
Mass	MBr	[Kg]	2,4					
Inertia	JBr	[Kgcm²]	13,5					
Additional motor Lenght	Lenght	[mm]	50					

Test Condition

1) Motor tested in horizontal position, ambient temperature 30°C; 2) Water inlet temperature max 20°C; 3) Typical data tolerance +/- 10%; 4) Treshold of built in PTC 130°C; 5) KTY84-130 6) Chopper frequency 8kHz; 7) DIN748-1 - Simultaneous transmission of a torque and a corresponding known bending moment (column b); 8) DIN748-1 - Simultaneous transmission of torque and an unknown bending moment (column c)

Technical Drawing



Total Lenght

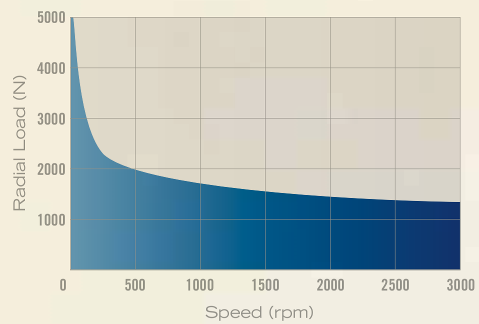
Type	A (mm)	B (mm)
0720C	257,2	57
0730C	307,2	105
0740C	358,2	155

Note: exit shaft dimensions to be defined according to the key options

Ref. To Performances Curves pag 40

Max. Radial Load

applicable in the middle of the shaft extension



U310 MOTOR

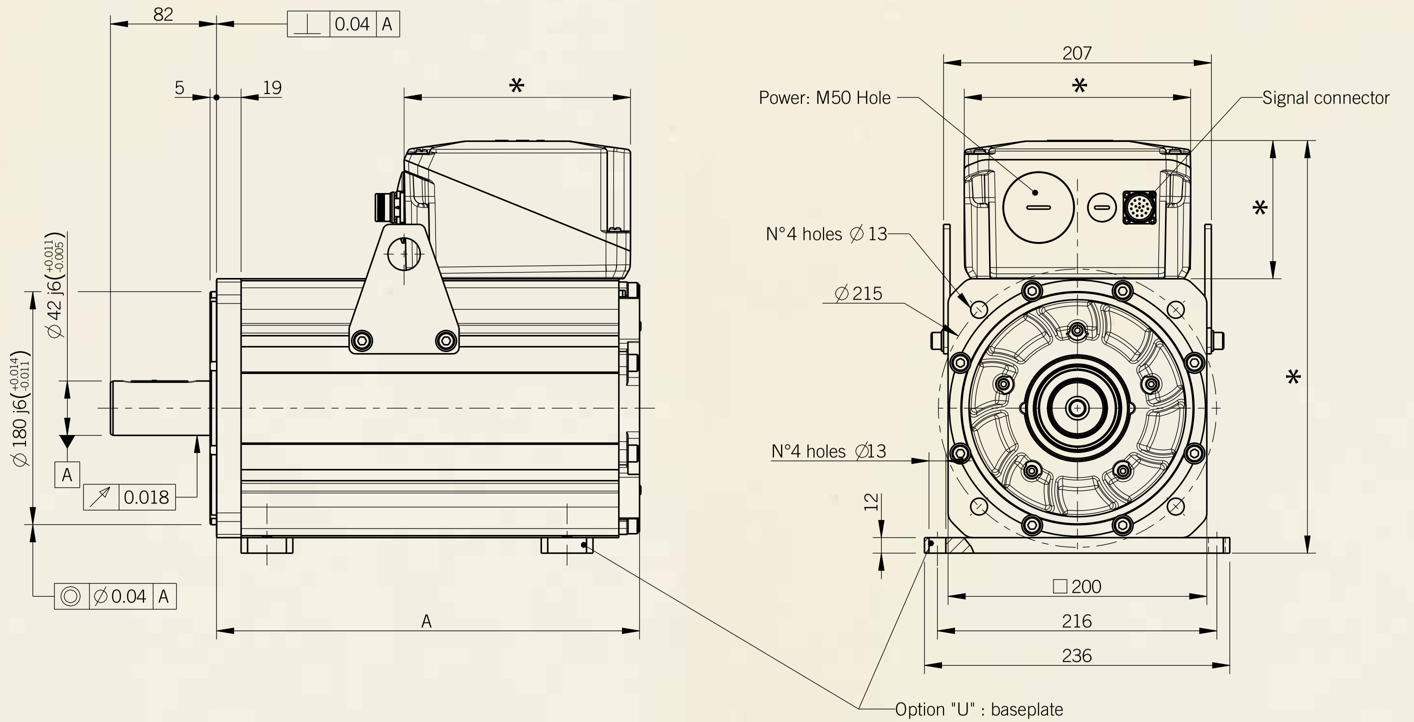
Natural Convection Cooling / For Inverter rated Voltage 380Vac to 480Vac

Motor Type U3			1004			1007			1010			1013		
Rated Speed	nM	[rpm]	1000	2000	3000	1000	2000	3000	1000	2000	3000	1000	2000	3000
Stall Torque 2)	Md0	[Nm]	35			60			88			105		
Current @ Stall Torque 2)	Id0	[A]	9	14	24	15	28	45	20	36	55	25	49	64
Number of Poles	2p		8											
Nominal Rating														
Rated Torque 2)	MdN	[Nm]	32	31	27	55	50	30	84	73	32	95	80	45
Rated Current 2)	IdN	[A]	8	13	18	14	23	22	19	30	20	22	38	28
Rated Power 2)	PdN	[kW]	3,3	6	8	6	10	9	9	15	10	10	17	14
Voltage Constant 3)		[V/1000rpm]	277	166	102	274	148	93	304	166	110	293	146	112
Torque Constant 3)	Kt	[Nm/A]	4,58	2,75	1,68	4,54	2,44	1,53	5,02	2,74	1,82	4,85	2,42	1,85
Torque Constant @ 130°C 3)	Kt100	[Nm/A]	4,03	2,42	1,48	4,00	2,15	1,35	4,42	2,41	1,60	4,27	2,13	1,63
Winding Resistance 3)	Ru-v	[Ω]	3,400	1,220	0,458	1,290	0,370	0,145	0,908	0,270	0,120	0,620	0,154	0,090
Winding Inductance 3)	Lu-v	[mH]	34,00	8,00	4,30	16,00	4,55	1,80	13,90	4,10	1,84	9,10	2,30	1,28
Derating Temp. Coeff. Of Back EMF	Dke/Dt	[%/°C]	-0,09											
Nominal Voltage	Vn	[V]	316	354	323	301	312	284	333	350	335	314	304	340
Minimum Flow Rate	Flow	[L/min]	n.a.			n.a.			n.a.			n.a.		
Losses	Loss	[kW]	0,55	0,55	0,55	0,63	0,62	0,62	0,78	0,78	0,78	0,81	0,81	0,81
Efficiency	Eff	[%]	86	92	94	90	94	94	92	95	93	92	95	95
Knee Speed @ 380Vac	nknee1	[rpm]	1219	2153	3536	1278	2445	4029	1149	2174	3410	1219	2507	3356
Knee Speed @ 480Vac	nknee2	[rpm]	1559	2740	4484	1627	3101	5096	1463	2756	4312	1549	3175	4244
Knee Speed 380Vac and Mmax	nknee3	[rpm]	730	1577	2270	782	1551	2521	694	1343	2039	754	1578	2146
Knee Speed 480Vac and Mmax	nknee4	[rpm]	953	2039	2901	1013	1984	3209	897	1716	2595	973	2014	2733
Maximum Values														
Max. Torque	Mmax	[Nm]	105			210			310			410		
Max. Current (peak value)	Imax	[A]	29	48	78	58	108	172	77	141	213	106	212	277
Max. Saturation Speed @ 380Vac	nmax1	[rpm]	1372	2286	3741	1384	2576	4108	1252	2294	3453	1296	2597	3397
Max. Saturation Speed @ 480Vac	nmax2	[rpm]	1733	2887	4726	1749	3254	5189	1582	2897	4362	1637	3281	4291
Max. Mechanical Speed	nmax	[rpm]	6000											
Mechanical Data														
Inertia	Jm	[Kgcm²]	50			90			130			170		
Mass	M	[Kg]	41			52			64			75		
Connection Box	Type		A			A		B	A	B		A	B	
Total Length	A	[mm]	255			327			399			471		
Shaft dimension 7)	ØDxL	[mm]	42k6 x 82 (110)											
Technical Data of the holding brake														
Holding Torque	MBr	[Nm]	143											
Rated Voltage (±10%)	UBr	[Vdc]	24											
Rated Current 2)	IBr	[A]	1,78											
Mass	MBr	[Kg]	11											
Inertia	JBr	[Kgcm²]	48,6											
Addditional motor lenght	Lenght	[mm]	65											

Test Condition

1) Motor tested in horizontal position in free still air, ambient temperature 30°C; 2) Motor flanged (Tflange = 30°C), to use on baseplate derate -30%; 3) Typical data tolerance +/- 10%; 4) Treshold of built in PTC 130°C; 5) KTY84-130; 6) Chopper frequency 8kHz; 7) DIN748-1 - Simultaneous transmission of torque and an unknown bending moment (column c)

Technical Drawing



Total Lenght

Type	A (mm)
1004	255
1007	327
1010	399
1013	471

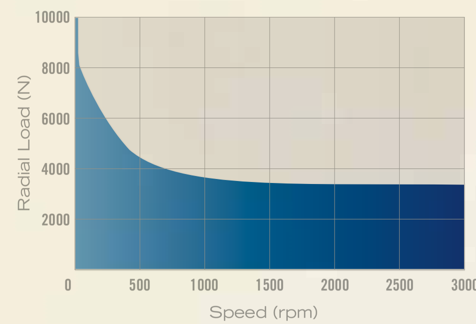
Connections

CONNECTION BOX / TYPE	A	B	C	D
Dimension (axbxc) mm	142x142x87.5	175x175x106.8	240x195x122	353x264.5x157.5

Note: exit shaft dimensions to be defined according to the key options

Max. Radial Load

applicable in the middle of the shaft extension



Ref. To Performances Curves pag 40

U310F MOTOR

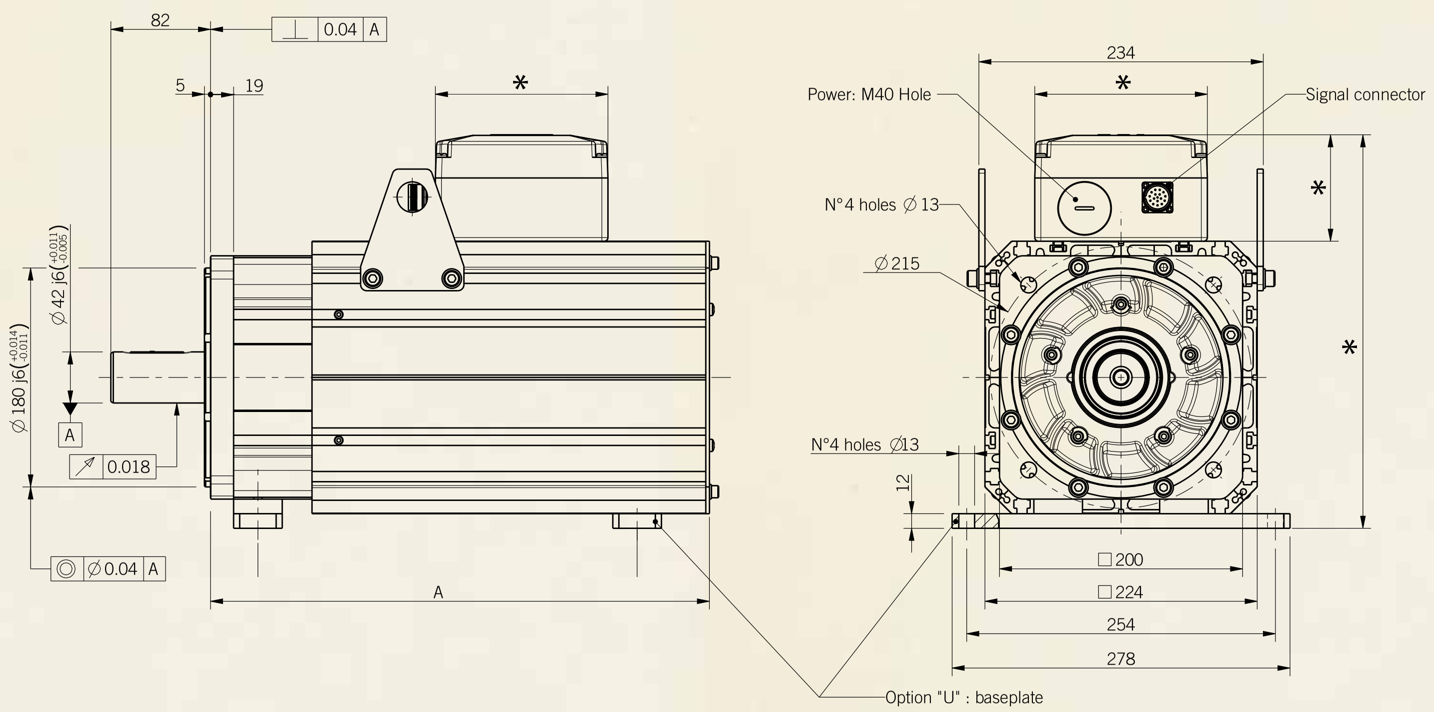
Servo Fan Cooling type F / For Inverter rated Voltage 380Vac to 480Vac

Motor Type U3			1004F			1007F			1010F			1013F		
Rated Speed	nM	[rpm]	1000	2000	3000	1000	2000	3000	1000	2000	3000	1000	2000	3000
Stall Torque 2)	Md0	[Nm]	45			90			130			170		
Current @ Stall Torque	Id0	[A]	11	22	30	22	41	66	29	64	80	39	79	103
Number of Poles	2p		8											
Nominal Rating														
Rated Torque 2)	MdN	[Nm]	42	40	38	74	72	70	100	97	95	149	142	135
Rated Current 2)	IdN	[A]	10	20	25	18	33	51	22	48	59	35	66	82
Rated Power 2)	PdN	[kW]	4	8	12	8	15	22	10	20	30	16	30	42
Voltage Constant 3)	Ke	[V/1000rpm]	277	139	102	274	148	93	302	138	110	293	146	112
Torque Constant 3)	Kt	[Nm/A]	4,58	2,30	1,68	4,54	2,44	1,53	5,00	2,28	1,82	4,85	2,42	1,85
Torque Constant @ 130°C 3)	Kt100	[Nm/A]	4,08	2,05	1,50	4,04	2,17	1,36	4,45	2,03	1,62	4,32	2,15	1,65
Winding Resistance 3)	Ru-v	[Ω]	3,400	0,860	0,458	1,290	0,370	0,145	0,910	0,190	0,120	0,620	0,154	0,090
Winding Inductance 3)	Lu-v	[mH]	34,00	8,60	4,30	16,00	4,55	1,80	13,90	1,87	1,84	9,10	2,30	1,28
Derating Temp. Coeff. Of Back EMF	Dke/Dt	[%/°C]	-0,09											
Nominal Voltage	Vn	[V]	332	317	337	314	325	301	339	291	356	332	321	361
Minimum Flow Rate	Flow	[L/min]	n.a.			n.a.			n.a.			n.a.		
Losses	Loss	[kW]	0,90	0,90	0,90	1,38	1,37	1,37	1,68	1,68	1,67	2,08	2,07	2,07
Efficiency	Eff	[%]	83	90	93	85	92	94	86	92	95	88	93	95
Knee Speed @ 380Vac	nknee1	[rpm]	1157	2415	3399	1226	2352	3800	1126	2629	3204	1153	2378	3165
Knee Speed @ 480Vac	nknee2	[rpm]	1485	3074	4316	1566	2987	4816	1435	3335	4061	1471	3018	4011
Knee Speed 380Vac and Mmax	nknee3	[rpm]	830	1768	2543	868	1712	2780	773	2140	2260	834	1741	2357
Knee Speed 480Vac and Mmax	nknee4	[rpm]	1080	2265	3246	1122	2188	3537	996	2733	2875	1075	2220	2999
Maximum Values														
Max. Torque	Mmax	[Nm]	102			210			310			410		
Max. Current (peak value)	Imax	[A]	23	47	64	49	91	144	65	143	179	89	178	233
Max. Saturation Speed @ 380Vac	nmax1	[rpm]	1372	2733	3741	1384	2576	4108	1257	2757	3453	1296	2597	3397
Max. Saturation Speed @ 480Vac	nmax2	[rpm]	1733	3452	4726	1749	3254	5189	1588	3482	4362	1637	3281	4291
Max. Mechanical Speed	nmax	[rpm]	6000											
Mechanical Data														
Inertia	Jm	[Kgcm²]	50			90			130			170		
Mass	M	[Kg]	46			56			70			78		
Total Length	A	[mm]	338,5			410,5			482,5			554,5		574
Connection Box	Type		A		B	B			B			B		
Shaft dimension 6)	ØDxL	[mm]	42k6 x 82 (110)											
Shaft dimension 7)	ØDxL	[mm]	***									45k6 x 82 (110)		
Technical Data of the holding brake														
Holding Torque	MBr	[Nm]	143											
Rated Voltage	UBr	[Vdc]	24											
Rated Current 2)	IBr	[A]	1,78											
Mass	MBr	[Kg]	11											
Inertia	JBr	[Kgcm²]	48,6											
Addditional motor lenght	Lenght	[mm]	65											

Test Condition

1) Motor tested in horizontal position, ambient temperature 30°C; 2) Motor flanged (Tflange = 30°C), to use on baseplate derate -30%; 3) Typical data tolerance +/- 10%; 4) Treshold of built in PTC 130°C; 5) KTY84-130; 6) Chopper frequency 8kHz; 7) DIN748-1 - Simultaneous transmission of a torque and a corresponding known bending moment (column b); 8) DIN748-1 - Simultaneous transmission of torque and an unknown bending moment (column c)

Technical Drawing



Total Lenght

Type	A (mm)
1004F	338,5
1007F	410,5
1010F	482,5
1013F	554,5

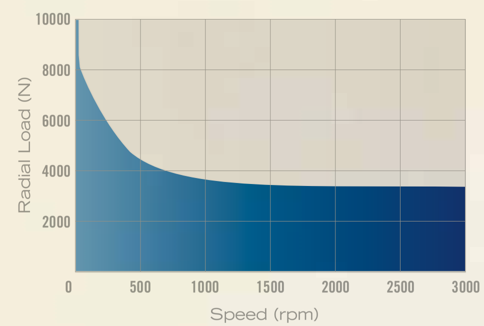
Connections

CONNECTION BOX / TYPE	A	B	C	D
Dimension (axbxc) mm	142x142x87.5	175x175x106.8	240x195x122	353x264.5x157.5

Note: exit shaft dimensions to be defined according to the key options

Max. Radial Load

applicable in the middle of the shaft extension



Ref. To Performances Curves pag 40

U310C MOTOR

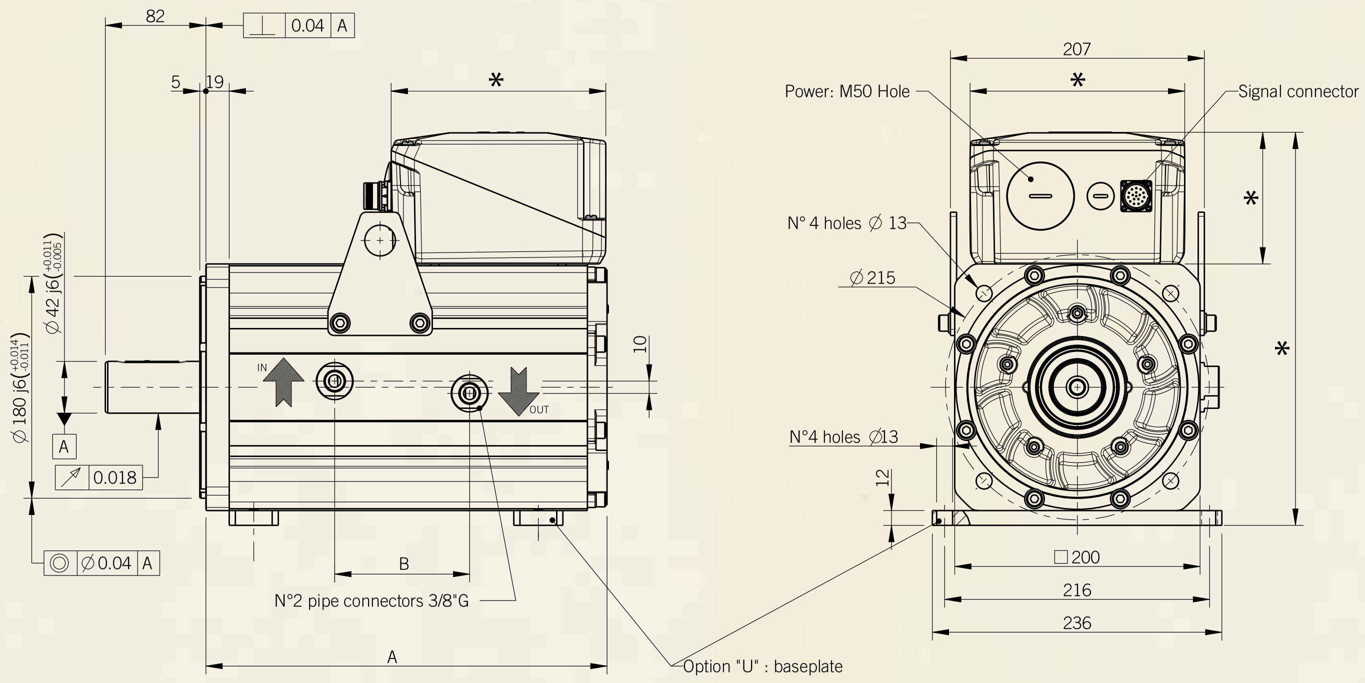
Water Cooling type C / For Inverter rated Voltage 380Vac to 480Vac

Motor Type U3			1004C			1007C			1010C			1013C		
Rated Speed	nM	[rpm]	1000	2000	3000	1000	2000	3000	1000	2000	3000	1000	2000	3000
Stall Torque 2)	Md0	[Nm]	55			110			165			220		
Current @ Stall Torque 2)	Id0	[A]	13	26	35	28	56	78	39	78	112	49	98	158
Number of Poles	2p		8											
Nominal Rating														
Rated Torque 2)	MdN	[Nm]	54	53	53	109	108	108	164	163	160	219	218	217
Rated Current 2)	IdN	[A]	13	25	34	28	55	76	39	77	109	49	98	156
Rated Power 2)	PdN	[kW]	6	11	17	11	23	34	17	34	50	23	46	68
Voltage Constant 3)	Ke	[V/1000rpm]	276	139	102	258	128	93	276	138	96	293	146	91
Torque Constant 3)	Kt	[Nm/A]	4,56	2,30	1,68	4,26	2,12	1,53	4,56	2,28	1,59	4,85	2,42	1,51
Torque Constant @ 130°C 3)	Kt100	[Nm/A]	4,21	2,12	1,55	3,93	1,96	1,41	4,21	2,10	1,47	4,48	2,23	1,39
Winding Resistance 3)	Ru-v	[Ω]	3,400	0,860	0,458	1,136	0,280	0,145	0,758	0,190	0,092	0,620	0,154	0,060
Winding Inductance 3)	Lu-v	[mH]	34,00	8,60	4,30	15,00	3,75	1,80	11,50	2,87	1,40	9,10	2,30	0,90
Derating Temp. Coeff. Of Back EMF	Dke/Dt	[%/°C]	-0,09											
Nominal Voltage	Vn	[V]	351	335	356	322	309	324	342	330	340	358	346	321
Minimum Flow Rate	Flow	[L/min]	2,5			4			5			7		
Losses	Loss	[kW]	1,25	1,25	1,24	1,92	1,91	1,90	2,52	2,52	2,51	3,23	3,23	3,23
Efficiency	Eff	[%]	86	90	93	86	92	95	87	93	95	88	93	95
Knee Speed @ 380Vac	nknee1	[rpm]	1092	2282	3208	1194	2480	3534	1118	2311	3358	1066	2201	3569
Knee Speed @ 480Vac	nknee2	[rpm]	1407	2910	4080	1529	3154	4486	1431	2937	4259	1365	2799	4526
Knee Speed 380Vac and Mmax	nknee3	[rpm]	790	1688	2436	861	1811	2661	1378	2757	2485	834	1741	2831
Knee Speed 480Vac and Mmax	nknee4	[rpm]	1029	2164	3111	1111	2311	3386	1741	3482	3159	1075	2220	3597
Maximum Values														
Max. Torque	Mmax	[Nm]	102			210			310			410		
Max. Current (peak value)	Imax	[A]	26	51	69	56	113	157	78	155	222	89	178	286
Max. Saturation Speed @ 380Vac	nmax1	[rpm]	1378	2733	3741	1475	2965	4108	1378	2757	3953	1296	2597	4162
Max. Saturation Speed @ 480Vac	nmax2	[rpm]	1741	3452	4726	1864	3745	5189	1741	3482	4993	1637	3281	5258
Max. Mechanical Speed	nmax	[rpm]	6000											
Mechanical Data 3)														
Inertia	Jm	[Kgcm²]	50			90			130			170		
Mass	M	[Kg]	41			52			64			75		
Total Length	A	[mm]	255			327			399			471		
Connection Box	Type		B			B			B		C	B	C	
Shaft dimension 7)	ØDxL	[mm]	42k6 x 82 (110)											
Shaft dimension 8)	ØDxL	[mm]	***						48k6 x 110 (82)					
Technical Data of the holding brake														
Holding Torque	MBr	[Nm]	143											
Rated Voltage	UBr	[Vdc]	24											
Rated Current 2)	IBr	[A]	1,78											
Mass	MBr	[Kg]	11											
Inertia	JBr	[Kgcm²]	48,6											
Addditional motor lenght	Lenght	[mm]	65											

Test Condition

1) Motor tested in horizontal position, ambient temperature 30°C; 2) Water inlet temperature max 20°C; 3) Typical data tolerance +/- 10%; 4) Treshold of built in PTC 130°C; 5) KTY84-130 6) Chopper frequency 8kHz; 7) DIN748-1 - Simultaneous transmission of a torque and a corresponding known bending moment (column b); 8) DIN748-1 - Simultaneous transmission of torque and an unknown bending moment (column c)

Technical Drawing



Total Lenght

Type	A (mm)	B (mm)
1004C	255	39
1007C	327	110
1010C	399	166
1013C	471	220

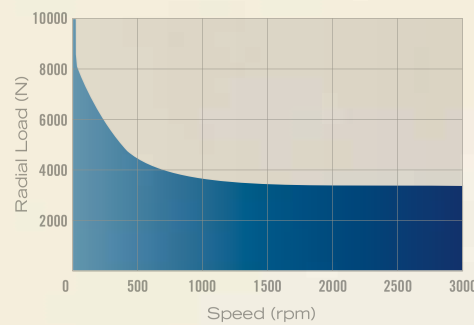
Connections

CONNECTION BOX / TYPE	A	B	C	D
Dimension (axbxc) mm	142x142x87.5	175x175x106.8	240x195x122	353x264.5x157.5

Note: exit shaft dimensions to be defined according to the key options

Max. Radial Load

applicable in the middle of the shaft extension



Ref. To Performances Curves pag 40

U313 MOTOR

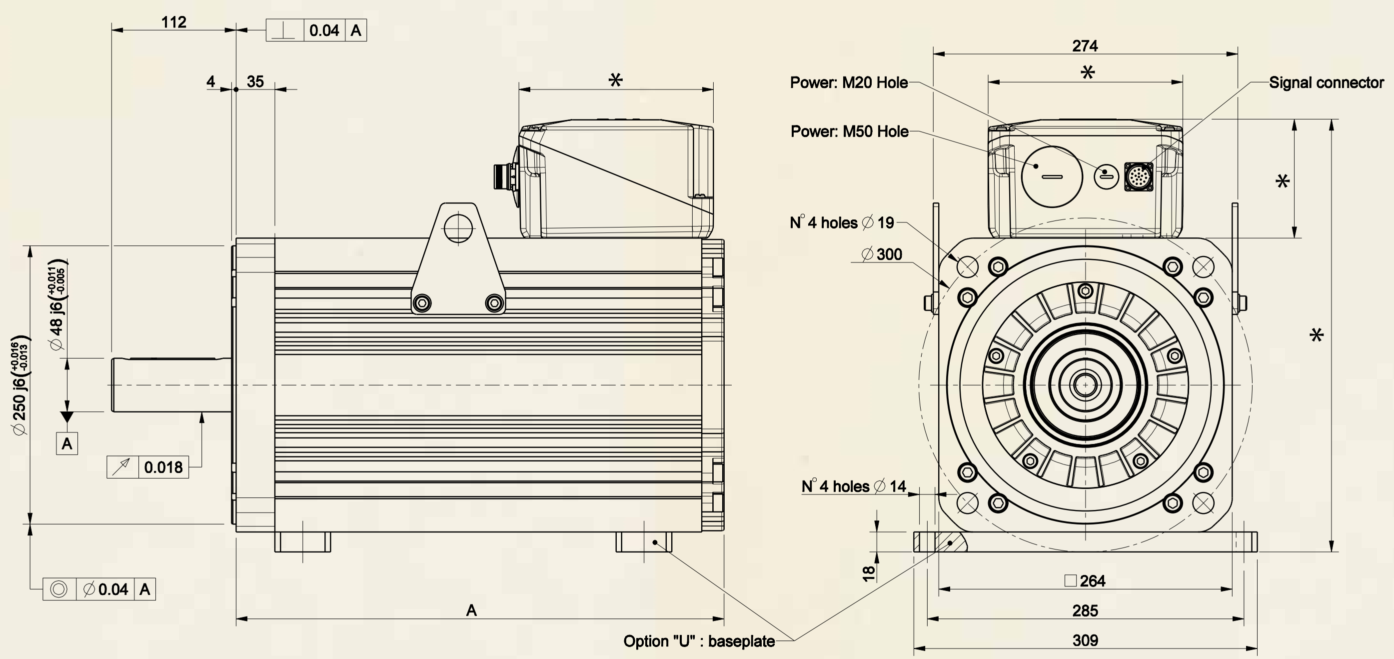
Natural Convection Cooling / For Inverter rated Voltage 380Vac to 480Vac

Motor Type U3			1310			1320			1330			1340		
Rated Speed	nM	[rpm]	1000	2000	3000	1000	2000	3000	1000	2000	3000	1000	2000	3000 (4)
Stall Torque 2)	Md0	[Nm]	100			190			260			350		
Current @ Stall Torque 2)	Id0	[A]	20	40	60	39	88	117	54	107	161	65	163	216
Number of Poles	2p		8											
Nominal Rating														
Rated Torque 2)	MdN	[Nm]	95	87	70	170	100	50	240	180	n.a. 4)	270	130	n.a. 4)
Rated Current 2)	IdN	[A]	19	35	42	35	47	31	50	70	n.a. 4)	50	61	n.a. 4)
Rated Power 2)	PdN	[kW]	10	18	22	18	21	16	25	38	n.a. 4)	28	27	n.a. 4)
Voltage Constant 3)	Ke	[V/1000rpm]	343	172	114	333	148	111	333	166	111	369	148	111
Torque Constant 3)	Kt	[Nm/A]	5,68	2,84	1,89	5,50	2,44	1,84	5,50	2,75	1,84	6,10	2,44	1,84
Torque Constant @ 130°C 3)	Kt100	[Nm/A]	5,00	2,50	1,66	4,84	2,15	1,62	4,84	2,42	1,62	5,37	2,15	1,62
Winding Resistance 3)	Ru-v	[Ω]	0,800	0,200	0,090	0,300	0,058	0,033	0,196	0,049	0,022	0,160	0,026	0,015
Winding Inductance 3)	Lu-v	[mH]	18,00	4,50	2,00	9,10	1,94	1,03	6,00	1,50	0,73	5,50	0,97	0,52
Derating Temp. Coeff. Of Back EMF	Dke/Dt	[%/°C]	-0,09											
Nominal Voltage	Vn	[V]	378	367	358	361	312	346	358	345	n.a. 4)	389	299	n.a. 4)
Minimum Flow Rate	Flow	[L/min]	n.a.			n.a.			n.a.			n.a.		
Losses	Loss	[kW]	0,69	0,69	0,70	1,00	0,98	0,98	1,22	1,22	1,23	1,47	1,49	1,51
Efficiency	Eff	[%]	93	96	97	95	96	97	96	97	n.a. 4)	96	97	n.a. 4)
Knee Speed @ 380Vac	nknee1	[rpm]	1007	2069	3186	1055	2439	3297	1064	2203	n.a. 4)	977	2540	n.a. 4)
Knee Speed @ 480Vac	nknee2	[rpm]	1281	2622	4031	1339	3087	4169	1350	2787	n.a. 4)	1238	3211	n.a. 4)
Knee Speed 380Vac and Mmax	nknee3	[rpm]	666	1384	2101	728	1618	2242	681	1400	2006	619	1507	2083
Knee Speed 480Vac and Mmax	nknee4	[rpm]	855	1762	2668	930	2053	2842	870	1779	2543	791	1912	2640
Maximum Values														
Max. Torque	Mmax	[Nm]	280			550			830			1100		
Max. Current (peak value)	Imax	[A]	62	123	185	111	250	332	189	377	564	225	564	747
Max. Saturation Speed @ 380Vac	nmax1	[rpm]	1107	2213	3325	1143	2576	3416	1143	2286	3416	1030	2576	3416
Max. Saturation Speed @ 480Vac	nmax2	[rpm]	1398	2795	4201	1443	3254	4315	1443	2887	4315	1301	3254	4315
Max. Mechanical Speed	nmax	[rpm]	6000											
Mechanical Data														
Inertia	Jm	[Kgcm²]	200			390			590			780		
Mass	M	[Kg]	50			80			110			140		
Total Length	A	[mm]	332			439			546			653		
Connection Box	Type		A	B		B		C	B		C	B	C	D
Shaft dimension 8)	ØDxL	[mm]	48k6 x 110											
Shaft dimension 9)	ØDxL	[mm]	***						50k6 x 110			55m6 x 140 (105)		
Technical Data of the holding brake														
Holding Torque	MBr	[Nm]	300											
Rated Voltage (±10%)	UBr	[Vdc]	24											
Rated Current 2)	IBr	[A]	1,74											
Mass	MBr	[Kg]	18											
Inertia	JBr	[Kgcm²]	200											
Addditional motor lenght	Lenght	[mm]	80											

Test Condition

1) Motor tested in horizontal position in free still air, ambient temperature 30°C; 2) Motor flanged (Tflange = 30°C), to use on baseplate derate -30% of the Md0; 3) Typical data tolerance +/- 10%; 4) Not available in S1 duty and DT100°C; 5) Treshold of built in PTC 130°C; 6) KTY84-130; 7) Chopper frequency 8kHz; 8) DIN748-1 - Simultaneous transmission of a torque and a corresponding known bending moment (column b); 9) DIN748-1 - Simultaneous transmission of torque and an unknown bending moment (column c)

Technical Drawing



Total Lenght

Type	A (mm)
1310	332
1320	439
1330	546
1340	653

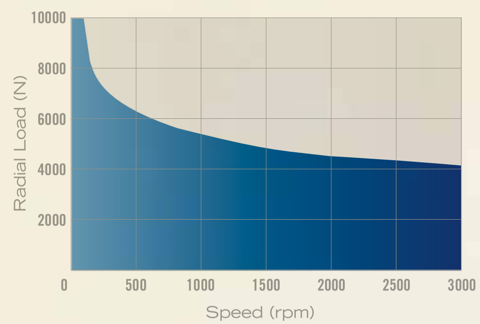
Connections

CONNECTION BOX / TYPE	A	B	C	D
Dimension (axbxc) mm	142x142x87.5	175x175x106.8	240x195x122	353x264.5x157.5

Note: exit shaft dimensions to be defined according to the key options

Max. Radial Load

applicable in the middle of the shaft extension



Ref. To Performances Curves pag 40

U313F MOTOR

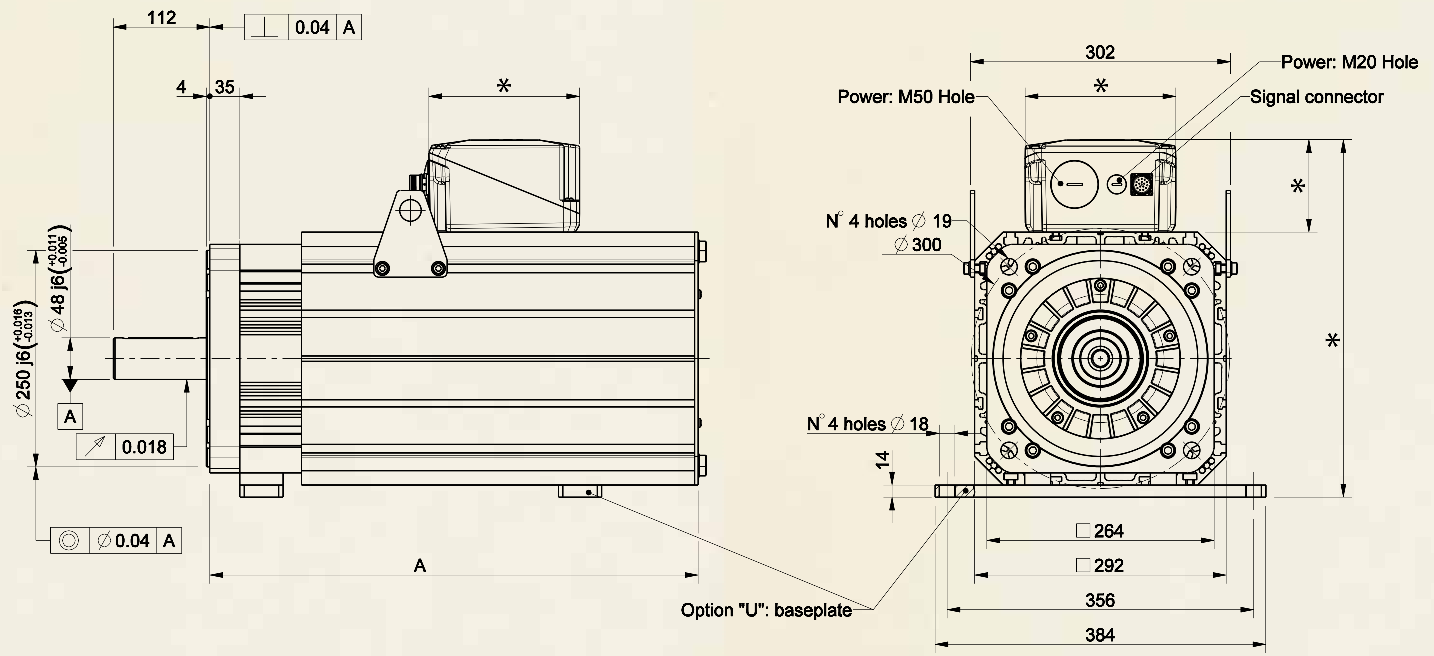
Servo Fan Cooling type F / For Inverter rated Voltage 380Vac to 480Vac

Motor Type U3			1310F			1320F			1330F			1340F		
Rated Speed	nM	[rpm]	1000	2000	3000	1000	2000	3000	1000	2000	3000	1000	2000	3000 (4)
Stall Torque 2)	Md0	[Nm]	150			280			410			540		
Current @ Stall Torque 2)	Id0	[A]	32	63	95	61	137	182	89	178	267	132	265	351
Number of Poles	2p		8											
Nominal Rating														
Rated Torque 2)	MdN	[Nm]	145	135	130	270	260	240	400	380	350	510	480	460
Rated Current 2)	IdN	[A]	31	57	82	59	127	156	87	165	228	124	235	299
Rated Power 2)	PdN	[kW]	15	28	41	28	54	75	42	80	110	53	100	144
Voltage Constant 1) 3)	Ke	[V/1000rpm]	343	172	114	333	148	111	333	166	111	296	148	111
Torque Constant 1) 3)	Kt	[Nm/A]	5,68	2,84	1,89	5,50	2,44	1,84	5,50	2,75	1,84	4,90	2,44	1,84
Torque Constant @ 130°C 3)	Kt100	[Nm/A]	5,00	2,50	1,66	4,84	2,15	1,62	4,84	2,42	1,62	4,31	2,15	1,62
Winding Resistance 3)	Ru-v	[Ω]	0,800	0,200	0,090	0,300	0,058	0,033	0,196	0,049	0,022	0,105	0,026	0,015
Winding Inductance 3)	Lu-v	[mH]	18,00	4,90	2,00	9,10	1,94	1,09	6,00	1,50	0,73	3,87	0,97	0,52
Derating Temp. Coeff. Of Back EMF	Dke/Dt	[%/°C]	-0,09											
Nominal Voltage	Vn	[V]	416	407	392	398	351	386	396	384	383	354	343	378
Minimum Flow Rate	Flow	[L/min]	n.a.			n.a.			n.a.			n.a.		
Losses	Loss	[kW]	1,72	1,72	1,75	2,40	2,36	2,36	3,37	3,37	3,38	3,94	3,94	3,86
Efficiency	Eff	[%]	91	95	95	92	95	96	93	95	96	93	96	97
Knee Speed @ 380Vac	nknee1	[rpm]	911	1865	2903	953	2169	2957	960	1978	2973	1076	2219	3020
Knee Speed @ 480Vac	nknee2	[rpm]	1163	2367	3679	1213	2748	3743	1221	2507	3764	1367	2810	3821
Knee Speed 380Vac and Mmax	nknee3	[rpm]	553	1088	1753	553	1218	1640	681	1400	2006	740	1507	2084
Knee Speed 480Vac and Mmax	nknee4	[rpm]	711	1385	2227	708	1546	2079	870	1779	2543	943	1912	2641
Maximum Values														
Max. Torque	Mmax	[Nm]	325			650			830			1100		
Max. Current (peak value)	Imax	[A]	81	163	244	168	378	502	189	377	564	281	564	747
Max. Saturation Speed @ 380Vac	nmax1	[rpm]	1107	2213	3325	1143	2576	3416	1143	2286	3416	1283	2576	3416
Max. Saturation Speed @ 480Vac	nmax2	[rpm]	1398	2795	4201	1443	3254	4315	1443	2887	4315	1620	3254	4315
Max. Mechanical Speed	nmax	[rpm]	6000											
Mechanical Data 3)														
Inertia	Jm	[Kgcm²]	200			390			590			780		
Mass	M	[Kg]	65			100			130			160		
Total Length	A	[mm]	470			577			684 8)			791 8)		
Connection Box	Type		A	B		B		C	B		C	B	C	D
Shaft dimension 7)	ØDxL	[mm]	48k6 x 110 (82)									50k6 x 110 (82)		
Shaft dimension 8)	ØDxL	[mm]	48k6 x 110 (82			50k6 x 110 (82)			60m6 x 140 (105)					
Technical Data of the holding brake														
Holding Torque	MBr	[Nm]	300											
Rated Voltage (±10%)	UBr	[Vdc]	24											
Rated Current 2)	IBr	[A]	1,74											
Mass	MBr	[Kg]	18											
Inertia	JBr	[Kgcm²]	200											
Addditional motor lenght	Lenght	[mm]	80											

Test Condition

1) Motor tested in horizontal position, ambient temperature 30°C; 2) Motor flanged (Tflange = 30°C), to use on baseplate derate -30%; 3) Typical data tolerance +/- 10%; 4) Treshold of built in PTC 130°C; 5) KTY84-130; 6) Chopper frequency 8kHz; 7) DIN748-1 - Simultaneous transmission of a torque and a corresponding known bending moment (column b); 8) DIN748-1 - Simultaneous transmission of torque and an unknown bending moment (column c)

Technical Drawing



Total Lenght

Type	A (mm)
1310F	460
1320F	567
1330F	674
1340F	781

If Id0 >= 200A:
+ 40mm of addtional lenght

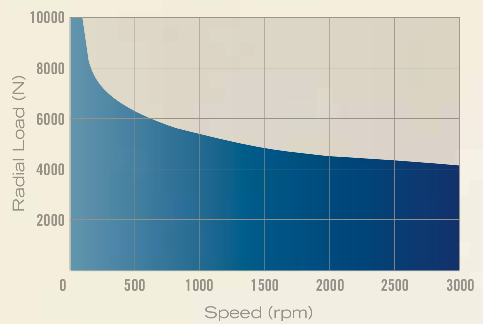
Connections

CONNECTION BOX / TYPE	A	B	C	D
Dimension (axbxc) mm	142x142x87.5	175x175x106.8	240x195x122	353x264.5x157.5

Note: exit shaft dimensions to be defined according to the key options

Max. Radial Load

applicable in the middle of the shaft extension



Ref. To Performances Curves pag 40

U313C MOTOR

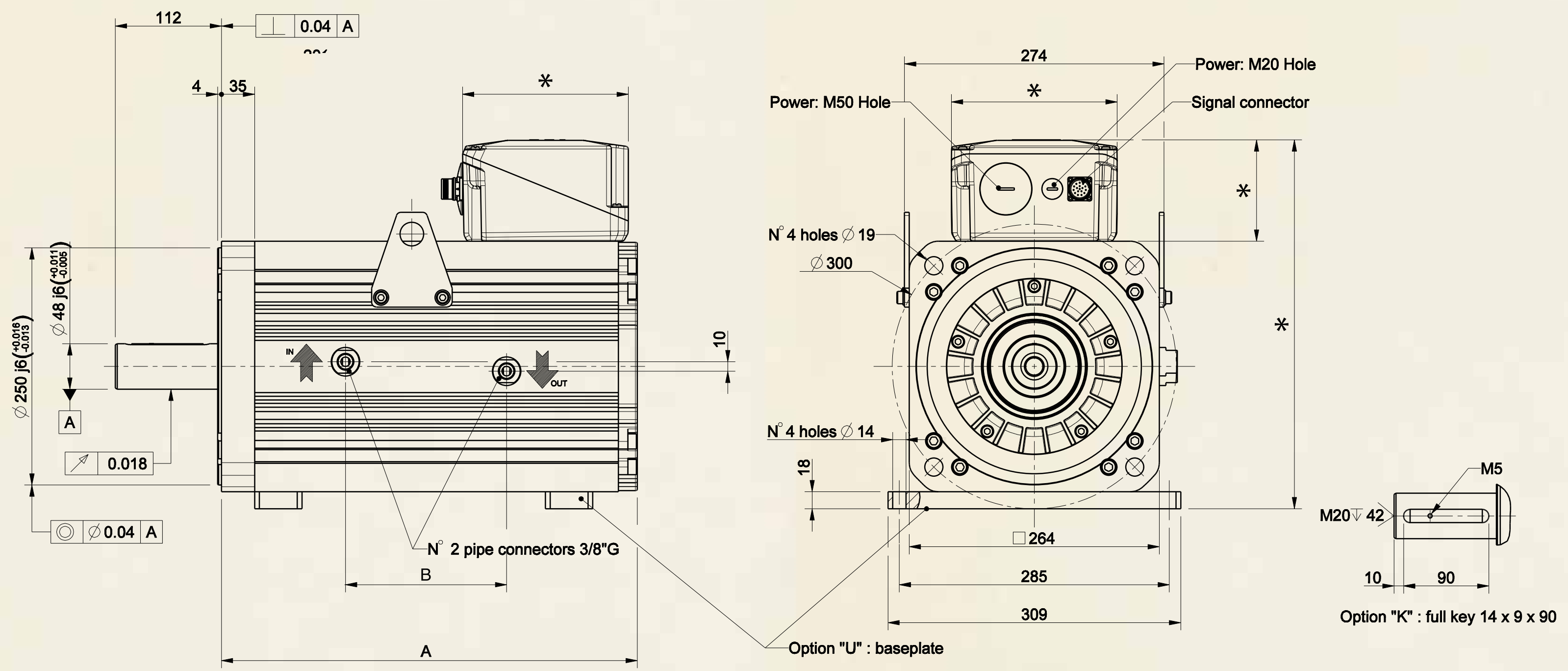
Water Cooling type C / For Inverter rated Voltage 380Vac to 480Vac

Motor Type U3			1310C			1320C			1330C			1340C		
Rated Speed	nM	[rpm]	1000	2000	3000	1000	2000	3000	1000	2000	3000	1000	2000	3000
Stall Torque 2)	Md0	[Nm]	180			360			540			720		
Current @ Stall Torque	Id0	[A]	41	69	103	80	160	212	128	254	318	142	320	424
Number of Poles	2p		8											
Nominal Rating														
Rated Torque 2)	MdN	[Nm]	179	178	175	357	353	348	539	530	520	715	710	700
Rated Current 2)	IdN	[A]	41	68	100	79	157	205	128	250	306	141	315	412
Rated Power 2)	PdN	[kW]	19	37	55	37	74	109	56	111	163	75	149	220
Voltage Constant 3)	Ke	[V/1000rpm]	287	172	114	296	148	111	277	139	111	333	148	111
Torque Constant 3)	Kt	[Nm/A]	4,74	2,84	1,89	4,89	2,44	1,84	4,58	2,30	1,84	5,50	2,44	1,84
Torque Constant @ 130°C 3)	Kt100	[Nm/A]	4,38	2,62	1,74	4,51	2,25	1,70	4,23	2,12	1,70	5,08	2,25	1,70
Winding Resistance 3)	Ru-v	[Ω]	0,560	0,200	0,090	0,243	0,060	0,034	0,135	0,034	0,022	0,127	0,026	0,015
Winding Inductance 3)	Lu-v	[mH]	12,50	4,90	2,00	7,10	1,80	1,00	4,20	1,05	0,73	4,50	0,97	0,52
Derating Temp. Coeff. Of Back EMF	Dke/Dt	[%/°C]	-0,09											
Nominal Voltage	Vn	[V]	358	429	413	373	366	406	351	343	418	417	375	411
Minimum Flow Rate	Flow	[L/min]	5			8			11			14		
Losses	Loss	[kW]	2,05	2,04	2,07	3,34	3,31	3,30	4,76	4,75	4,80	5,52	5,63	5,63
Efficiency	Eff	[%]	86	95	96	92	96	97	92	96	97	93	96	98
Knee Speed @ 380Vac	nknee1	[rpm]	1064	1765	2756	1020	2079	2803	1087	2220	2726	908	2029	2769
Knee Speed @ 480Vac	nknee2	[rpm]	1357	2241	3494	1299	2636	3550	1383	2813	3453	1156	2570	3505
Knee Speed 380Vac and Mmax	nknee3	[rpm]	854	1394	2214	817	1661	2244	1372	2733	2125	761	1674	2303
Knee Speed 480Vac and Mmax	nknee4	[rpm]	1093	1774	2811	1042	2108	2845	1733	3452	2694	970	2123	2917
Maximum Values														
Max. Torque	Mmax	[Nm]	280			550			830			1100		
Max. Current (peak value)	Imax	[A]	67	112	169	128	257	341	207	412	514	211	475	629
Max. Saturation Speed @ 380Vac	nmax1	[rpm]	1326	2213	3325	1285	2576	3416	1372	2733	3416	1143	2576	3416
Max. Saturation Speed @ 480Vac	nmax2	[rpm]	1675	2795	4201	1624	3254	4315	1733	3452	4315	1443	3254	4315
Max. Mechanical Speed	nmax	[rpm]	6000											
Mechanical Data 3)														
Inertia	Jm	[Kgcm²]	200			390			590			780		
Mass	M	[Kg]	50			80			110			140		
Total Length	A	[mm]	332			439 9)			546 9)			653 9)		
Connection Box	Type		B			B	C		B	C	D	B	D	
Shaft dimension 7)	ØDxL	[mm]	48k6 x 110						55k6 x 110					
Shaft dimension 8)	ØDxL	[mm]	***			55k6 x 110			60m6 x 140 (105)			70m6 x 140 (105)		
Technical Data of the holding brake														
Holding Torque	MBr	[Nm]	300											
Rated Voltage	UBr	[Vdc]	24											
Rated Current 2)	IBr	[A]	1,74											
Mass	MBr	[Kg]	18											
Inertia	JBr	[Kgcm²]	200			390			590			780		
Addditional motor lenght	Lenght	[mm]	80											

Test Condition

1) Motor tested in horizontal position, ambient temperature 30°C; 2) Water inlet temperature 20°C; 3) Typical data tolerance +/- 10%; 4) Treshold of built in PTC 130°C; 5) KTY84-130; 6) Chopper frequency 8kHz; 7) DIN748-1 - Simultaneous transmission of a torque and a corresponding known bending moment; 8) DIN748-1 - Simultaneous transmission of torque and an unknown bending moment

Technical Drawing



Total Lenght

Type	A* (mm)	B (mm)
1310C	332	75
1320C	439	170
1303C	546	279
1340C	653	385

* If Id0 >= 200A:
+ 40mm of addtional lenght

Ref. To Performances Curves pag 40

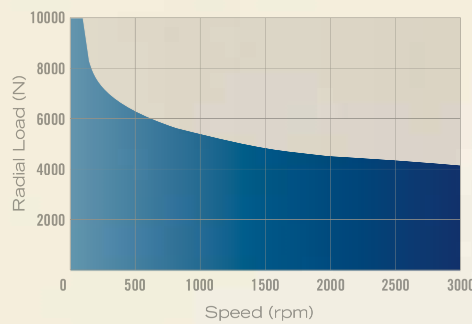
Connections

CONNECTION BOX / TYPE	A	B	C	D
Dimension (axbxc) mm	142x142x87.5	175x175x106.8	240x195x122	353x264.5x157.5

Note: exit shaft dimensions to be defined according to the key options

Max. Radial Load

applicable in the middle of the shaft extension



U318 MOTOR

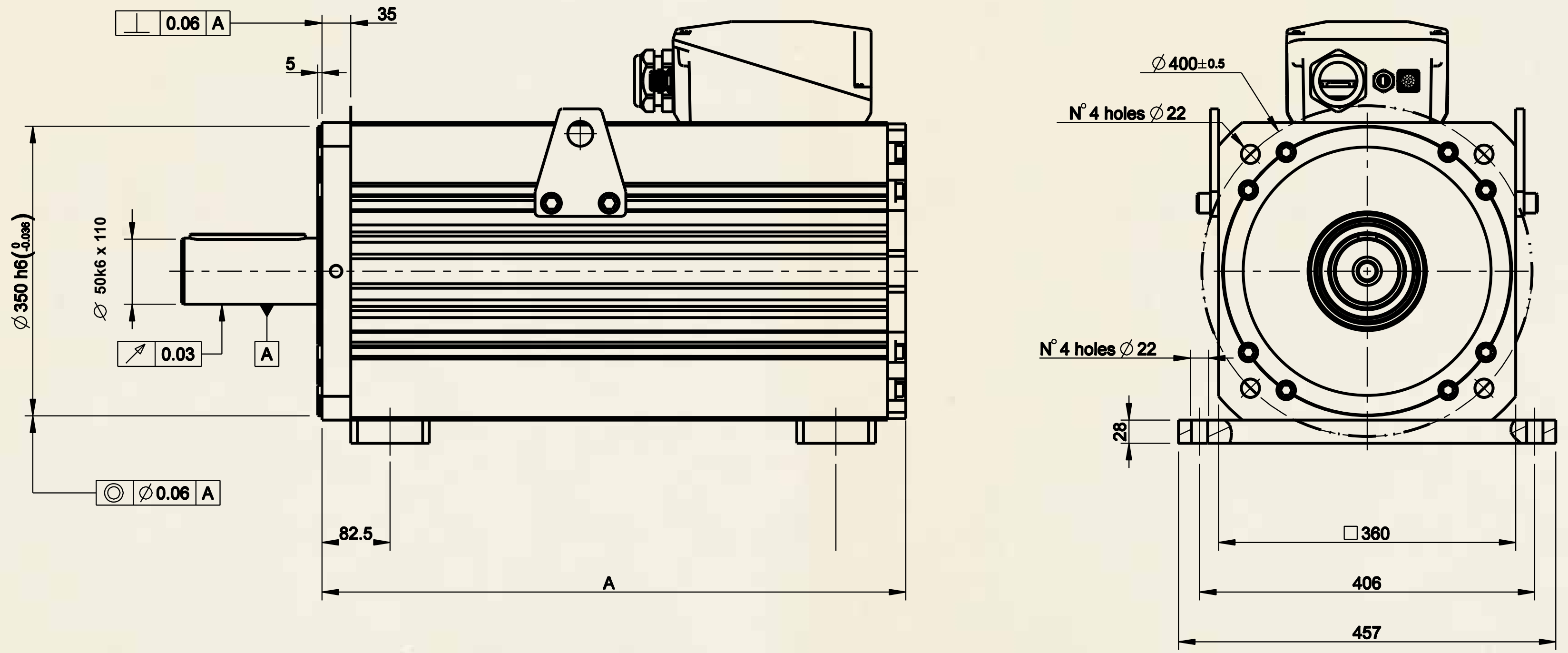
Natural Convection Cooling / For Inverter rated Voltage 380Vac to 480Vac

Motor Type U3			1835		1870		18100	
Rated Speed	nM	[rpm]	1000	2000	1000	2000	1000	2000
Stall Torque 2)	Md0	[Nm]	300		560		730	
Current @ Stall Torque 2)	Id0	[A]	53	106	99	197	145	290
Number of Poles	2p		12					
Nominal Rating								
Rated Torque 2)	MdN	[Nm]	200	n.a. 4)	300	n.a. 4)	290	n.a. 4)
Rated Current 2)	IdN	[A]	35	n.a. 4)	53	n.a. 4)	57	n.a. 4)
Rated Power 2)	PdN	[kW]	21	n.a. 4)	31	n.a. 4)	30	n.a. 4)
Voltage Constant 3)	Ke	[V/1000rpm]	390	195	390	195	347	173
Torque Constant 3)	Kt	[Nm/A]	6,45	3,23	6,45	3,23	5,74	2,86
Torque Constant @ 130°C 3)	Kt100	[Nm/A]	5,68	2,84	5,68	2,84	5,05	2,52
Winding Resistance 3)	Ru-v	[Ω]	0,16	0,042	0,066	0,017	0,037	0,009
Winding Inductance 3)	Lu-v	[mH]	2,2	0,55	1,1	0,28	0,65	0,16
Derating Temp. Coeff. Of Back EMF	Dke/Dt	[%/°C]	-0,09					
Nominal Voltage	Vn	[V]	396	n.a. 4)	394	n.a. 4)	349	n.a. 4)
Minimum Flow Rate	Flow	[L/min]	n.a.					
Losses	Loss	[kW]	0,97	1,01	1,39	1,43	1,67	1,63
Efficiency	Eff	[%]	95	94	94	94	95	95
Knee Speed @ 380Vac	nknee1	[rpm]	959	n.a. 4)	965	n.a. 4)	1089	n.a. 4)
Knee Speed @ 480Vac	nknee2	[rpm]	1215	n.a. 4)	1221	n.a. 4)	1377	n.a. 4)
Knee Speed 380Vac and Mmax	nknee3	[rpm]	795	1658	816	1681	917	1900
Knee Speed 480Vac and Mmax	nknee4	[rpm]	1023	2114	1046	2139	1173	2414
Maximum Values								
Max. Torque	Mmax	[Nm]	1300		2500		3500	
Max. Current (peak value)	Imax	[A]	252	504	484	969	762	1529
Max. Saturation Speed @ 380Vac	nmax1	[rpm]	974	1949	974	1949	1095	2197
Max. Saturation Speed @ 480Vac	nmax2	[rpm]	1231	2462	1231	2462	1383	2775
Max. Mechanical Speed	nmax	[rpm]		4000				
Mechanical Data								
Inertia	Jm	[Kgcm²]	2820		5340		7010	
Mass	M	[Kg]	240		425		510	
Total Length	A	[mm]	515		707		835	
Connection Box	Type		D					
Shaft dimension 8)	ØDxL	[mm]	50k6 x 110					
Shaft dimension 9)	ØDxL	[mm]	60m6 x 140					
Technical Data of the holding brake								
Holding Torque	MBr	[Nm]	n.a.					
Rated Voltage (±10%)	UBr	[Vdc]	n.a.					
Rated Current 2)	IBr	[A]	n.a.					
Mass	MBr	[Kg]	n.a.					
Inertia	JBr	[Kgcm²]	n.a.					
Addditional motor lenght	Lenght	[mm]	n.a.					

Test Condition

1) Motor tested in horizontal position in free still air, ambient temperature 30°C; 2) Motor flanged (Tflange = 30°C), to use on baseplate derate -30% of the Md0; 3) Typical data tolerance +/- 10%; 4) Not available in S1 duty and DT100°C; 5) Treshold of built in PTC 130°C; 6) KTY84-130; 7) Chopper frequency 8kHz; 8) DIN748-1 - Simultaneous transmission of a torque and a corresponding known bending moment (column b); 9) DIN748-1 - Simultaneous transmission of torque and an unknown bending moment (column c)

Technical Drawing



Total Lenght

Type	A (mm)
18035A	515
18070A	707
18100A	835

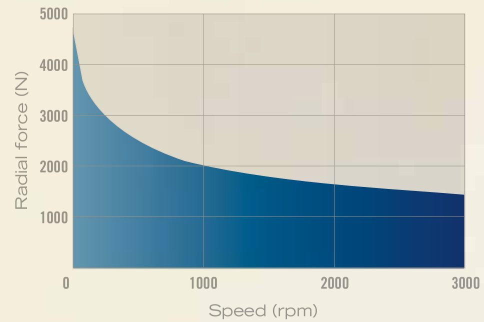
Connections

CONNECTION BOX / TYPE	D
Dimension (axbxc) mm	353x264.5x157.5

Note: exit shaft dimensions to be defined according to the key options

Max. Radial Load

applicable in the middle of the shaft extension



Ref. To Performances Curves pag 40

U318F MOTOR

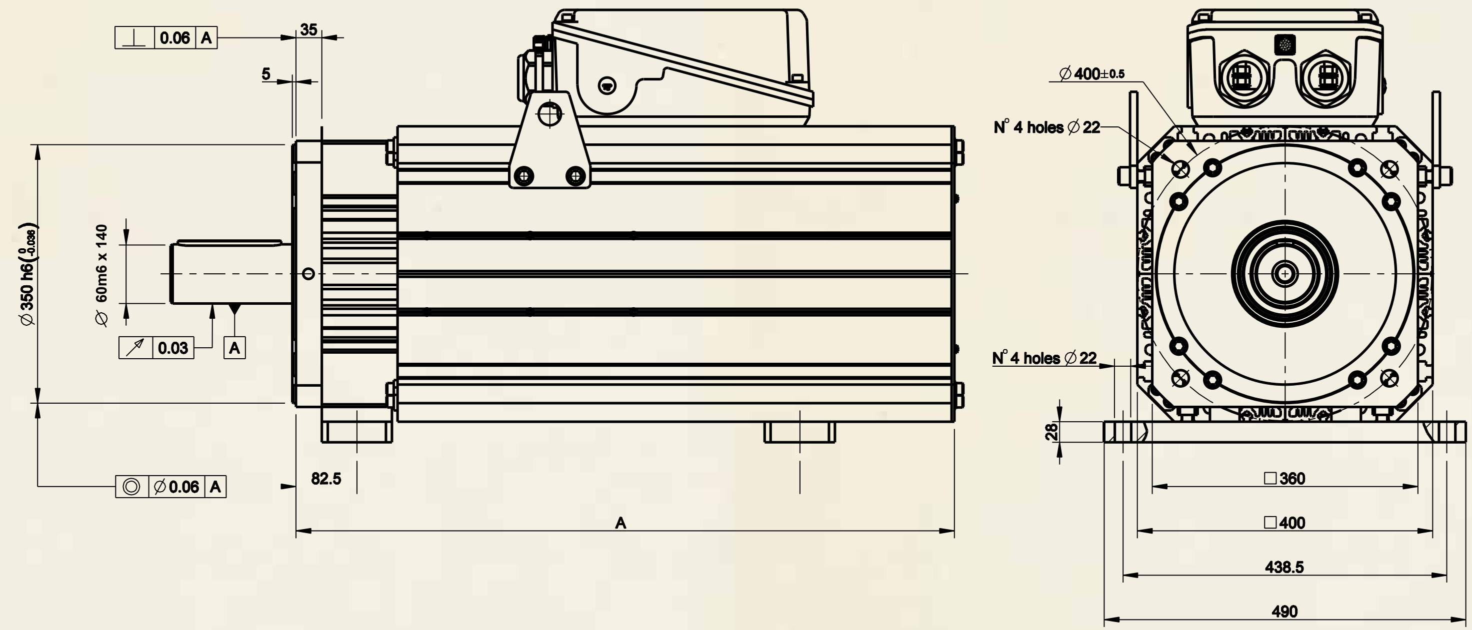
Servo Fan Cooling type F / For Inverter rated Voltage 380Vac to 480Vac

Motor Type U3			1835F		1870F		18100F	
Rated Speed	nM	[rpm]	1000	2000	1000	2000	1000	2000
Stall Torque 2)	Md0	[Nm]	500		1000		1270	
Current @ Stall Torque 2)	Id0	[A]	88	176	176	352	251	504
Number of Poles	2p		12					
Nominal Rating								
Rated Torque 2)	MdN	[Nm]	520	420	890	790	1150	900
Rated Current 2)	IdN	[A]	92	148	157	278	228	357
Rated Power 2)	PdN	[kW]	54	88	93	165	120	188
Voltage Constant 3)	Ke	[V/1000rpm]	390	195	390	195	347	173
Torque Constant 3)	Kt	[Nm/A]	6,45	3,23	6,45	3,23	5,74	2,86
Torque Constant @ 130°C 3)	Kt100	[Nm/A]	5,68	2,84	5,68	2,84	5,05	2,52
Winding Resistance 3)	Ru-v	[Ω]	0,16	0,042	0,066	0,017	0,037	0,009
Winding Inductance 3)	Lu-v	[mH]	2,2	0,55	1,1	0,28	0,65	0,16
Derating Temp. Coeff. Of Back EMF	Dke/Dt	[%/°C]	-0,09					
Nominal Voltage	Vn	[V]	409	400	404	398	358	351
Minimum Flow Rate	Flow	[L/min]	n.a.					
Losses	Loss	[kW]	2,68	2,82	4,42	4,56	5,05	4,95
Efficiency	Eff	[%]	95	94	94	94	95	95
Knee Speed @ 380Vac	nknee1	[rpm]	926	1900	940	1908	1062	2165
Knee Speed @ 480Vac	nknee2	[rpm]	1178	2407	1193	2415	1346	2739
Knee Speed 380Vac and Mmax	nknee3	[rpm]	795	1658	816	1681	917	1900
Knee Speed 480Vac and Mmax	nknee4	[rpm]	1023	2114	1046	2139	1173	2414
Maximum Values								
Max. Torque	Mmax	[Nm]	1300		2500		3500	
Max. Current (peak value)	Imax	[A]	252	504	484	969	762	1529
Max. Saturation Speed @ 380Vac	nmax1	[rpm]	974	1949	974	1949	1095	2197
Max. Saturation Speed @ 480Vac	nmax2	[rpm]	1231	2462	1231	2462	1383	2775
Max. Mechanical Speed	nmax	[rpm]	4000					
Mechanical Data								
Inertia	Jm	[Kgcm²]	2820		5340		7010	
Mass	M	[Kg]	320		380		460	
Total Length	A	[mm]	700		892		1020	
Connection Box	Type		D					
Shaft dimension 8)	ØDxL	[mm]	60m6 x 140					
Shaft dimension 9)	ØDxL	[mm]	60m6 x 140		80m6 x 170		90m6 x 170	
Technical Data of the holding brake								
Holding Torque	MBr	[Nm]	n.a.					
Rated Voltage (±10%)	UBr	[Vdc]	n.a.					
Rated Current 2)	IBr	[A]	n.a.					
Mass	MBr	[Kg]	n.a.					
Inertia	JBr	[Kgcm²]	n.a.					
Addditional motor lenght	Lenght	[mm]	n.a.					

Test Condition

1) Motor tested in horizontal position in free still air, ambient temperature 30°C; 2) Motor flanged (Tflange = 30°C), to use on baseplate derate -30% of the Md0; 3) Typical data tolerance +/- 10%; 4) Not available in S1 duty and DT100°C; 5) Treshold of built in PTC 130°C; 6) KTY84-130; 7) Chopper frequency 8kHz; 8) DIN748-1 - Simultaneous transmission of a torque and a corresponding known bending moment (column b); 9) DIN748-1 - Simultaneous transmission of torque and an unknown bending moment (column c)

Technical Drawing



Total Lenght

Type	A (mm)
18035F	700
18070F	892
18100F	1020

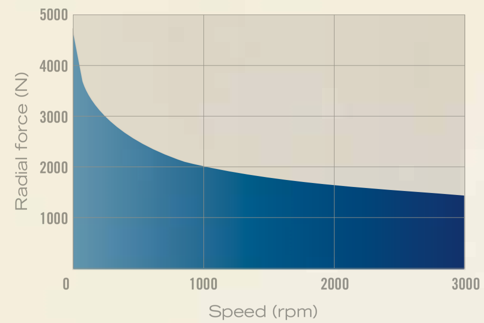
Connections

CONNECTION BOX / TYPE	D
Dimension (axbxc) mm	353x264.5x157.5

Note: exit shaft dimensions to be defined according to the key options

Max. Radial Load

applicable in the middle of the shaft extension



Ref. To Performances Curves pag 40

U318C MOTOR

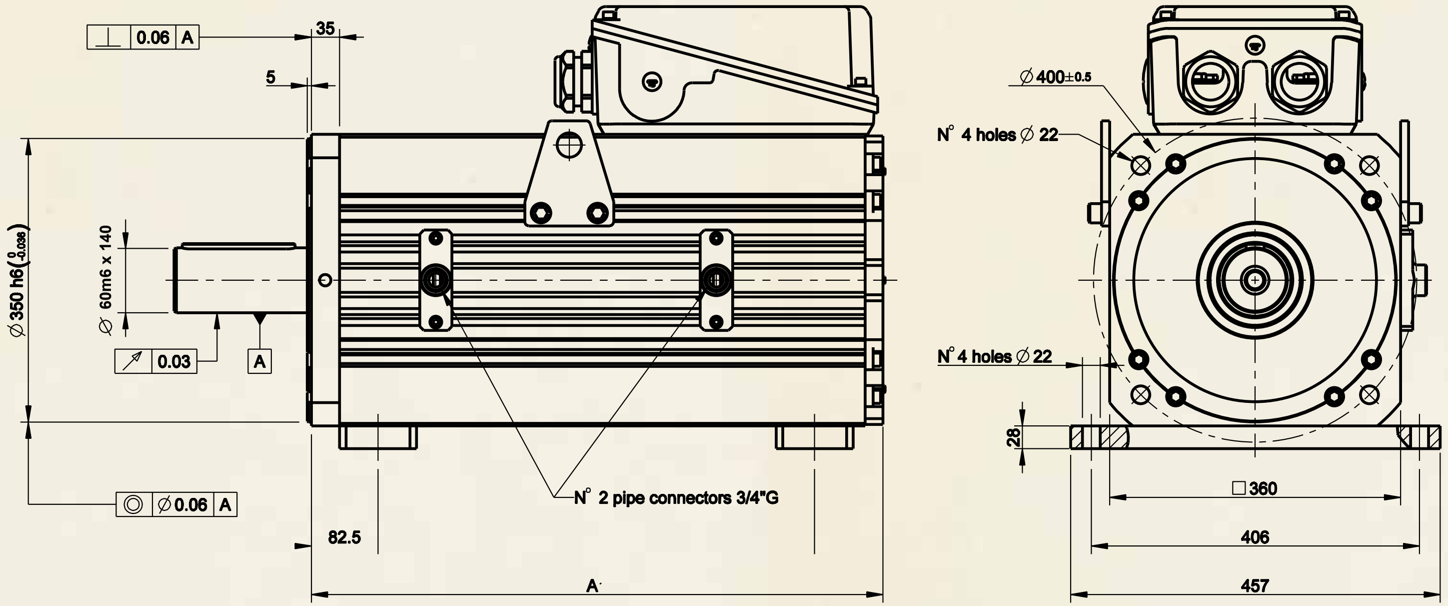
Water Cooling type C / For Inverter rated Voltage 380Vac to 480Vac

Motor Type U3			1835C		1870C		18100C	
Rated Speed	nM	[rpm]	1000	2000	1000	2000	1000	2000
Stall Torque 2)	Md0	[Nm]	550		1100		1600	
Current @ Stall Torque 2)	Id0	[A]	97	194	194	388	317	635
Number of Poles	2p		12					
Nominal Rating								
Rated Torque 2)	MdN	[Nm]	500	497	1000	980	1540	1480
Rated Current 2)	IdN	[A]	88	175	176	345	305	588
Rated Power 2)	PdN	[kW]	52	104	105	205	161	310
Voltage Constant 3)	Ke	[V/1000rpm]	390	195	390	195	347	173
Torque Constant 3)	Kt	[Nm/A]	6,45	3,23	6,45	3,23	5,74	2,86
Torque Constant @ 130°C 3)	Kt100	[Nm/A]	5,68	2,84	5,68	2,84	5,05	2,52
Winding Resistance 3)	Ru-v	[Ω]	0,16	0,042	0,066	0,017	0,037	0,009
Winding Inductance 3)	Lu-v	[mH]	2,2	0,55	1,1	0,28	0,65	0,16
Derating Temp. Coeff. Of Back EMF	Dke/Dt	[%/°C]	-0,09					
Nominal Voltage	Vn	[V]	408	402	406	401	364	357
Minimum Flow Rate	Flow	[L/min]	n.a.					
Losses	Loss	[kW]	3,24	3,41	5,35	5,52	8,02	7,85
Efficiency	Eff	[%]	95	95	94	94	95	95
Knee Speed @ 380Vac	nknee1	[rpm]	929	1887	934	1893	1045	2130
Knee Speed @ 480Vac	nknee2	[rpm]	1181	2391	1186	2397	1328	2697
Knee Speed 380Vac and Mmax	nknee3	[rpm]	795	1658	816	1681	917	1900
Knee Speed 480Vac and Mmax	nknee4	[rpm]	1023	2114	1046	2139	1173	2414
Maximum Values								
Max. Torque	Mmax	[Nm]	1300		2500		3500	
Max. Current (peak value)	Imax	[A]	252	504	484	969	762	1529
Max. Saturation Speed @ 380Vac	nmax1	[rpm]	974	1949	974	1949	1095	2197
Max. Saturation Speed @ 480Vac	nmax2	[rpm]	1231	2462	1231	2462	1383	2775
Max. Mechanical Speed	nmax	[rpm]	4000					
Mechanical Data								
Inertia	Jm	[Kgcm²]	2820		5340		7010	
Mass	M	[Kg]	240		425		510	
Total Length	A	[mm]	515		707		835	
Connection Box	Type		D					
Shaft dimension 8)	ØDxL	[mm]	n.a.					
Shaft dimension 9)	ØDxL	[mm]	60m6 x 140		80m6 x 170		90m6 x 170	
Technical Data of the holding brake								
Holding Torque	MBr	[Nm]	n.a.					
Rated Voltage (±10%)	UBr	[Vdc]	n.a.					
Rated Current 2)	IBr	[A]	n.a.					
Mass	MBr	[Kg]	n.a.					
Inertia	JBr	[Kgcm²]	n.a.					
Addditional motor lenght	Lenght	[mm]	n.a.					

Test Condition

1) Motor tested in horizontal position in free still air, ambient temperature 30°C; 2) Motor flanged (Tflange = 30°C), to use on baseplate derate -30% of the Md0; 3) Typical data tolerance +/- 10%; 4) Not available in S1 duty and DT100°C; 5) Treshold of built in PTC 130°C; 6) KTY84-130; 7) Chopper frequency 8kHz; 8) DIN748-1 - Simultaneous transmission of a torque and a corresponding known bending moment (column b); 9) DIN748-1 - Simultaneous transmission of torque and an unknown bending moment (column c)

Technical Drawing



Total Lenght

Type	A (mm)
18035C	515
18070C	707
18100C	835

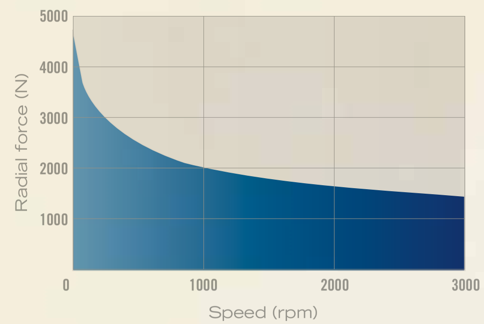
Connections

CONNECTION BOX / TYPE	D
Dimension (axbxc) mm	353x264.5x157.5

Note: exit shaft dimensions to be defined according to the key options

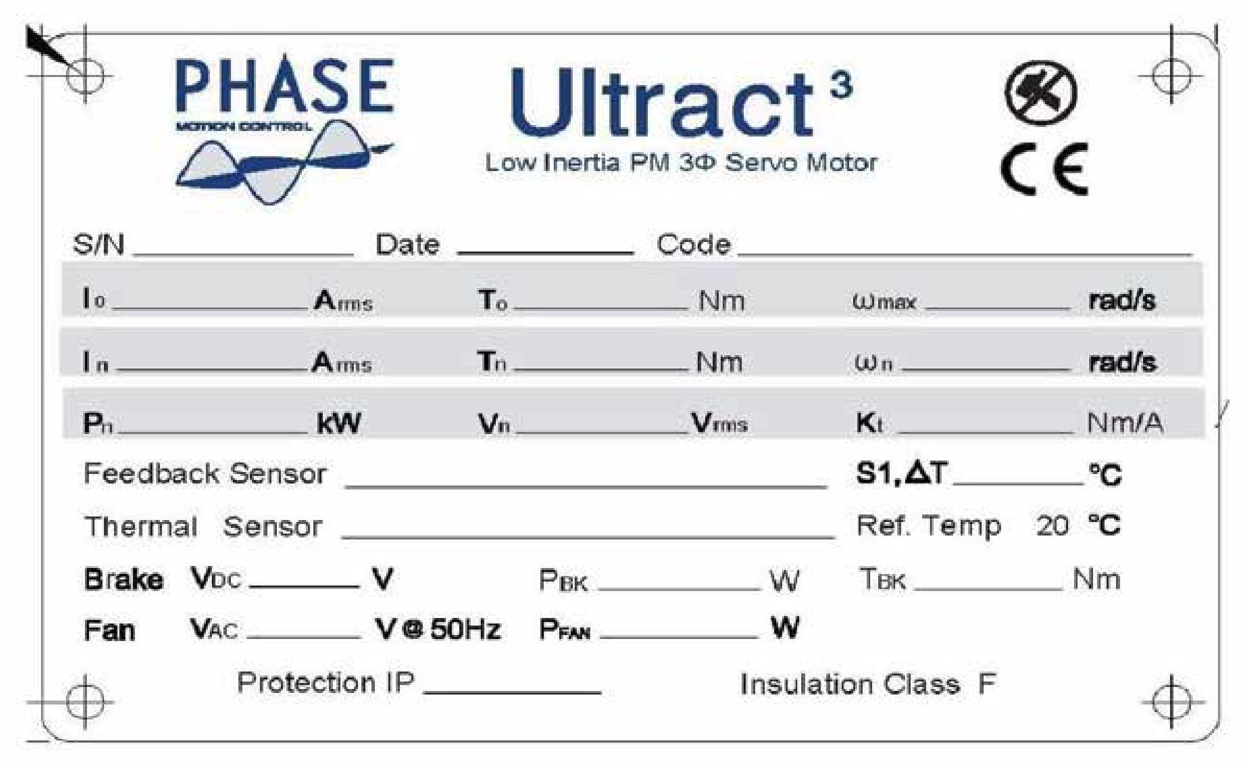
Max. Radial Load

applicable in the middle of the shaft extension



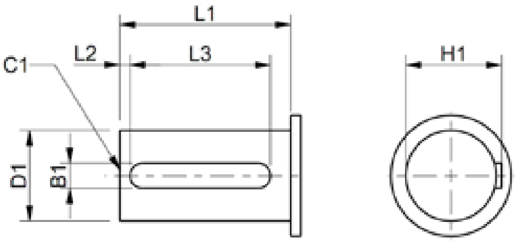
Ref. To Performances Curves pag 40

NAME PLATE



Description	Brochure		Name plate
Rated Speed	nM	[rpm]	ω_n
Stall Torque	Md0	[Nm]	To
Current @ Stall Torque	Id0	[A]	Io
Rated Torque	MdN	[Nm]	Tn
Rated Current	IdN	[A]	In
Rated Power	PdN	[kW]	Pn
Torque Constant	Kt	[Nm/A]	Kt
Nominal Voltage	Vn	[V]	Vn
Max. Mechanical Speed	nmax	[rpm]	ω_{max}
Holding Torque	MBr	[Nm]	TBK
Rated Voltage (±10%)	UBr	[Vdc]	Brake VDC
Brake Power	none	[W]	PBK
Fan Voltage (±10%)	none	[V]	Fan VAC
Fan Power	none	[W]	Pfan
Feedback sensor	none		
Thermal sensor	none		

OPTION “K”



Shaft with key

ØD1 [mm]	Toll.	L1 [mm]	L2 [mm]	L3 [mm]	B1 [mm]	H1 [mm]	Key type B1 x h (DIN 6885)
14	j6	30	6	16	5	16.5	5 x 5
19		40	5	28	6	21.5	6 x 6
24		50	7.5	32	8	27	8 x 7
28		60	7.5	40	8	31	8 x 7
32	k6	60	7.5	40	10	35	10 x 8
42		80	9	56	12	45	12 x 8
45		80	10	56	14	48.5	14 x 9
48		110	10	90	14	51.5	14 x 9
50		110	10	90	14	53.5	14 x 9
55	m6	140	10	110	16	59	16 x 10
60		140	10	125	18	64	18 x 11
70		140	10	125	20	74.5	20 x 12
80			10	140	22	85.4	22 x 14
90		170	10	140	25	95.4	25 x 14

U3 MOTOR ASSEMBLY

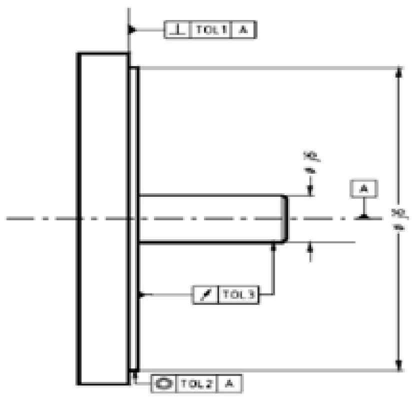
Mechanical Coupling without Keyway

A rigid mechanical coupling to the shaft, free from angular backlash, is mandatory to ensure fast system dynamics.
An interface fastening is recommended, e.g. Ringblocks (1) clamps.
JOINTS: Use only joints with high angular stiffness (steel bellows), e.g. Rodoflex (2) or Gerwah (3).
Gearboxes: IP65 motor version, with shaft lip seal, is recommended for coupling to oil filled gearboxes.
Caution: screw type gearboxes are not adeguate for low speed applications.

Accuracy to DIN 42955 - IEC 72, reduced tolerance

Flange to shaft perpendicularity
TOL1 = 0,040 mm.
Flange to shaft concentricity
TOL2 = 0,040 mm.
Shaft run out
TOL3 = 0,018 mm.

Instant motor torque is
T0 = KT*I
where I is the r.m.s. supplied by the drive



1 Ringblock: made by Ringblock - Nerviano (MI), Italy - Tel. +39-(0)2-585711
2 Rodoflex (type ATMK): made by Getecno - Genova, Italy - Tel. +39-(0)10-8356016
3 Gerwah (type AKD, AKN): represented by Fitec - Milano, Italy - Tel. +39 (0)2-7380683

MOTOR CONNECTIONS: SIGNAL

Signal Connector M23 - 17 Pin
EnDat Type Mx, Nx, O, U

PIN	Function	AxM Port E1
1	A +	n.c.
2	A –	n.c.
3	DATA +	14
4	PTC +	8
5	CLOCK +	3
6	n.c.	n.c.
7	0 V	1
8	KTY84 +	n.c.
9	KTY84 –	n.c.
10	+ Vac	
11	B +	n.c.
12	B –	n.c.
13	DATA –	9
14	CLOCK –	4
15	0V sense	n.c.
16	Vac sense	n.c.
17	PTC –	1

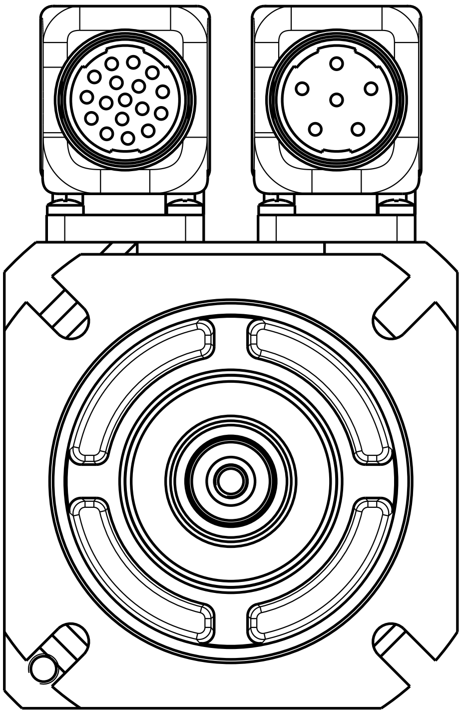
Signal Connector M23 - 17 Pin
Resolver Type R

PIN	Function	AxM Port E1 PIN
1	n.c.	n.c.
2	n.c.	n.c.
3	n.c.	n.c.
4	Sin –, 1 c/r	5
5	Cos +, 1 c/r	3
6	Cos –, 1 c/r	4
7	Resex +	10
8	KTY84 +	n.c.
9	KTY84 –	n.c.
10	Resex –	11
11	n.c.	n.c.
12	n.c.	n.c.
13	n.c.	n.c.
14	Sin +, 1 c/r	2
15	n.c.	n.c.
16	PTC +	8
17	PTC –	1

Signal Connector M23 - 17 Pin
SinCos Encoder Type Sx*

PIN	Function	AxV Port S2 PIN	AxM Port E1 PIN
1	A +	1	7
2	A –	14	12
3	I + (index)	3	14
4	Sin –, 1 c/r	6	5
5	Cos +, 1 c/r	17	3
6	Cos –, 1 c/r	5	4
7	0 V	10	1
8	PTC +	11	8
9	PTC – / KTY –	13	1
10	+ Vcc (5Vdc)	25	6
11	B +	2	15
12	B –	15	13
13	I – (index –)	16	9
14	Sin +, 1 c/r	18	2
15	0V sense	n.c.	n.c.
16	+ Vcc sense	n.c.	n.c.
17	KTY +	n.c.	n.c.

MOTOR CONNECTIONS: POWER (SIZE 3, 5, 7)



Wiring

1) Use shielded cable only, with shield coverage > 85%
2) Power cables longer than 20 meters may generate overvoltages on the motors and damage to the drives. Insert series inductance > 1mH

Encoder

Phasing performed at factory, no further phasing is necessary if the motor is coupled to Phase Motion Control drives.

Power Connector
M23 Size 1- 5+ PE

PIN	Description
1	Phase A
2	Phase B
3	GND
4	BR + (Option)
5	BR – (Option)
6	Phase C

For motors with Inom <= 30 Arms

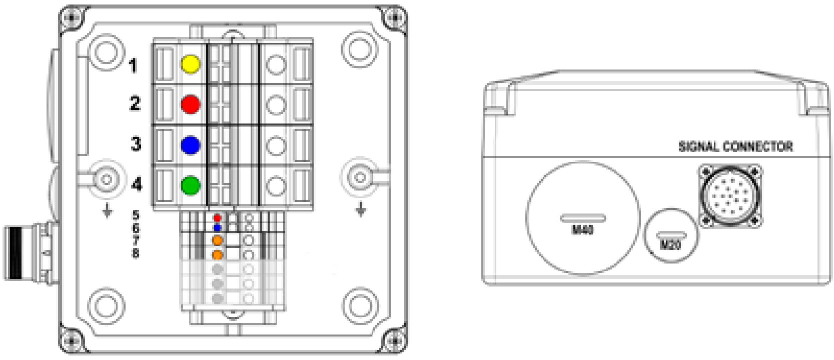
Power Connector
M40 Size 1,5-2+3+PE

PIN	Description
U	Phase A
V	Phase B
W	Phase C
+	BR + (Option)
–	BR – (Option)

For motors with Inom > 30 Arms

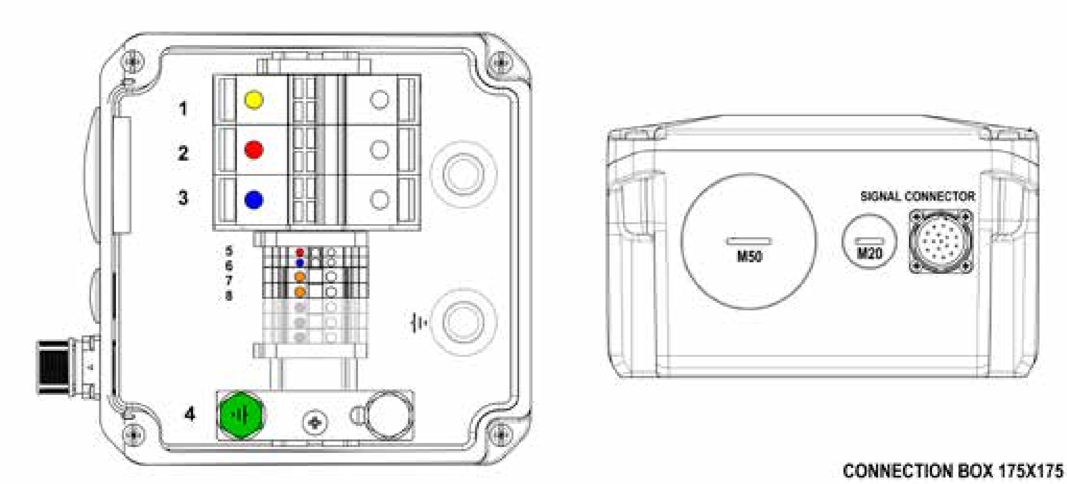
MOTOR CONNECTIONS: POWER (SIZE 10, 13)

Size A



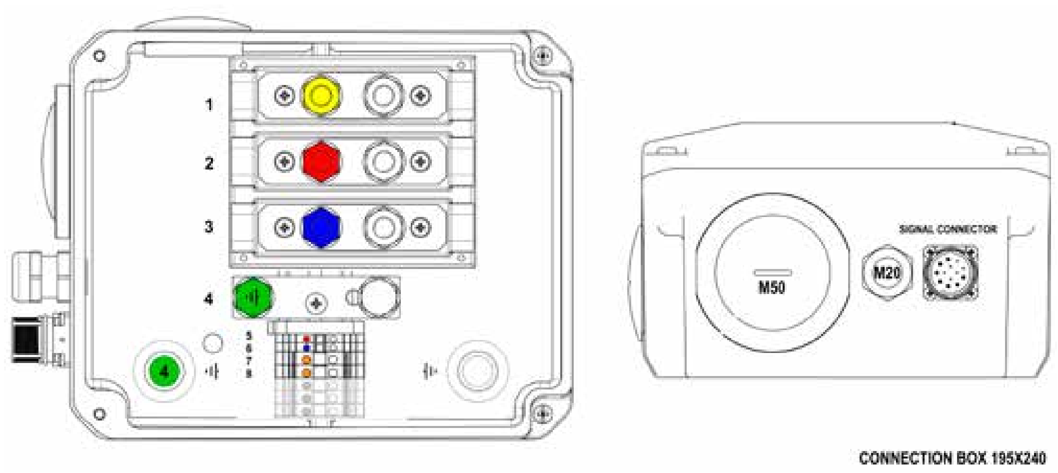
CONNECTION BOX 142X142

Size B

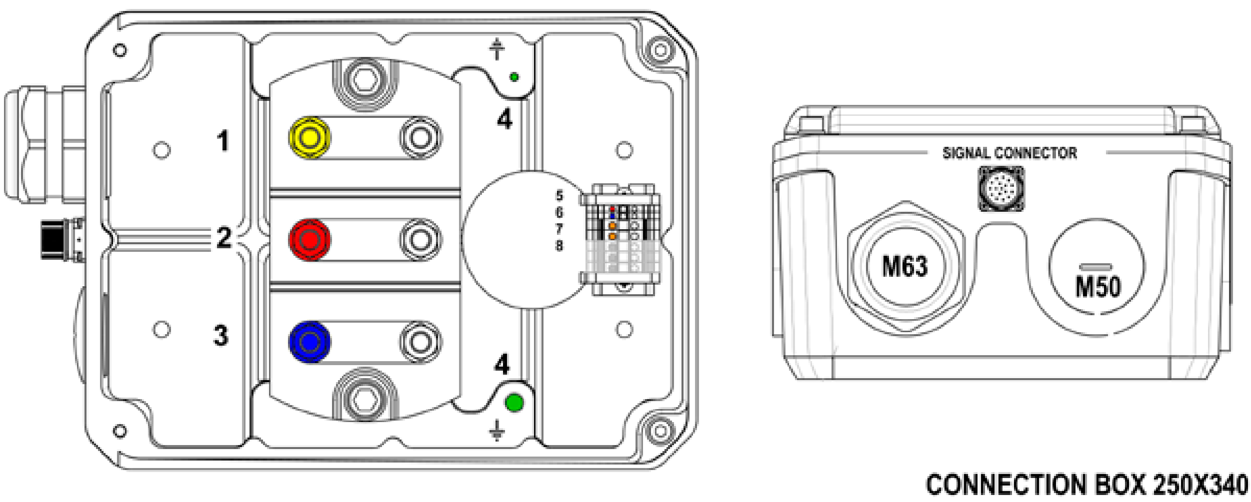


CONNECTION BOX 175X175

Size C



Size D

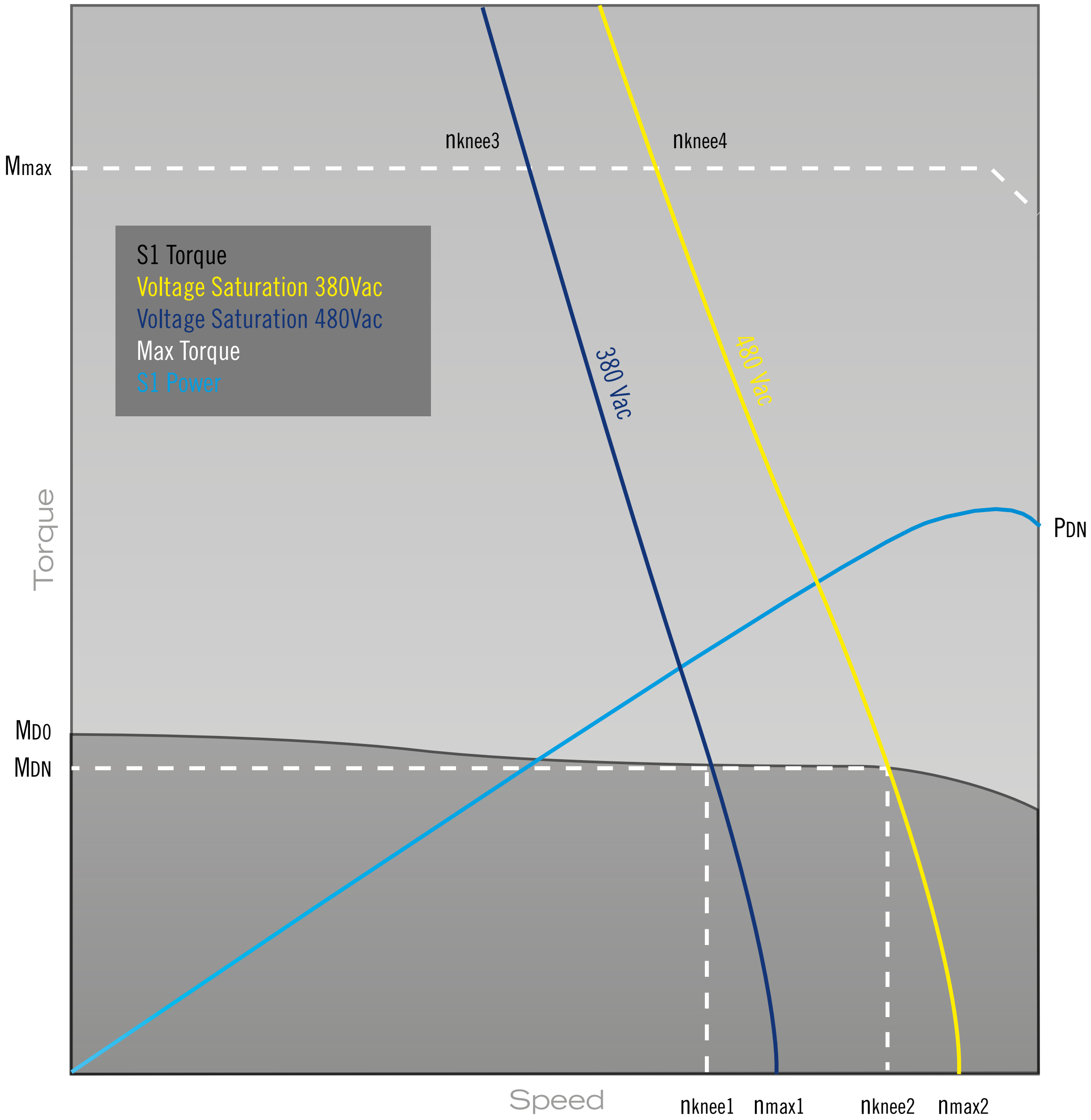


	Connection box configuration
1	Phase W
2	Phase V
3	Phase U
4	GND
5	Brake (+ 24V) *
6	Brake (0V) *

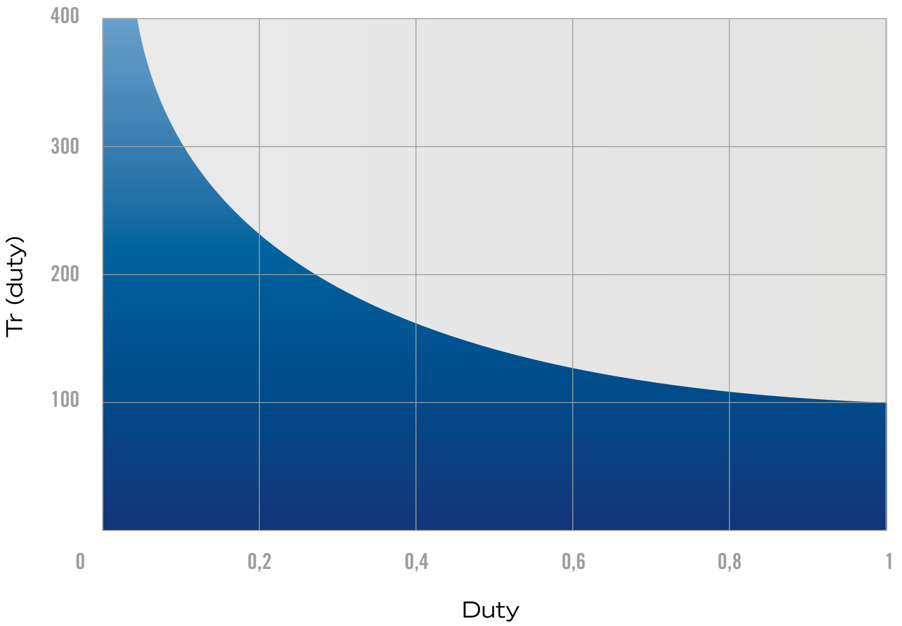
	Connection box configuration
7	Fan *
8	Fan *
9	Reserved for internal use
10	Reserved for internal use
11	Reserved for internal use

(*) If present!

MOTORS PERFORMANCE CURVES

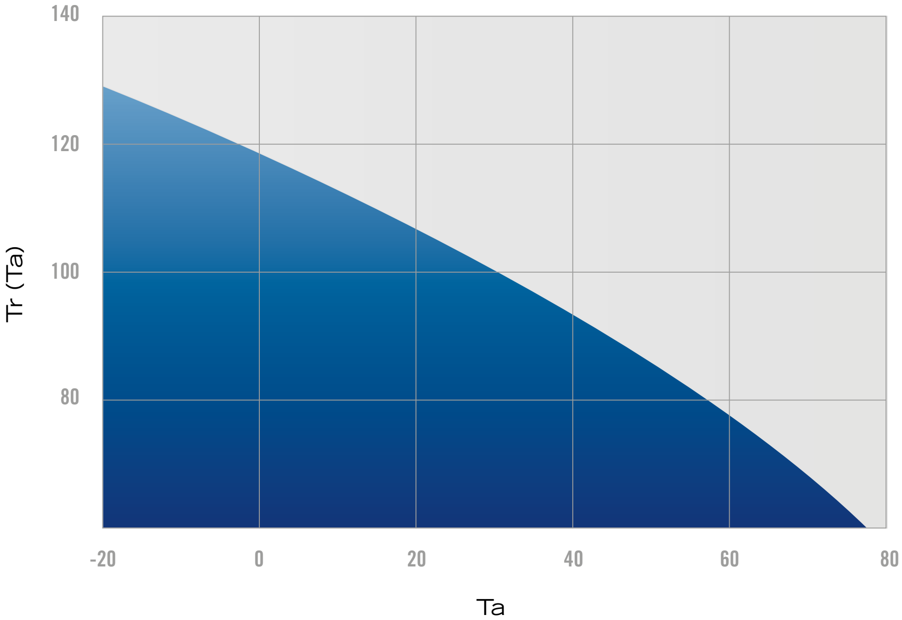


OVERLOAD RATING



Permissible torque overload vs. duty cycle, all motors.

THERMAL DERATING



Permissible torque vs. ambient temperature, % of Md0

APPLICATION GUIDELINES

Forward

AC brushless servo drive systems, based on rare earth PM magnets, provide the highest level of dynamic performance and torque density available today. The trend to replace conventional hydraulic, DC, stepper or inverter driven AC drives with brushless drives yields to a new level of system performance, in terms of shorter cycle times, higher productivity, improved accuracy coupled with shorter settling times, increased reliability and longer life. In order to achieve the steep performance improvement which is feasible with the new motors, however, a good understanding of the characteristics of this technology is a prerequisite. In fact, just replacing a conventional motor with a new technology drive on a machine not designed for high speed control could result in unexpected problems and at times even in a deterioration of the machine operability.
These application guidelines were designed to provide a basic tool for the optimization of new applications without prior knowledge of these new drives. For applications where the performance or the motor stress is perceived to be critical, or where a full optimization could be beneficial, contact the Factory.

Drive and Mechanical Linkage Selection

The success of all drive applications dictate a careful selection of the complete system parameters. This in turn is based on a good understanding of the capabilities, which are very high but often not fully understood, of modern brushless drive systems. In fact, brushless drives are not motors, but complete, and complex, control systems; this results in more degrees of design freedom, and more parameters to select, than a conventional drive.
From a conceptual viewpoint, a high performance brushless motor is more similar to the membrane of a loudspeaker than to a standard induction motor. Just as a loudspeaker, the motor has a very short response time, limited inertia, and therefore it faithfully copies the control signal, whatever it may be. Just like a loudspeaker, the quality of the result depends more on the system parameters and drive conditions than on the motor itself.
The design choices facing the system designer are thus at the same time mechanical, electric and electronic, and such choices are interwoven, requiring an interdisciplinary approach.
In particular, all systems require two fundamental selections:

- mechanical level: choice of the mechanical linkage, of the transmission ratio, of the motion type conversion, of the couplings and clutches;
- electronic level: Feedback strategy, sensor type and number selection, sensor placement, amplifier type, synchronization and control bus.

The next chapters outline a few guidelines to help with the selection as a function of the application characteristics.

The Brushless Drive:Operational Principles, Characteristics and Limitations

All brushless servo systems consist of an electronic drive, a servo motor, and at least one feedback sensor. All these component operate in a control loop: the drive accepts a reference from the outside world, and feeds current to the motor. The motor is a torque transducer and applies torque to the load. The load reacts, or accelerates, according to its own characteristics. The sensor measures the load position, enabling the drive to compare the motion with the reference and to change the motor current to force the motion to copy the reference.
As an example, if constant speed is required, the drive would increase the current to the motor until the motor speed equals the reference. If the load is suddenly stepped up, the speed diminishes; the sensor detects the speed change and consequently the drive increases the motor torque to match the increased load and to return to the set speed. From this example, a few deductions are possible:

- the speed accuracy is virtually independent of load and motor, but depends on the quality of the sensor signal and the speed and control algorithm of the drive;

- the time lag between load perturbation and speed correction depends critically on the speed and resolution of the sensor and on the parameters of the electronic drive.

Modern brushless servo drives react to sensor signals with time lags in the order of a millisecond or less, providing for very high loop performance.
At this level, however, the propagation time through the mechanical linkages often becomes the prime limit to the system dynamics.
As an example, consider a system in which a servo motor drives a constant speed, large inertia load through a timing belt. The timing belt has a finite, and significant, elasticity. Analyzing a speed correction at the millisecond timescale, the following sequence is obtained:

- the drive sets a current level through the motor which applies a torque almost instantly;

- initially, while the belt is being stretched, the load does not accelerate as fast as the motor;

- consequently, the motor reaches the set speed before the load; the sensor, on the motor, cuts the current and consequently the torque;

- the increased tension of the belt slows the motor down forcing the drive to increase the current again, and a new cycle is initiated.

In this example, the system is oscillating; the motor torque pulsates and so does the load speed. The end result is noise, overheat and wear, none of which are clearly due to the motor. However, superficial users would claim that the motor is noisy; in practice, if this motor is replaced with an older generation, large and high inertia drive, the problem would likely disappear, increasing the feeling that the new drives are not adequate.
This simplistic understanding is erroneous. In fact, analyzing the above example:

- the instability is due to the mismatch between the system reaction speed (high) and the mechanical propagation or reaction time (long); the motor reacts quicker than the time required by the system to settle through the new torque configuration;

- the possible solutions are:
  either to reduce the mechanical system reaction time, by stiffening the linkage and lowering the inertias, e.g. going direct drive or replacing the

belt with a gearbox; or to lower the speed of the control system, giving up some control bandwidth which would have been achievable with the new technology.

The second solution, of course, sells away some quality, as it impairs the capability to react quickly to sudden load variations. In fact, older drives, which were anyway slower, compensated the lack of speed with a large motor inertia; on the other side, brushless motors, where inertia is minimized, need a good bandwidth to guarantee good rotation accuracy.
All this explains why brushless drives are relatively unforgiving of mechanical inaccuracies, backlash, keyways etc.; for this reason, the best motors are manufactured with round shaft without keyway, for interference coupling with conical fittings (e.g. Ring-feder) and their shafts and flanges are machined to a reduced tolerance to remove the need for flexible couplings. If a coupling is needed, it needs to be torsionally stiff, such as the metallic bellows type.
In conclusion:
while traditional drive systems (DC of PM DC, inverter driven AC) would limit themselves, with their own inertia and response time, the performance of the application, the high level of the new brushless drives move the performance threshold above the mechanical limits of most traditional applications. As a result, the design verification of the mechanical system, and its upgrade to the new requirements, is more important than it used to be up until now.
The success of a new application hinges critically on a good dynamical design of the whole system.
A few rules can also be derived from the simple examples above:

» the speed accuracy does not depend on the motor but on the sensor;

» the following speed, and therefore the ability to compensate for sudden load variations, depends critically on the stiffness and quality of the mechanical linkage.

The motor noise, which is often observed in poor or retrofit applications, is not due either to the motor or the drive but often enough to a "primeval" mechanical linkage. In fact, noise in due to the motor "hunting" for the correct torque; in this situation, the motor is likely to overheat irrespectively of loading.
The same system might have worked well with an older drive, where the large motor inertia "rolls over" all imperfections.
The dynamic study of the application is fundamental to the motor selection. To this aim, this broad concept can be divided in two elements:

» large signal bandwidth: this is the raw ability to deliver enough torque and speed, in sufficiently short time, to force the load on the desired trajectory. This depends exclusively on motor and load torque and inertia, and can be studied considering all components as infinitely stiff;

» small signal bandwidth or control bandwidth, which relates to the inverse of the settling time. This is necessarily lower than any mechanical resonance frequency in the system; its inverse expresses the settling time of the control loop, i.e. the time required at the end of a motion command to settle in the target position within a required accuracy. Typically, it will be impossible to achieve a settling time better than 2-3 times the damping time of all the oscillations or resonances in the load and linkage.

As an example, consider the indexing axis of a high speed notching machine. The rate target is set at 10 strokes per second, i.e. the drive starts and stops the workpiece in a new position ten times per second. If the whole linkage (shaft, reducer, belts, ball screw etc) has a first resonance frequency of 50 Hz, the system will settle in about 50-60 msec, leaving only 40 msec for the move and the punch! This application is near impossible, as very high torque and accelerations would be needed. However, if the linkage is stiffened, by removing the belt, adopting a larger screw, etc. so that the resonance frequency of the linkage is increased to 100 Hz, the settling time is reduced to 25-30 msec, the time available for the move is doubled, the required torque is halved, and the application is feasible.

Optimal Drive Design: the Transmission Ratio, the Type of Conversione, the Couplings

Brushless motors, like all other motors, are sized on supplied torque and not on output power. In all applications, therefore, low motor speed yields to a low specific power and relatively low efficiency. On the other hand, brushless motors have no minimum speed (the speed depends only on the sensor used; there are applications whose axis speed is 1 revolution/year); as a consequence, a high gearing is advisable only to minimize the motor mass (e.g. with electric traction) or to maximize the efficiency; it is often not advisable from the viewpoint of cost or dynamic performance. Wherever the motor is applied directly on the load, the control bandwidth is maximized because maximum transmission stiffness is achieved; consequently, these applications provide the best position or following accuracy with the shortest settling time.
Before starting with the selection of the right drive for a specific system, it is necessary to know the type of mechanical transmission which can be used. The most common transmissions are the following:

ROTATION-ROTATION CONVERSION
» timing belt;
» reducer with helical wheels and parallel axes;
» cycloid and epicyclic reducer;
» Harmonic Drive™;
» tangent screw reducer or Gleason gears.

ROTATIONAL-LINEAR MOTION CONVERSION
» timing belts;
» pinion-rack;
» metallic band;
» ball screw.

For any transmission system, the load parameters can be transferred to the motor axis as follows.
If n = transmission ratio (ratio between the motor and the load speed, rad/m in the case of a conversion from linear motion):

» Motor torque = Torque (thrust) to the load/n

» Motor speed = Load speed x n

» Load inertia reduced to the motor axis = inertia (or mass) of load/n^2

Among all the listed transmissions, the first ones, which are the least expensive, are also the slowest; they result in low control bandwidth (lower than 10 Hz, using a high stiffness belt); for the same reason, it is important to avoid the ratios which make the load inertia transferred to the motor axis too much higher than the motor one. The belt transmission should not be applied for positioning applications with cycle times a lot shorter than one second.
Gear reducers are a good solution, provided that their angular backlash is considerably lower than the accuracy required by the system; the best type of reducer (the most expensive too) is the epicyclic; there are special series of cycloid and epicycloid reducers purpose designed for servo controls, where the angular backlash at the output shaft is limited to 1-3 arc minutes. Such reducers are the only ones that can be specified for applications with control bandwidth higher than 10 Hz. The "servo series" reducers are designed to be coupled directly to the motor with a stiff coupling device, without keyway.

The Harmonic Drive™ gearbox was specifically designed for positioning. It has limited size, high ratio and low backlash. The angular stiffness is not very good and the achievable control bandwidth is in the 10-30 Hz range. Because of its limited efficiency, it should be used for positioning only.
Tangent screw reducers fit in a class apart. These gears, although common and inexpensive, are not suitable for position control. The tangent screw, whose efficiency is based on an effective lubrication, display a low efficiency which drops dramatically at low speed, because below a critical speed the oil film collapses, efficiency drops and a quick wear ensues.

Wherever a rotary to linear conversion is required, ball screws provide a quality solution up to about 4 m/s, especially if they are driven directly by the motor. Direct drive with a low inertia motor generally avoids the need of a torque limiting clutch. For very long movements it is necessary to check the flexure and torsional stiffness of the screw, which may limit the system bandwidth. Longer movements are carried out with rack and pinion, which have always a significant backlash which generally results in limit cycling and motor noise. The traditional backlash elimination methods add stick-slip non linearity instead, and so do friction wheels, typically with similar limit cycling results.
Fast and accurate movements can be obtained with metallic tapes replacing the timing belts with superior stiffness. This technique, while not well known and therefore not standardized, is able to reach excellent performances in the control of small loads (a few kilos).
In general, however, linear motors rest as the best solution for high accuracy control of a linear motion.

In order to select the most suitable reduction method and transmission ratio for a specific application, it is useful to classify first the applications into two broad families:

- » Power services: the motor supplies power to a process (spindles, traction, winding, conveying etc.), where the dynamic performance is of marginal importance, the power controlled is significant, the motor cost is an important fraction of the system cost;
- » Position control or high rate cycling (electronic camshaft), in which most of the energy is used to accelerate, to brake and to position objects in a short time and with a more or less high accuracy.

Traditionally, the two above mentioned categories are referred to respectively as spindle drives and axis drive.

In the first case, the dynamic properties are often not important, therefore simple speed reducers are acceptable and, as the power is often relevant, a mechanical transmission with a reduction stage is normally useful. In order to choose the best transmission ratio, consider that up to ~ 4000 RPM, the cost and size of the motor decrease in a quasi linear way with the increase of the transmission ratio. On the contrary, the cost of the transmission increases step by step according to the number of gear stages or pulleys; from an application cost viewpoint, the minimum overall cost can only be found in a few points, precisely:

- » either with a direct drive;
- » or at the speed corresponding to the maximum ratio which is possible with just one reduction stage;
- » or at the speed corresponding to the maximum ratio which is possible with two reduction stages and so on.

The economic optimization, in this case, is carried out checking these points and adding the costs of the motor to that of the reducer.
For all dynamic applications (axes) the situation is completely different. If the torque required in the drive cycle is dominated by the inertial torques both of the motor and of the load, for an increase in the reduction ratio there is a decrease in the impact of the load inertia and an increase of the impact of the motor inertia. Consequently, for an application where the required torque is exclusively inertial, the reduction ratio at which the load inertia, translated to the motor axis, equals the motor inertia (inertial match) is characterized by the minimum motor torque and therefore by the smallest motor.
For this reason, inertial matching was long considered the best gear ratio selection tool. Such rule, on the contrary, is just a useful indication. In fact, the minimum size motor, considering that the cost of a quality reducer can double the cost of the motor, does not correspond to the lowest cost application sizing. Furthermore, the level of quality and performance is determined a lot more by gear backlash and shaft elasticity than by the motor itself. Consequently, a ratio selection which accounts for the motor only is clearly flawed. A better set of rules is the following;

- » any transmission ratio higher than the inertial ratio is wrong;
- » the best ratio is always lower or equal to the inertial one, and it is obtained considering the motor and reducer costs;
- » high ratios always yield a narrower control bandwidth and a lower degree of accuracy (with a higher energetic consumption) than what can be obtained with lower ratios.

These considerations explain the current attempt to replace step down gears with direct drives.
Wherever the load inertia transferred to the motor shaft is more than a few times the motor inertia, however, care must be taken, because the motor inertia is not there to carry out a stabilizing action on the possible mechanical resonances or load disturbance on the system. As a consequence, a high control bandwidth needs to be achieved, to compensate electronically what is not obtained by inertia alone; to do this, the mechanical linkage in these applications needs to be of high quality, stiff and without backlash (no keyways!).
From an analytical viewpoint, extreme direct drives mandate a check on the torsional stiffness of the system. The torsional stiffness of the motor shaft needs to be considered as well; this, although minimized in the ULTRACT II design by means of large shafts, is significant for the long and thin motors. In fact, the ULTRACT II range was purposefully overlapped, so that the same torque can be obtained either with a long and narrow motor or with a short and stocky one. For this reason:

- » long motors have a minimum moment of inertia; they are intended for high acceleration with low inertia loads;
- » stocky motors have a maximum torsional stiffness; they are intended for high inertia loads, where the motor inertia is small compared to the load.

As a reference, the torsional stiffness of a shaft whose diameter is D and whose length is L, made of steel, is:

$$S_m = \frac{\pi}{32} \times \frac{D^4}{L} \times 78,5 \times 10^9 \times \frac{N}{m^2}$$

while the frequency of torsional resonance of a load with inertia JI connected to an axis with torsional stiffness Sm is:

$$F_1 = \frac{1}{(2 \times \pi)} \times \sqrt{\frac{S_m}{JI}}$$

In all applications with large inertia and short settling time, a check on the first torsional resonance frequency is highly advisable.

Control Strategy Selection

All drive system can be configured according to three main control strategies:

- » torque control (the speed depends on the load);
- » speed control (the torque depends on the load);
- » position control (the torque depends on the load)

The first strategy is the easiest to implement and can be used when it is necessary to control a force or a pull (winders/unwinders, textile, tape/paper processing, etc.). Torque control is native, or intrinsic to the brushless motors, which are always current controlled. For this reason, torque control has minimum sensor requirement (just commutation or Hall sensor), is very fast (control bandwidth >300 Hz) and intrinsically stable and robust irrespective of load. Torque controlled drives are simple amplifiers which require no calibration or adjustment whatsoever and are therefore the simplest controllers. Accuracy is not too high due to motor friction, cogging, ripple, sensor drift; typically it can range in the 5-10% area.
In the multi-axes applications with very fast and modern NCs or controller boards, where multiple axes must be linked (multiple electric gears and cams), or with adaptive control or with variable parameters, a simple and effective strategy is to set the drives in torque control mode and to assign the other loops to the NC. In this way the encoders are fed to the NC, all drives are equal, intrinsically stable and need no programming; all the system and control parameters (offsets, PID values, etc) are lumped in the NC or control PC. The drives can be replaced without programming and no download of parameters is necessary. The control signal to the drives is a simple differential torque reference, offset insensitive. The encoders are fed directly to the NC; the drive only reads the commutation system. This simple and elegant approach provides very good performance in multiple systems without incurring the cost and complexity of high speed field buses, which are anyway rather limited in the number of axes and in the achievable speed. On the down side, it downloads on the NC or PC the processing of the encoders, which could be cumbersome where very high resolution is needed.
Speed control is the most traditional strategy. It usually embodies an integration term so that the speed error is limited to the system offsets. In the digital drives, the speed loop is derived from the space loop (see next).
Position or space control in servo amplifiers is carried out only by digital drives (AX-V). In this way, the steady state position and speed following error is limited to a few points of the sensor, that is in the case of an encoder with 4096 pulse/revolutions, 1/16,000 of a revolution. Position loop capability, inside or outside the drive, is necessary to synchronize several axes (electrical axis or electronic cam).

Check of the Drive and Motor Sizing

After selecting the motor and the transmission, a check of the correct sizing of motor and drive is required. Such check is easy for applications where speed and load are quite steady or which vary on a timescale which is long with respect to the time constant of the motor (or of the electronics). In this case, it is only necessary to check for the maximum load to be within the specified limits of the motor and the electronics.

For the applications where the load varies on a fast cycle, verification should proceed as follows:

1 Trace the speed/time diagram of the cycle, considering that the acquisition of a precise position or speed requires, apart from the time determined by the limits on the speed and acceleration of the system, also a settling time equal to 2-3 times the inverse of the system control bandwidth;

2 Transfer the inertia and the loads of the system to the motor shaft;

3 Calculate the cycle of the accelerations and the inertial torques [acceleration x (motor inertia + load inertia transferred to the motor shaft)], checking also the inertia of couplings, clutches, transmission devices;

4 Add the load on the motor axis to the inertial torque and derive a torque/time diagram in the cycle;

5 By inspection of the torque vs. time diagram obtain the root mean square value of the torque: e.g. divide the cycle into time segments t1,t2.... tn inside of which the torque is constant; if the torque values in each segment of the cycle are respectively C1,C2...Cn, the root mean square torque in the cycle is:

6

$$Ceff = \sqrt{\frac{C_1^2 \times t_1 \times C_2^2 \times t_2 \times C_n^2 \times t_n}{(t_1 \times t_2 \times \ldots\ldots\ldots\ldots\ldots\ t_n)}}$$

7 Calculate the root mean square or effective speed in the cycle veff with the same formula;

8 Calculate the mean torque in the cycle Cave;

9 Calculate the maximum duration time of the maximum torque in the cycle tcmax;

10 Calculate the required torque at the maximum speed Cwmax;

11 Calculate the maximum torque Cpk.

The data thus obtained needs to be compared with the motor and electronic limits to validate the application.

Motor Size Verification

Brushless motors are excellent torque transducers, linear to a peak torque several times the nominal. As a consequence, the obtainable peak torque is usually determined only by the choice of the electronic drive. The correct sizing of the motor is thermal and electric; <u>the optimally sized motor</u> is the one which, on the worst load, settles at the correct temperature rise, usually 40-50°C above the room temperature.

The complete check of the selection of the proper motor is carried out in three steps:

- » Control of the peak or demagnetizing torque;
- » Thermal dimensioning;
- » Electric, or winding, dimensioning.

1 - Demagnetization current check
Compare the peak current, expressed by:

$$I_{pk} = \frac{C_{pk}}{K_t} \times \sqrt{2}$$

with the motor demagnetization current, considering that the motor demagnetization current increases as the temperature decreases. This check is usually meaningful for small motors only.

2 - Temperature rise check
Preliminarily, check that the point C_{eff}, v_{eff} is within in the continuous operation area (S1) of the chosen motor. More accurately, the temperature rise of the motor can be predicted by:

$$\Delta_{mot} = \frac{65}{L_n} \times [(\frac{C_{eff}}{T_n})^2 \times (\frac{\omega_{eff}}{\omega_n})^2 \times L_0]$$

where Ln represents the nominal losses of the motor with temperature rise of 65°C.
If the predicted temperature rise is higher than the motor maximum or acceptable temperature rise, it is necessary to select a larger motor.
NOTE: the excessive temperature rise is generally the only good reason for the use of a larger motor.

3 - Electric sizing check
At the maximum speed, the voltage required by the motor to supply the required torque must be lower or equal to what is available from the drive, for the minimum mains supply voltage which is specified for full specification operation (usually 90% of the nominal voltage).
If Emin is the voltage value which can be supplied by the electronic power supply at the minimum supply voltage, it is necessary to check that:

$$V_{max} = \sqrt{3} \times \sqrt{(K_e \times \frac{\omega_p k}{\sqrt{3}} + \frac{R_w}{2} \times \frac{C_{\omega max}}{K_t})^2 + (\frac{C_{\omega max}}{K_t} \times \frac{PN}{4} \times \omega_p k \times L_w)^2} \leq E_{min}$$

If this condition is not verified, it is necessary to choose a motor with a higher speed winding; this will of course also require a higher drive current.

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