

Semester Thesis

Sensing and characterization of the motor dynamics on an omnidirectional flying vehicle

Spring Term 2020



Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

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Preface

Bla bla ...

Abstract

Hier kommt der Abstact hin ...

Symbols

Symbols

ϕ, θ, ψ	roll, pitch and yaw angle
b	gyroscope bias
Ω_m	3-axis gyroscope measurement

Indices

x	x axis
y	y axis

Acronyms and Abbreviations

ETH	Eidgenössische Technische Hochschule
EKF	Extended Kalman Filter
IMU	Inertial Measurement Unit
UAV	Unmanned Aerial Vehicle
UKF	Unscented Kalman Filter

Chapter 1

Introduction

Hier kommt die Einleitung

Bibliography

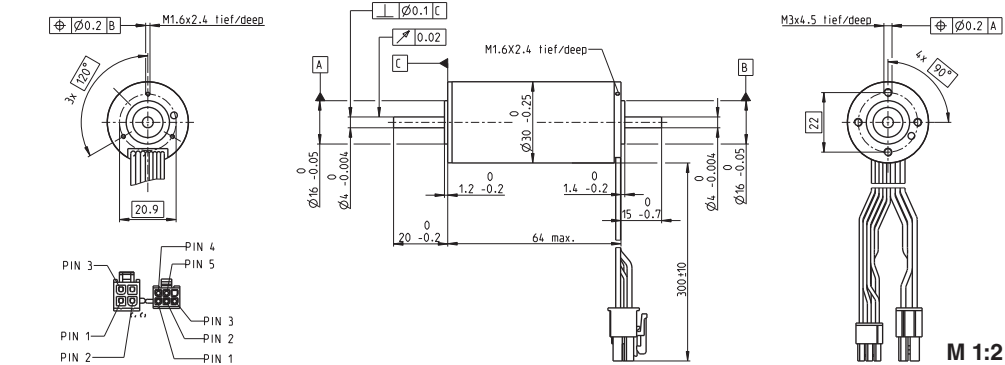
Appendix A

Irgendwas

Bla bla ...

Appendix B

Datasheets

EC-max 30 Ø30 mm, brushless, 60 Watt

■ Stock program
 □ Standard program
 ■ Special program (on request)

Part Numbers

272762 272763 272764 272765

Motor Data**Values at nominal voltage**

1 Nominal voltage	V	12	24	36	48
2 No load speed	rpm	7980	9340	9490	9350
3 No load current	mA	302	191	130	95.4
4 Nominal speed	rpm	6590	8040	8270	8130
5 Nominal torque (max. continuous torque)	mNm	63.6	60.7	63.7	64.1
6 Nominal current (max. continuous current)	A	4.72	2.66	1.88	1.4
7 Stall torque	mNm	381	458	522	519
8 Starting current	A	26.8	18.8	14.5	10.7
9 Max. efficiency	%	80	81	82	82

Characteristics

10 Terminal resistance phase to phase	Ω	0.447	1.27	2.48	4.49
11 Terminal inductance phase to phase	mH	0.049	0.143	0.312	0.573
12 Torque constant	mNm/A	14.2	24.3	35.9	48.6
13 Speed constant	rpm/V	672	393	266	197
14 Speed/torque gradient	rpm/mNm	21.2	20.6	18.4	18.2
15 Mechanical time constant	ms	4.86	4.73	4.21	4.17
16 Rotor inertia	gcm ²	21.9	21.9	21.9	21.9

Specifications**Thermal data**

17 Thermal resistance housing-ambient	7.4 K/W
18 Thermal resistance winding-housing	0.5 K/W
19 Thermal time constant winding	2.76 s
20 Thermal time constant motor	1000 s
21 Ambient temperature	-40...+100°C
22 Max. permissible winding temperature	+155°C

Mechanical data (preloaded ball bearings)

23 Max. permissible speed	15000 rpm
24 Axial play at axial load < 6.0 N	0 mm
> 6.0 N	0.14 mm
25 Radial play	preloaded
26 Max. axial load (dynamic)	5 N
27 Max. force for press fits (static) (static, shaft supported)	98 N
28 Max. radial loading, 5 mm from flange	1300 N
	25 N

Other specifications

29 Number of pole pairs	1
30 Number of phases	3
31 Weight of motor	305 g

Values listed in the table are nominal.

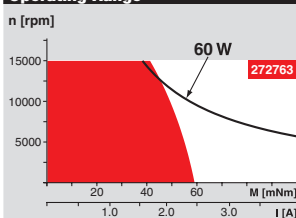
Connection motor (Cable AWG 20)	
red	Motor winding 1 Pin 1
black	Motor winding 2 Pin 2
white	Motor winding 3 Pin 3
N.C.	N.C. Pin 4

Connector	Part number
Molex	39-01-2040

Connection Sensors (Cable AWG 26)	
yellow	Hall sensor 1 Pin 1
brown	Hall sensor 2 Pin 2
grey	Hall sensor 3 Pin 3
blue	GND Pin 4
green	V _{DD} 3...24 VDC Pin 5
N.C.	N.C. Pin 6

Connector	Part number
Molex	430-25-0600

Wiring diagram for Hall sensors see p. 35

Operating Range**Comments**

■ **Continuous operation**
 In observation of above listed thermal resistance (lines 17 and 18) the maximum permissible winding temperature will be reached during continuous operation at 25°C ambient.
 = Thermal limit.
 □ **Short term operation**
 The motor may be briefly overloaded (recurring).
 — **Assigned power rating**

maxon Modular System**Planetary Gearhead**

Ø32 mm

8.0 Nm

Page 266

Koaxdrive

Ø32 mm

1.0 - 4.5 Nm

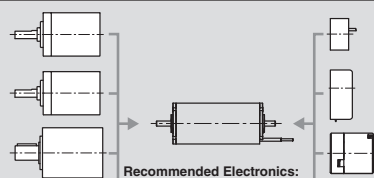
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Planetary Gearhead

Ø42 mm

3 - 15 Nm

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**Recommended Electronics:**

ESCON 36/3 EC Page 320

ESCON 50/5, Module 50/5 321

ESCON 70/10 321

DECS 50/5 324

DEC Module 24/2 325

DEC Module 50/5 325

EPOS2 24/5, 50/5 331

EPOS2 P 24/5 334

EPOS3 70/10 EtherCAT 337

Notes 24

Overview on page 20 - 25**Encoder MR**

500/1000 CPT,

3 channels

Page 302

Encoder HEDL 5540

500 CPT,

3 channels

Page 308

Brake AB 20

24 VDC

0.1 Nm

Page 346

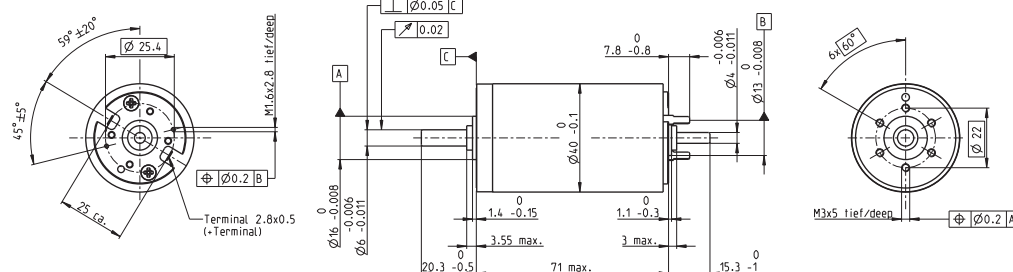
maxon EC motor 193

maxon EC-max

RE 40 Ø40 mm, Precious Metal Brushes, 25 Watt

NEW

maxon DC motor



M 1:2

■ Stock program
 □ Standard program
 ▨ Special program (on request)

Part Numbers

Motor Data		448588	448589	448590	448591	448592
Values at nominal voltage						
1 Nominal voltage	V	9	18	24	42	48
2 No load speed	rpm	2850	2850	2780	2920	2690
3 No load current	mA	49.7	24.8	18.1	11	8.62
4 Nominal speed	rpm	2610	2600	2480	2640	2410
5 Nominal torque (max. continuous torque)	mNm	87.8	87.8	88.2	87.6	87.6
6 Nominal current (max. continuous current)	A	2.96	1.48	1.09	0.65	0.524
7 Stall torque	mNm	873	956	794	895	818
8 Starting current	A	29	15.9	9.66	6.53	4.81
9 Max. efficiency	%	92	92	92	92	92
Characteristics						
10 Terminal resistance	Ω	0.311	1.14	2.49	6.43	9.97
11 Terminal inductance	mH	0.0624	0.33	0.613	1.7	2.62
12 Torque constant	mNm/A	30.2	60.3	82.2	137	170
13 Speed constant	rpm/V	317	158	116	69.7	56.2
14 Speed / torque gradient	rpm/mNm	3.27	2.98	3.51	3.27	3.3
15 Mechanical time constant	ms	4.85	4.29	4.36	4.14	4.13
16 Rotor inertia	gcm ²	142	137	119	121	120

Specifications

Thermal data	
17 Thermal resistance housing-ambient	4.65 K/W
18 Thermal resistance winding-housing	1.93 K/W
19 Thermal time constant winding	41.5 s
20 Thermal time constant motor	809 s
21 Ambient temperature	-20...+85°C
22 Max. permissible winding temperature	+100°C

Mechanical data (ball bearings)	
23 Max. permissible speed	3330 rpm
24 Axial play	0.05 - 0.15 mm
25 Radial play	0.025 mm
26 Max. axial load (dynamic)	5.6 N
27 Max. force for press fits (static) (static, shaft supported)	110 N
28 Max. radial loading, 5 mm from flange	1200 N
	28 N

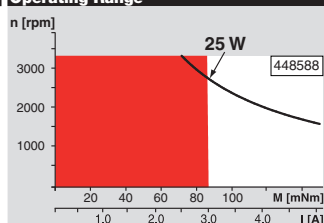
Other specifications	
29 Number of pole pairs	1
30 Number of commutator segments	13
31 Weight of motor	480 g

Values listed in the table are nominal.
Explanation of the figures on page 71.

Option

Preloaded ball bearings

Operating Range



Comments

Continuous operation
 In observation of above listed thermal resistance (lines 17 and 18) the maximum permissible winding temperature will be reached during continuous operation at 25°C ambient.
 = Thermal limit.

Short term operation
 The motor may be briefly overloaded (recurring).

Assigned power rating

maxon Modular System

Overview on page 20 - 25

