ESAIL D3.3.2
Design description auxiliary tether reel

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List of Acronym and Abbreviation

DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
ESAIL	Electric Sail
EU	European Union
FP-7	Seventh Framework Programme
EPS	Electrical Power Subsystem
OBDH	On board data Handling Subsystem
Tartu	Tartu University
FMI	Finnish Meteorological Institute
ASTC	Angstöm Space Technology Center
ECSS	European Cooperation on Space Standardization
AMTAG	Alfred Merelbach Technologie AG

Reference Documents

RD-1	ESAIL Proposal - Part B: Description of Work
RD-2	D3.3.1, Requirements specification of the auxiliary tether reel
RD-3	ECSS-E-30 Part 3A Mechanical

1. Scope of this document

This document describes the design of the auxiliary tether deployment mechanism [RD-01]. This document is a deliverable item of the EU-FP7 funded Esail-Project.

In this document include a short remark to the constraints changes and a detailed description of two concepts which have been implemented in a CAD model as well as a description of the assembled deployment mechanism. In the appendix a description of several reel designs and an evaluation of these designs are listed, furthermore it includes the data sheets of the selected motor, gear and motor control.

2. Constrains Changes

During the design process of the auxiliary tether (WP 2.4) and the remote unit (WP 4.1) it figured out that the constraints ACS-331-03 and ACS-331-04 [RD-2] must be changed. Therefore the peak tensile load of 3 kg is changed to 60 g and the thickness of the tether changes to 13.5 µm.

The new constraints are as the follow.

Number	**Description**	**Reference**
ACS-331-03a	The auxiliary tether peak tensile load shall not exceed 60 g.	RD-2
ACS-331-04a	The thickness of the auxiliary tether shall not exceed 13.5 µm	RD-2

These changes had a serious influence of the auxiliary tether reel mechanism design. Due to the new thickness of the tether, the dimension of the Tether reel will increase. Furthermore the diameter will be enhanced in case of fail safety in the deployed auxiliary tether is required. This fail safety in the deployed tether means that if one motor failed completely still the whole 1.25 km could be deployed.

3. Concept Realisation

The following chapter describes the detailed design of the two separate reel and motor concepts.

3.1. System Overview

The system overview of the deployment system is shown in Figure 8. This overview is the same for the two different concepts which were implemented.

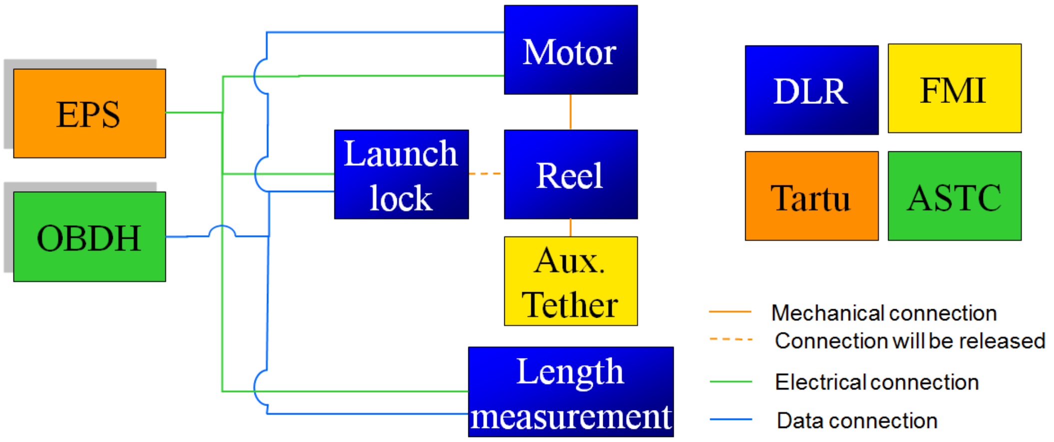


Figure 1: System overview

The blue boxes in Figure 8 are the components of the deployment mechanism. The colored lines are the connection between the deployment mechanism and the other subsystems of the remote unit. The deployment mechanism consists of the tether reel, the motor, the launch lock and the length measurement system. The motor, length measurement and the launch lock are electrical connected to the EPS. These two components and the tether length measurement system are connected to the OBDH of the remote unit. The motor received control parameter for rotation speed from the OBDH. To control the unreeling speed as well as the tether length the length measurement system received and transmits data to the OBDH. The launch lock is required to fix the reel during launch, until the signal from the OBDH unlock the reel for the tether deployment

3.2. Geared Motor

The selection of the motor has two main drivers. The first is the required torque and the second is the dimension. Another selection criteria is, that the motor should be usable in both concepts.

The required torque is calculated as required in ACS-331-03 with a tension load of 0.6 N and a maximal diameter of 150 mm for the tether reel [RD-2].

The tether length on the reel is defined with a tether width of 30 mm, a tether thickness of 13.5µm and according to the reel diameter [RD-2].

With the difference of the external and internal radius and the thickness of the tether the layers on top of each other can be calculated with

$$N_L = (r_e - r_i) / t.$$

With this equation $N_L = 4961$. To calculate the whole tether length the following equation was used

$$L = 2 * \pi * (r_1 + \sum_{n=2}^{NL} (r_n + t))$$

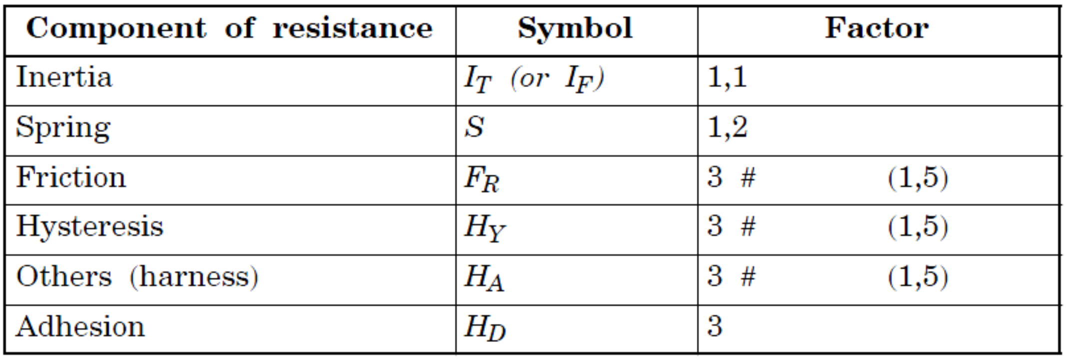
with $r_1 = r_e + t$. The outcome of this is L = 1.33 km tether length. This equation can be calculated with different external and internal diameters. In case of the 1.33 km tether length the internal diameter is 22 mm and the external 150 mm. In case that the reel has a capacity of 628 m tether length, the internal diameter is still the same and the external diameter will change to 110 mm.

Hence the required maximum torques for the external diameter of 150 mm is 45 mNm and for the 110 mm diameter 33 mNm.

To improve the reliability of the deployment mechanism the motor required torque calculated above was again calculated with the ECSS document [RD-3].

$$T_{min} = 2.0\ x\ (1.11 I_T + 1.2 S + 3 F_R + 3 H_Y + 3 H_A + 3 H_D) + 3 T_L.$$

The different factors and their denotation are listed in Table 1.



Component of resistance	Symbol	Factor
Inertia	I_T (or I_F)	1,1
Spring	S	1,2
Friction	F_R	3 # (1,5)
Hysteresis	H_Y	3 # (1,5)
Others (harness)	H_A	3 # (1,5)
Adhesion	H_D	3

Table 1: Minimum uncertainty factors [RD-3]

In the case of the auxiliary tether deployment the inertia is calculated with reel mass $m_d = 0.046$ kg and a reel diameter $r_d = 0.15$ m. With the calculated values it is $I_T = 5.175 \times 10^{-4}$ kgm².

The friction in this system is assumed as $F_r = 0.1 \times 10^{-3}$ N.

The also needed value for the tether bending force is calculated with the static beam equation. The calculated force $F_b = 1.9 \times 10^{-3}$ N.

The required torque according to the ECSS simplified to

$$T_{min} = 2.0\, x\, (1.11 I_T + 3F_r + 3F_b) + 3T_L.$$

Therefore the required Torque is 58.13 mNm.

To accomplish this required torque the brushless DC servomotor with an planetary gear from Faulhaber company was chosen. The motor has the denotation 1226 012B. This motor has a torque of 2.2 mNm. With the appropriate gearbox 10/1 and a reduction of 256:1 the generated torque is 100 mNm. To drive the motor a motion controller MCBL 3003 S/C is chosen. It has a RS232/CAN interface. For all three components the data sheet are listed in chapter 7.

For the implementation the gear motor is realized in CAD, and shown in Figure below.

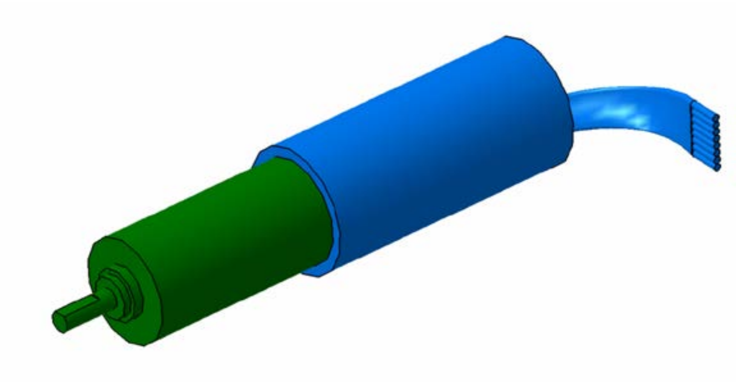


Figure 2: Motor 1226 12b combined with 10/1 gearbox

3.3.Design details of “separate reel” deployment design

This is the implementation of the concept „separate two reel”. This design shows that a deployment system can be built with few parts and a very low mass. This is possible due to that the motor is placed inside the reel axis. But a big drawback of this design is that the center of gravity change during the deployment process. The difference between the center of gravity at the beginning, where the whole tether is reeled on the reel, and the end of the deployment phase are around 10 mm. This difference could lead to tilting of the whole remote unit and needs to be avoided.

In this design the motor is placed congruent in the reels rotation axis. Therefore a motor holder is needed to mount the motor inside the remote unit. This holder is a small cylinder with an edge to mount the sliding bearing. This holder is shown in Figure 10 (turquoise color). It is mounted to the remote unit structure with seven m3 screws. It has a weight of 9 mm on this holder the sliding bearing is mounted (colored in orange). This sliding bearing replaced due to the small place the ball bearing on which the tether reel rolls. The sliding bearing is fabricated from AMTAG. This sliding bearing has a PTFE layer and is self-lubricant and maintenance free. It has a weight of 4 g, the total height is 19.5 mm. With a press fit it is mounted to the holder, so that the reel can slide on it. The motor is the brushless DC servo motor described before. The motor has an external diameter of 12 mm and a total length of 31 mm. The planetary gear 10/1 has a diameter of 10 mm and a length of 19 mm. In combination the total length is 45 mm. The tether reel is directly mounted on the motor axis with a press fit. The reel (colored grey) has an external diameter of 150 mm and a height of 34 mm. It is possible to reel 1.33 km tether on the reel. To build it light wise, six pockets are countersank of the side plates. The total weight of the reel in case of polyimide as material is 32 g. The length measurement is implemented in the motion control of the motor. The motion controller is not shown on Figure 10, it will be implemented on the remote unit data handling board to save mass and reduce the number of parts. As the launch lock for the reel, the holding torque of the motor is sufficient.

The overall system dimensions are the following: The total height is 62.3 mm with a mass of 71 g.

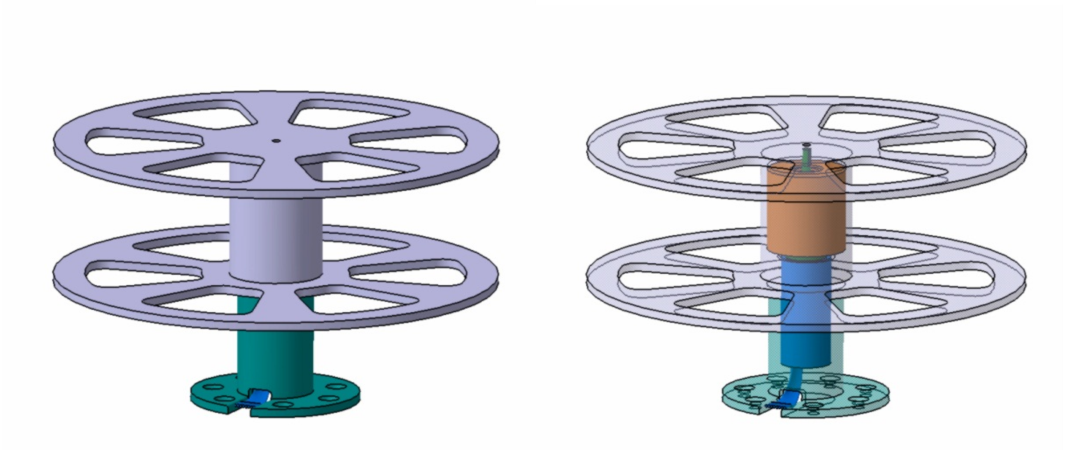


Figure 3: Assembled separate reel deployment mechanism, on the right side the reel and a holder are transparent to show the position of the motor and the sliding bearing.

Quantity	Value
Tether capacity	1.33 km
Reel diameter	150 mm
Total height	62.3 mm
Total weight (material polyimide)	71 g
Motor gear reduction	4096:1
Motor torque	100 mNm

3.4.Design details of “Separate gear” deployment design

The implementation of the concept “separate two gears” is described in this chapter. To avoid the change of the center of gravity the reels are placed directly on the structure of the remote unit. Therefore the center of gravity from the deployment mechanism is in the same plane as the main tether and avoided the tilting of the whole remote unit. But the price for this is the increasing number of parts and of the deployment mechanism mass. The number of parts increases to 12, in comparison to the “separate reel” design this is a massively increased.

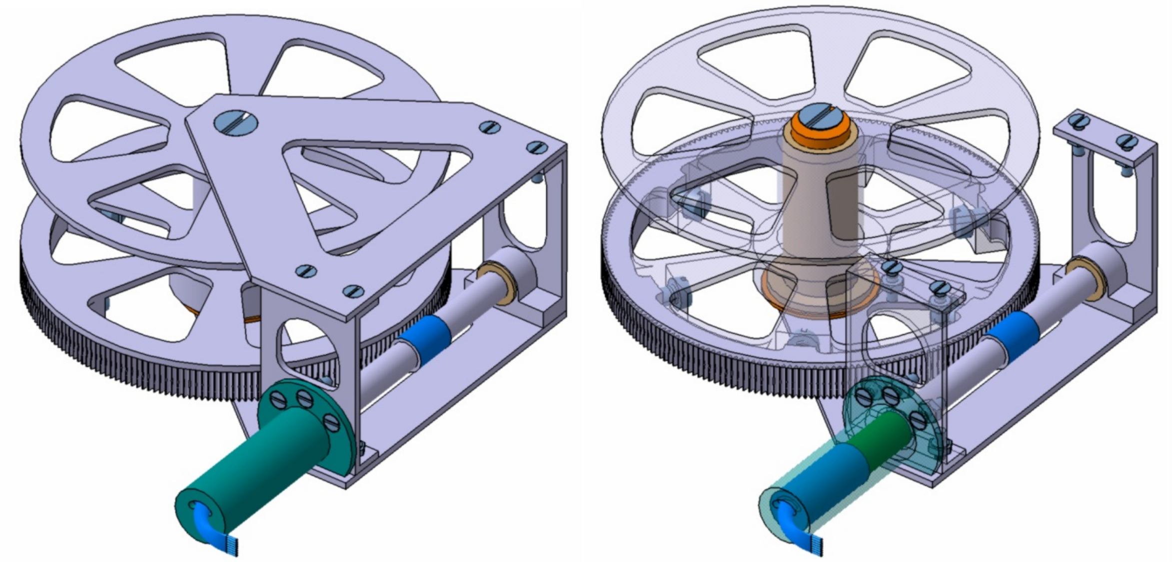


Figure 4: Assembled separate gear deployment mechanism, on the right side the parts which covered other parts transparent to show the position of the motor, the mounting of the reel gear wheel and the sliding bearings.

In this case the motor is placed perpendicular to the rotation axis of the tether reel; hence to drive the tether reel a gear wheel is needed. Regarding to the relatively high number of parts, the motor is going be again used as the launch lock. But due to the missing connection between the tether reel and the motor the gear connection is going to be used as the launch lock. Therefore a worm gear with a self-locking property is chosen as connection. The worm gear is shown in Figure 11 as a small blue cylinder with a grey axis on the both sides. The mass of the worm gear is 6 g if it is built of polyimide. The module of the worm gear is 0.5 because with this module it is self-locking. One end of the worm gear axis is mounted with a press fit to the motor axis (the blue and green cylinder), the other end is placed rotatable in a sliding bearing (colored brown). The mass of the sliding bearing is 4 g; also this sliding bearing is fabricated by AMTAG and has the same properties. On the bottom plate, the reel axis and the two side plates are mounted. The mass of the polyimide bottom plate and the top plate is 11g. These two plates are needed to fix the rotation axis of the tether reel. The two side plates are colored grey as well as the bottom plate and the plate on top. They are mounted with m3 screws to the bottom plate and the top plate. The side plate which holds the motor cover has a smaller countersank pockets but have a higher width of 30 mm. The thickness for all plates is 2 mm. Therefore the mass of the motor holder side plate is 4 g. The other side plate has a width of 25 mm and also a weight of 4 g. The motor cover is mounted with m3 screws on the motor side plate. The cover has a diameter of 16 mm, the mass is 7g. For this design the in chapter 5.2 described brushless motor is used. It mass is still 26 g. The gear wheel is mounted with six m5 screws to the tether reel and has a reduction of 10:1. The mass of it is 26 g. The tether reel in this design has only an external diameter of 110 mm and therefore a tether capacity of 706 m but still the same high of 34 mm. The smaller diameter is due to the mass reduction of the deployment system. To mount the gear wheel to the tether reel six mounting points are placed on the reel side therefore the tether reel mass increase to 47 g. The tether reel is placed on a sliding bearing, colored brown in Figure 11. It is also from AMTAG and has a mass of 7 g. This sliding bearing is press fit mounted to the reel axis, colored orange. This axis is mounted with two m6 screws to the bottom- and top plate. The mass of the axis is 12 g.

The overall system dimensions for this design are: The total height of 54 mm the length of 138 mm and width of 128.25 mm. The total mass for this deployment mechanism is 182 g.

Quantity	Value
Tether capacity	706 m
Reel diameter	110 mm
Dimension (H,W,L)	54, 128.25, 138 mm
Total weight (material polyimide)	182 g
Motor gear reduction	4096:1
Motor torque	100 mNm
Gear wheel reduction	10:1

4. Appendix

4.1.Reel Concepts

To find the most suitable unreeling mechanism two different configurations were under investigation. In number one the motor for the reel is placed inside the tether reel, that means the motor represent the rotation axis and is directly connected to the reel, in the other the reel rotation axis is perpendicular to the rotation axis of the motor, the connection between this two components are realized with a worm gear. The tether length which should be unreeled from every remote unit in both directions is 628 m. For these two motor configurations, different concepts are developed. In the following part this concepts are described.

4.2.Congruent Motor Configuration

As described before in this configuration the motor is placed in the middle of the reel and both spin axis are congruent.

4.2.1. Stacked Reel Concept

In this concept two tethers are reeled side by side each other, stacked in the rotation axis direction. Each of this tether bays has a capacity of 628 m. This tether length results in an external diameter of 110 mm and an internal diameter of 35 mm. With the required tensile load the maximum torque on the motor is 33 mNm.

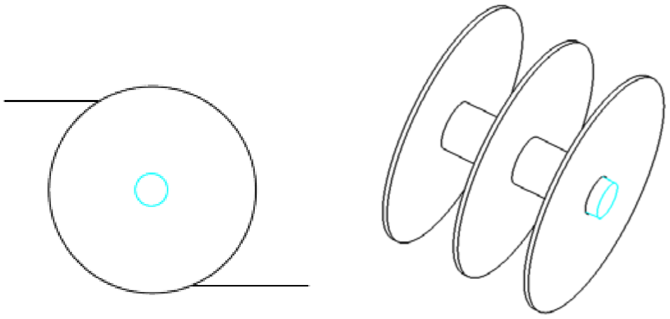


Figure 5: Stacked reel schematics

The two tethers will be deployed simultaneously from the reel directly into space without any guidance or capstans. This allows a very low mass and less number of components. But due to the two tether bays the tether has different height levels. In the combination of several remote units it must be made sure that in the adjacent remote unit the tether level is the same, because at the beginning of the deployment every remote unit is placed on the main spacecraft and cannot mounted on different height levels. Furthermore the drop out point of the tethers has a difference of 180°, these results in a momentum that could tilt the remote unit. Due to this an additional torque arises on the reel which increase the required torque for the motor.

The advantage of this concept is the simple configuration. The whole mechanism consists of only two parts, the motor and the reel. Therefore the mass of the whole system is very low.

The disadvantages in this concept are the different levels in height and plane as well as that the center of gravity of the remote unit changes with decreasing tether length in the reel. Furthermore if length error is allowed and one remote unit fails, the distance between the failed remote unit and his neighbor is 628 m otherwise the diameter should be increased. Additionally the two tether deployment cannot be controlled separately.

Advantage	Disadvantage
• Simple configuration • Lowest number of parts • Lowest mass	• Different tether height level • Different tether drop out point • Changing center of gravity • Additional resulting torque • No separate deployment possibility

4.2.2. Layer on Layer Concept

In the second concept the two tethers are reeled layer on layer on the same reel so the second layer is on top of the first. With this configuration the reel shall have a tether capacity of 1.25 km. Therefore the external diameter will be raised to 150 mm. The maximum required torque is 45 mNm.

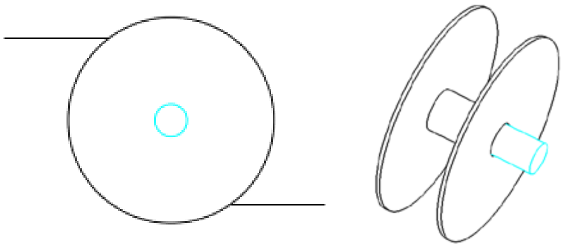


Figure 6: Layer on layer concept schematic

In the concept before the tether is deployed directly from the reel which leads to a simple design and low mass. With the layer on layer configuration the drawback of the different tether heights from the first concept was erased. Thus the remote unit configuration on the main spacecraft is simplified.

The advantage in this concept is again the simplicity of the configuration. The number of parts for whole mechanism is two, the motor and the reel. Therefore the mass of the whole system is very low

The disadvantages here are the difference between the drop out point and the center of gravity changes with decreasing tether length in the reel. Anymore in case of a failure of a remote unit the distance between the failed remote unit and his neighbor is fixed and cannot be compensated by a redundant mechanism. Even if the external diameter increases to take the 1.2 km. If the length error is not tolerable the reel diameter will be increased. Also in this concept the deployment of the two directions is simultaneous.

Advantage	Disadvantage
• Simple configuration • Lowest number of parts • Lowest mass	• Different tether drop out point • Changing center of gravity • Additional resulting torque • No separate deployment possibility

4.2.3. Guided Layer on Layer Concept

This concept is similar to concept two; the difference is that two capstans are added to guide the tether. Hence the external diameter as well as the maximum torque is still the same at 150 mm and 45 mNm.

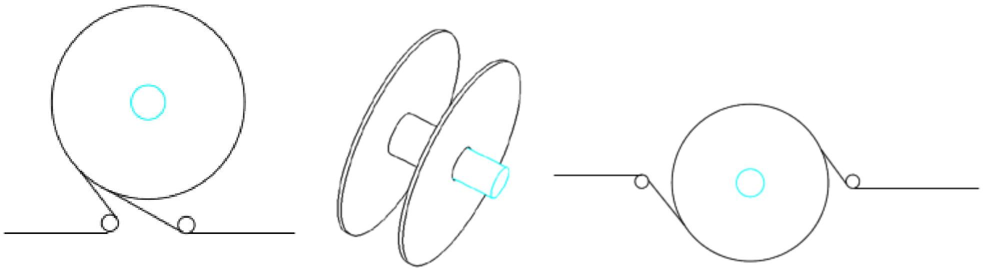


Figure 7: Guided layer on layer concept schematics

To compensate the disadvantage of the second concept with the different tether drop points and to bring it on one level two small capstans are added. Therefore the resulting torque due to the different drop point is compensated. Through these small changes the mass and the number of parts will be increased.

The advantages here are again a low number of parts and a low mass.

The disadvantage for this is the change of the center of gravity of the remote unit during the unreeling process. In case of failure, the distance to the next remote unit is fixed. The deployment of the two tethers is simultaneous and cannot be controlled separately.

This concept can be a little bit modified; to have the deployment plane of the tether in the same as the motor axis the position of the capstans can change (right picture in Figure 3). This can be done to have all acting forces during the deployment in one plane.

Advantage	Disadvantage
• Small number of parts • Low mass	• Changing center of gravity • No separate deployment possibility

4.2.4. Separate Two Reel Concept

In this concept the tether is reeled on two single reels. Each of these reels is driven by an individual motor and has a tether capacity of 628 m. Therefore the reel has an external diameter of 110 mm and requires a maximum torque of 33 mNm.

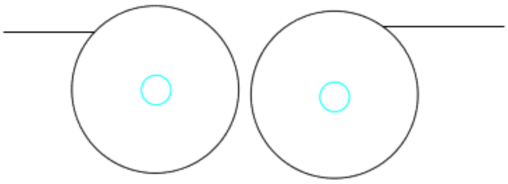


Figure 8: Two reel concept schematics

Regarding to the reliability of the system this concept was designed. In this case every reel has his own motor and can be controlled separately. This fact decreases the possibility of a length error but due to the double number of reels and motors it increase the system mass and the number of parts by a factor of two. The tether is deployed directly from the reel and at the same level.

The advantage of this concept is that every reel can be controlled separately and if a remote unit fails than the neighbored remote unit can compensate the missing tether length.

The disadvantage here is the doubled number of parts and tether length as well with it the doubled mass. Additionally due to the double number of parts the possibility of a motor failure is increased but its effect is limited.

Advantage	Disadvantage
• Separate controlled reel	• Changing center of gravity • Double number of reels and motor • Double mass

4.3.Perpendicular Motor Configuration

The concepts described in the following chapter have a configuration, where the motor spin axis is perpendicular to the reel rotation axis.

4.3.1. Combined Two Reel Concept

The first concept in which the motor is placed perpendicular consists of two reels. Both of this reels has a tether capacity of 628 m and therefore an external diameter of 110 mm. The Maximum required torque is 33 mNm.

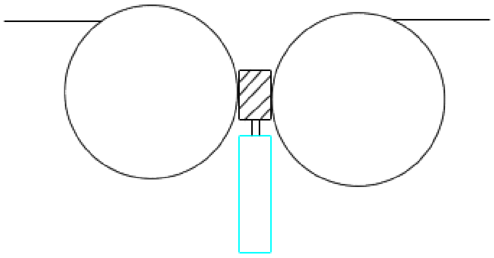


Figure 9: Combined two reel concept schematics

To reduce the number of parts and with it the mass of the deployment mechanism on motor is placed in the middle of the two reels and mechanically connected by a worm gear. With this motor configuration the change of the center of gravity from the remote unit viewpoint is avoided. The tether is reeled out again without guidance of the tether and the drop point is on the same level.

The advantage in this concept is the avoided change the center of gravity and that only one motor per remote unit is needed.

The disadvantage is that the reels are doubled and therefore the mass is increased. Furthermore an additional worm gear is needed and also the two tether deployment directions cannot be controlled separately.

Advantage	Disadvantage
• No Changing center of gravity • One motor	• Double number of reels • Additional gear wheels needed • Higher mass • No separate deployment possibility

4.3.2. Separate Gear Concept

In this concept each tether reel has his own motor connected with a gear wheel to the tether reel. The external diameter of each reel is 110 mm and has a tether capacity of 628 m. The required torque is 33 mNm.

Based on the development in separate two reel concept, also in this concept each reel can be controlled separately by a motor and therefor the tethers can be independently reeled up. Hence the tether length error can be compensated, if the reel has enough capacity for it. The tether is deployed directly from the reel on the same level and with this motor configuration the change of gravity is avoided.

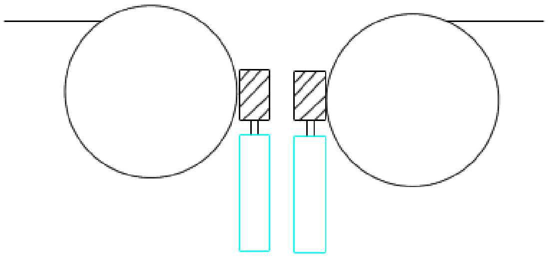


Figure 10: Separate two gear concept

The advantage of this concept is that the reel can be controlled separately and that the change of gravity is avoided.

The disadvantages here are that the double number of motors and gear wheels. Thus the numbers of parts as well as the system mass are increased.

Advantage	Disadvantage
• No Changing center of gravity • Separate controlled reel	• Double number of reels and motor • Additional gear wheels needed • Higher mass

4.4.Concept Evaluation

To find the most suitable concept for the deployment mechanism all in chapter 3 described concepts are evaluated. The criteria for the evaluation are the following:

- **Complexity:**

  This analyses the overall complexity of the concept. This point is massively influenced by mechanisms and moveable parts that could get stuck. If the concept has only the motor and the reel the rating is good and with increasing number of mechanisms the rating for the concept will be decrease.
- **Number of Parts:**
  This evaluates the number of parts in the concepts. With increasing part numbers the rating will decrease.
- **Required Volume:**
  This analyses the estimated overall required volume for the concept. With increasing volume the rating decreases
- **Length error compensation:**
  This evaluation criteria analyses the possibility of the concepts to compensate an length error. That means if a neighbored remote unit fails, is it possible to unreel from the functional neighbored remote unit the needed length. This is only possible if in every remote unit two motors are placed which can separately controlled and unreel the tether. Therefore a failsafe concept has the best rating.
- **Control possibility:**
  The rating criteria represent the possibility to control the unreeling of both tether deployment directions separately.
- **Mass:**
  This evaluates how high the estimated mass of the concept is. The lowers mass receive the best rating.
- **Deployment Stability:**
  This analyzed the concept influence to the remote unit. The different drop points of the tether and the different height levels influence the implementation of the remote unit on the main spacecraft as well as they generate a resulting torque. Additional the change of the center of gravity should be avoided. The best rating receives the concept without influence of the remote units performance during deployment. With increasing numbers of influence the rating decreases

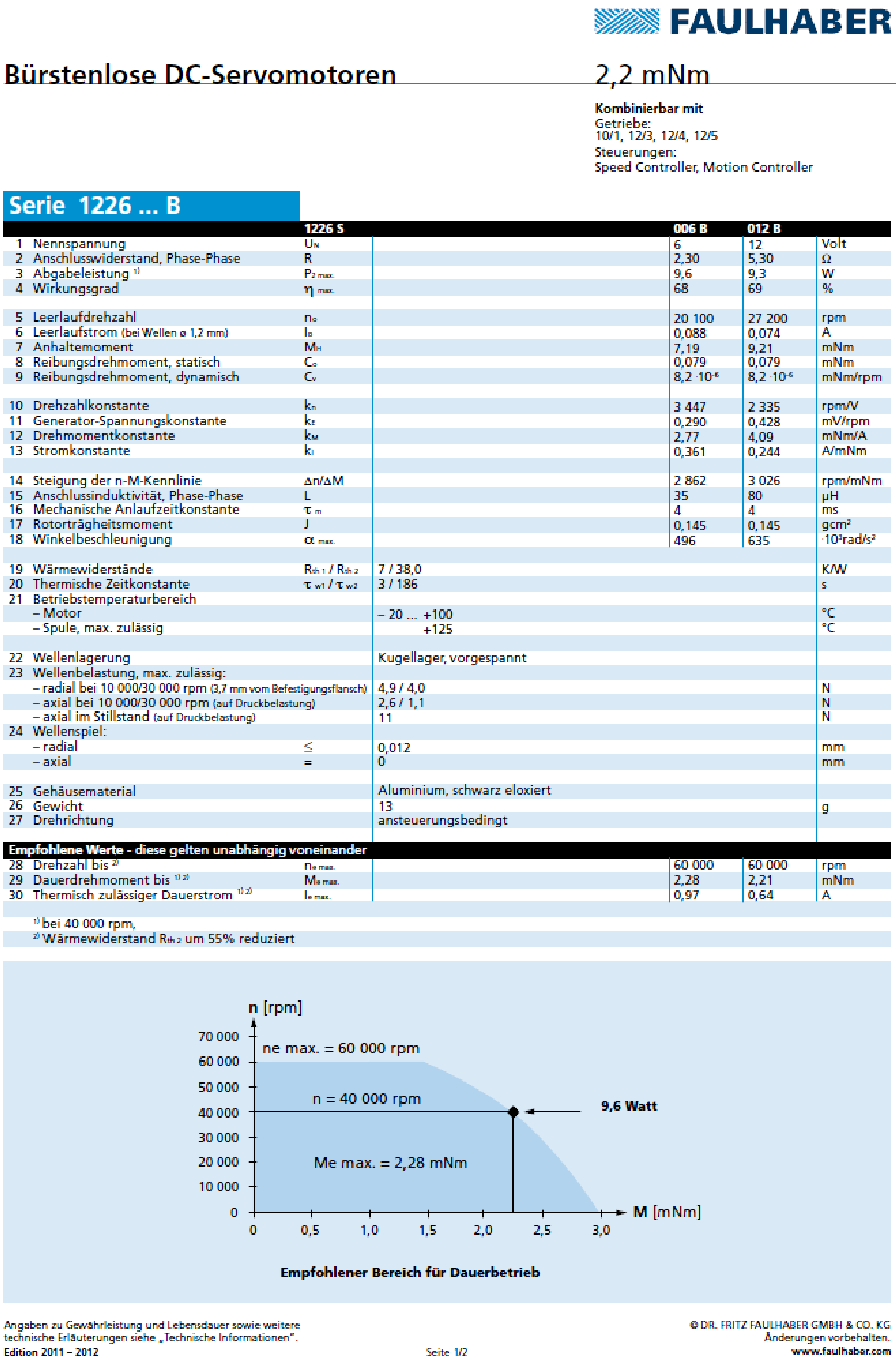
The following Table valued the different designs of the reel after the following system:

Very Good	Good	Neutral	Bad	Very Bad
++	+	o	-	--

	Concept 1 Stacked Reel	**Concept 2 Layer on Layer**	**Concept 3 Guided Layer on Layer**	**Concept 4 Separate Two Reel**	**Concept 5 Combined Two Reel**	**Concept 6 Separate Two Gear**
Complexity	++	++	+	++	-	-
Number of Parts	4	4	6	8	6	8
Required volume [cm³]	693	641	644	969	887	938
Length error compensation	--	--	--	++	--	++
Control possibility	No	No	No	Yes	No	Yes
Mass [g]	333	294	304	830	645	830
Deployment stability	--	--	-	-	++	++

The evaluation matrix shows that the best rating without weighting has concept 2 the “layer on layer” concept. The redundancy in this case has a high priority because in case of a full scale flight mission with hundred remote units, the possibility of a failure is high and leads in case of one motor failure to the failure of the whole mission. Hence the reliability and redundancy of the mechanism received an additional weighting. Therefore the criteria “length error compensation” and “control possibility” have a double rating. Due to that evaluation the two separate reel and gear concepts are the concepts which are the best reliable for the future mission and became realized in a CAD model.

4.5. Data Sheets



FAULHABER

Bürstenlose DC-Servomotoren

2,2 mNm

Kombinierbar mit
Getriebe:
10/1, 12/3, 12/4, 12/5
Steuerungen:
Speed Controller, Motion Controller

Serie 1226 ... B

		1226 S		006 B	012 B	
1	Nennspannung	U_N		6	12	Volt
2	Anschlusswiderstand, Phase-Phase	R		2,30	5,30	Ω
3	Abgabeleistung [1]	$P_{2\,max.}$		9,6	9,3	W
4	Wirkungsgrad	$\eta_{max.}$		68	69	%
5	Leerlaufdrehzahl	n_0		20 100	27 200	rpm
6	Leerlaufstrom (bei Wellen ø 1,2 mm)	I_0		0,088	0,074	A
7	Anhaltemoment	M_H		7,19	9,21	mNm
8	Reibungsdrehmoment, statisch	C_0		0,079	0,079	mNm
9	Reibungsdrehmoment, dynamisch	C_v		$8{,}2 \cdot 10^{-6}$	$8{,}2 \cdot 10^{-6}$	mNm/rpm
10	Drehzahlkonstante	k_n		3 447	2 335	rpm/V
11	Generator-Spannungskonstante	k_E		0,290	0,428	mV/rpm
12	Drehmomentkonstante	k_M		2,77	4,09	mNm/A
13	Stromkonstante	k_I		0,361	0,244	A/mNm
14	Steigung der n-M-Kennlinie	$\Delta n/\Delta M$		2 862	3 026	rpm/mNm
15	Anschlussinduktivität, Phase-Phase	L		35	80	µH
16	Mechanische Anlaufzeitkonstante	τ_m		4	4	ms
17	Rotorträgheitsmoment	J		0,145	0,145	gcm^2
18	Winkelbeschleunigung	$\alpha_{max.}$		496	635	$\cdot 10^3 rad/s^2$
19	Wärmewiderstände	$R_{th\,1} / R_{th\,2}$	7 / 38,0			K/W
20	Thermische Zeitkonstante	τ_{w1} / τ_{w2}	3 / 186			s
21	Betriebstemperaturbereich					
	– Motor		– 20 ... +100			°C
	– Spule, max. zulässig		+125			°C
22	Wellenlagerung		Kugellager, vorgespannt			
23	Wellenbelastung, max. zulässig:					
	– radial bei 10 000/30 000 rpm (3,7 mm vom Befestigungsflansch)		4,9 / 4,0			N
	– axial bei 10 000/30 000 rpm (auf Druckbelastung)		2,6 / 1,1			N
	– axial im Stillstand (auf Druckbelastung)		11			N
24	Wellenspiel:					
	– radial	≤	0,012			mm
	– axial	=	0			mm
25	Gehäusematerial		Aluminium, schwarz eloxiert			
26	Gewicht		13			g
27	Drehrichtung		ansteuerungsbedingt			
Empfohlene Werte - diese gelten unabhängig voneinander						
28	Drehzahl bis [2]	$n_{e\,max.}$		60 000	60 000	rpm
29	Dauerdrehmoment bis [1] [2]	$M_{e\,max.}$		2,28	2,21	mNm
30	Thermisch zulässiger Dauerstrom [1] [2]	$I_{e\,max.}$		0,97	0,64	A

[1] bei 40 000 rpm,
[2] Wärmewiderstand $R_{th\,2}$ um 55% reduziert

Empfohlener Bereich für Dauerbetrieb

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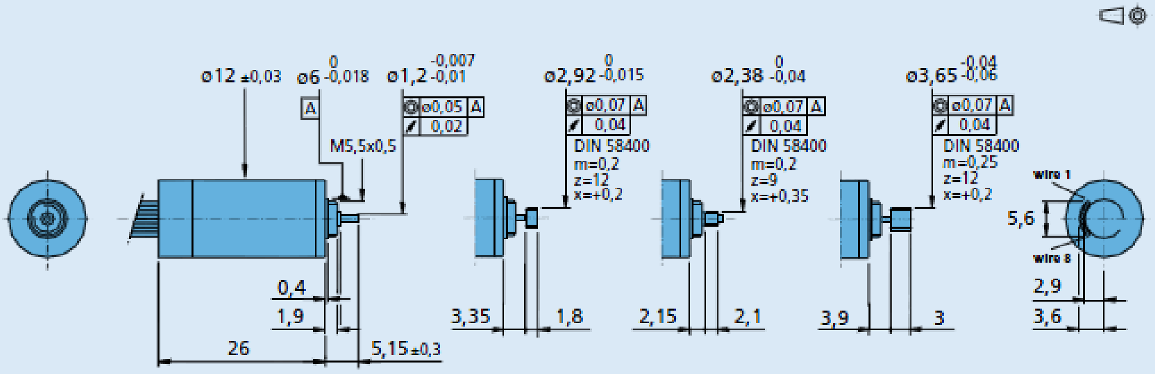
Sonderausführungen
K1855:
Motoren für den Betrieb mit Motion Controller
MCBL 3003 S/C, MCBL 3006 S/C.

1226 ... B



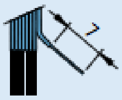
1226 S

1226 M
für Getriebe 10/1

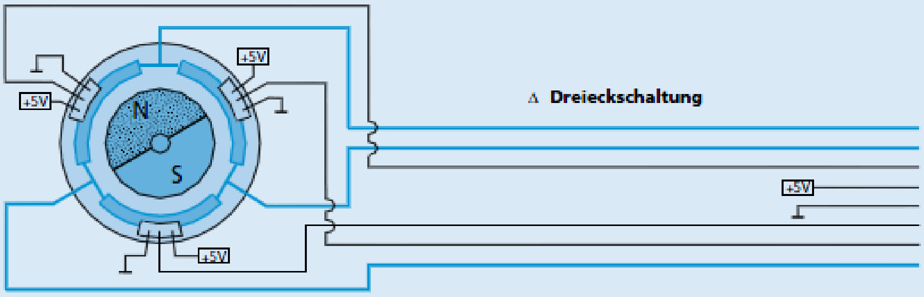
1226 E
für Getriebe 12/3, 12/5

1226 A
für Getriebe 12/4

Kabel- und Anschlussinformationen



Kabel
Einzelne Litzen in PTFE
Länge 80 mm ± 3 mm
8 Litzen, AWG 30



Anschlüsse

No.	Funktion	Farbe
1	Phase C	gelb
2	Phase B	orange
3	Hall-Sensor C	grau
4	+5V	rot
5	GND	schwarz
6	Hall-Sensor A	grün
7	Hall-Sensor B	blau
8	Phase A	braun

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Planetengetriebe

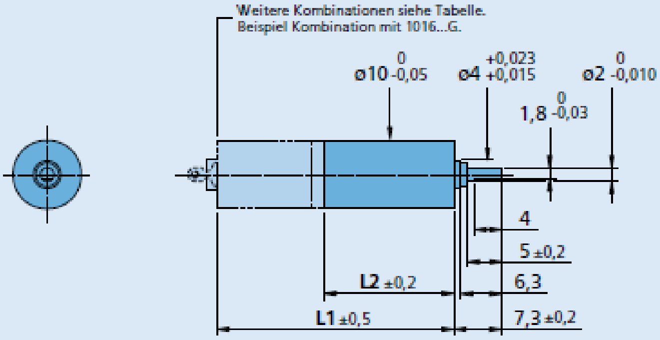
0,1 Nm

Kombinierbar mit
DC-Kleinstmotoren
Bürstenlose DC-Motoren
Schrittmotoren

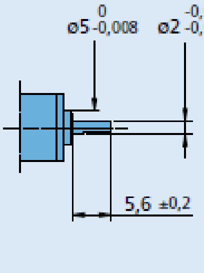
Serie 10/1

	10/1	10/1K
Gehäusewerkstoff	Metall	Metall
Zahnräderwerkstoff	Stahl	Stahl
Max. empfohlene Eingangsdrehzahl für:		
– Dauerbetrieb	5 000 rpm	5 000 rpm
Getriebespiel, unbelastet	≤ 3 °	≤ 3 °
Abtriebswellenlager	Sinterlager	Kugellager, vorgespannt
Max. zulässige Wellenbelastung:		
– radial (5 mm vom Befestigungsflansch)	≤ 1 N	≤ 7 N
– axial	≤ 2 N	≤ 5 N
Maximale Aufpresskraft	≤ 10 N	≤ 5 N
Wellenspiel:		
– radial (5 mm vom Befestigungsflansch)	≤ 0,04 mm	≤ 0,02 mm
– axial	≤ 0,1 mm	= 0 mm
Betriebstemperaturbereich	- 30 ... + 100 °C	- 30 ... + 100 °C

Technische Daten							
Anzahl Getriebestufen		1	2	3	4	5	6
Dauerdrehmoment	mNm	5	15	54	100	100	100
Kurzzeitdrehmoment	mNm	200	200	200	200	200	200
Gewicht ohne Motor, ca.	g	6	7	8	10	11	13
Wirkungsgrad, max.	%	90	80	70	60	55	48
Drehsinn der Welle, Antrieb zu Abtrieb		=	=	=	=	=	=
Untersetzung (absolut)		4:1	16:1	64:1	256:1	1 024:1	4 096:1
L2 [mm] = Getriebelänge		9,7	12,8	15,9	19,0	22,1	25,2
L1 [mm] = Länge mit Motor	1016M...G	25,4	28,5	31,6	34,7	37,8	40,9
	1024M...S	33,4	36,5	39,6	42,7	45,8	48,9
	1219M...G	28,4	31,5	34,6	37,7	40,8	43,9
	1224M...S	33,9	37,0	40,1	43,2	46,3	49,4
	1224M...SR	33,9	37,0	40,1	43,2	46,3	49,4
	1226M...B	35,7	38,8	41,9	45,0	48,1	51,2
	ADM1220...-05	27,2	30,3	33,4	36,5	39,6	42,7
	ADM1220S...-55	27,2	30,3	33,4	36,5	39,6	42,7
	AM0820...-10	23,4	26,5	29,6	32,7	35,8	38,9
	AM1020...-08	25,5	28,6	31,7	34,8	37,9	41,0



10/1



10/1 K
(L1, L2 = + 1)

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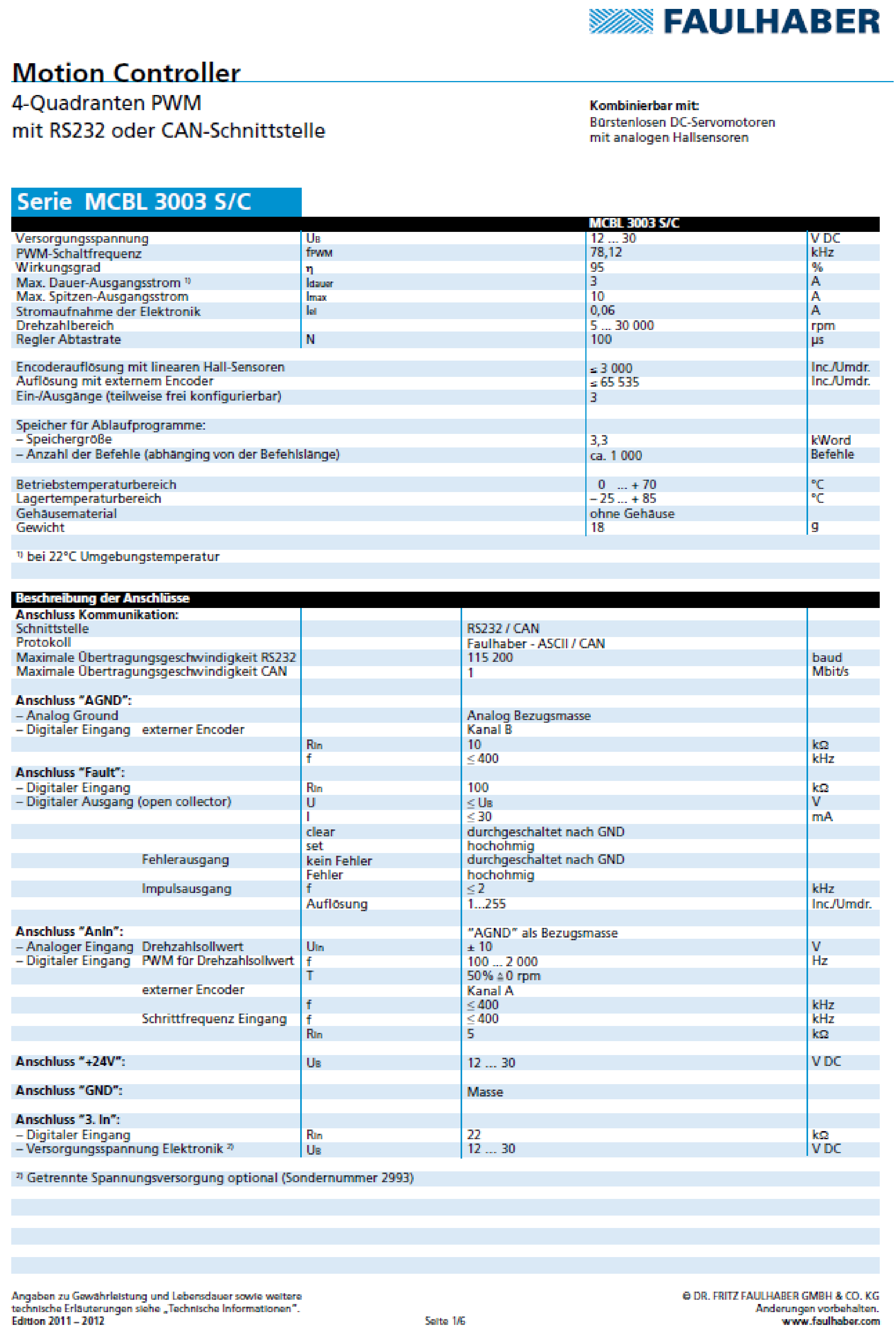

FAULHABER

Motion Controller

4-Quadranten PWM
mit RS232 oder CAN-Schnittstelle

Kombinierbar mit:
Bürstenlosen DC-Servomotoren
mit analogen Hallsensoren

Serie MCBL 3003 S/C

		MCBL 3003 S/C	
Versorgungsspannung	U_B	12 ... 30	V DC
PWM-Schaltfrequenz	f_{PWM}	78,12	kHz
Wirkungsgrad	η	95	%
Max. Dauer-Ausgangsstrom [1]	I_{dauer}	3	A
Max. Spitzen-Ausgangsstrom	I_{max}	10	A
Stromaufnahme der Elektronik	I_{el}	0,06	A
Drehzahlbereich		5 ... 30 000	rpm
Regler Abtastrate	N	100	µs
Encoderauflösung mit linearen Hall-Sensoren		≤ 3 000	Inc./Umdr.
Auflösung mit externem Encoder		≤ 65 535	Inc./Umdr.
Ein-/Ausgänge (teilweise frei konfigurierbar)		3	
Speicher für Ablaufprogramme:			
– Speichergröße		3,3	kWord
– Anzahl der Befehle (abhänging von der Befehlslänge)		ca. 1 000	Befehle
Betriebstemperaturbereich		0 ... + 70	°C
Lagertemperaturbereich		– 25 ... + 85	°C
Gehäusematerial		ohne Gehäuse	
Gewicht		18	g

[1] bei 22°C Umgebungstemperatur

Beschreibung der Anschlüsse			
Anschluss Kommunikation:			
Schnittstelle		RS232 / CAN	
Protokoll		Faulhaber - ASCII / CAN	
Maximale Übertragungsgeschwindigkeit RS232		115 200	baud
Maximale Übertragungsgeschwindigkeit CAN		1	Mbit/s
Anschluss "AGND":			
– Analog Ground		Analog Bezugsmasse	
– Digitaler Eingang externer Encoder		Kanal B	
	R_{in}	10	kΩ
	f	≤ 400	kHz
Anschluss "Fault":			
– Digitaler Eingang	R_{in}	100	kΩ
– Digitaler Ausgang (open collector)	U	≤ U_B	V
	I	≤ 30	mA
	clear	durchgeschaltet nach GND	
	set	hochohmig	
Fehlerausgang	kein Fehler	durchgeschaltet nach GND	
	Fehler	hochohmig	
Impulsausgang	f	≤ 2	kHz
	Auflösung	1...255	Inc./Umdr.
Anschluss "AnIn":		"AGND" als Bezugsmasse	
– Analoger Eingang Drehzahlsollwert	U_{in}	± 10	V
– Digitaler Eingang PWM für Drehzahlsollwert	f	100 ... 2 000	Hz
	T	50% ≙ 0 rpm	
externer Encoder		Kanal A	
	f	≤ 400	kHz
Schrittfrequenz Eingang	f	≤ 400	kHz
	R_{in}	5	kΩ
Anschluss "+24V":	U_B	12 30	V DC
Anschluss "GND":		Masse	
Anschluss "3. In":			
– Digitaler Eingang	R_{in}	22	kΩ
– Versorgungsspannung Elektronik [2]	U_B	12 30	V DC

[2] Getrennte Spannungsversorgung optional (Sondernummer 2993)

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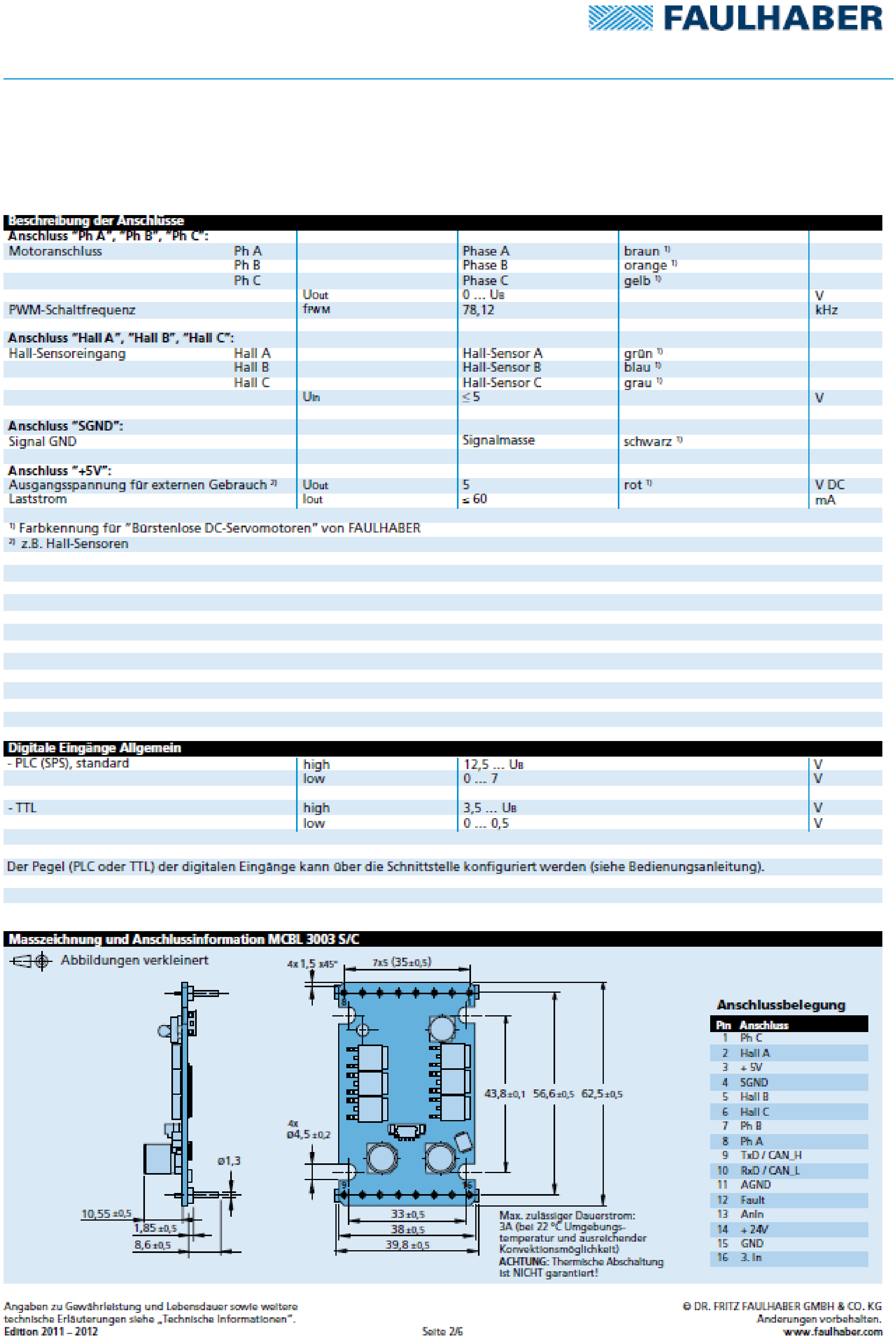

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Beschreibung der Anschlüsse

Anschluss "Ph A", "Ph B", "Ph C":					
Motoranschluss	Ph A		Phase A	braun [1]	
	Ph B		Phase B	orange [1]	
	Ph C		Phase C	gelb [1]	
		U_{out}	0 ... U_B		V
PWM-Schaltfrequenz		f_{PWM}	78,12		kHz
Anschluss "Hall A", "Hall B", "Hall C":					
Hall-Sensoreingang	Hall A		Hall-Sensor A	grün [1]	
	Hall B		Hall-Sensor B	blau [1]	
	Hall C		Hall-Sensor C	grau [1]	
		U_{in}	≤ 5		V
Anschluss "SGND":					
Signal GND			Signalmasse	schwarz [1]	
Anschluss "+5V":					
Ausgangsspannung für externen Gebrauch [2]		U_{out}	5	rot [1]	V DC
Laststrom		I_{out}	≤ 60		mA

[1] Farbkennung für "Bürstenlose DC-Servomotoren" von FAULHABER

[2] z.B. Hall-Sensoren

Digitale Eingänge Allgemein

- PLC (SPS), standard	high	12,5 ... U_B	V
	low	0 ... 7	V
- TTL	high	3,5 ... U_B	V
	low	0 ... 0,5	V

Der Pegel (PLC oder TTL) der digitalen Eingänge kann über die Schnittstelle konfiguriert werden (siehe Bedienungsanleitung).

Masszeichnung und Anschlussinformation MCBL 3003 S/C

Abbildungen verkleinert

Max. zulässiger Dauerstrom: 3A (bei 22 °C Umgebungstemperatur und ausreichender Konvektionsmöglichkeit)

ACHTUNG: Thermische Abschaltung ist NICHT garantiert!

Anschlussbelegung

Pin	Anschluss
1	Ph C
2	Hall A
3	+ 5V
4	SGND
5	Hall B
6	Hall C
7	Ph B
8	Ph A
9	TxD / CAN_H
10	RxD / CAN_L
11	AGND
12	Fault
13	AnIn
14	+ 24V
15	GND
16	3. In

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