

**ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA**

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**SCUOLA DI INGEGNERIA**

DIPARTIMENTO DI  
INGEGNERIA DELL'ENERGIA ELETTRICA E DELL'INFORMAZIONE  
"Guglielmo Marconi"  
DEI

CORSO DI LAUREA IN - DEGREE NAME -

**TESI DI LAUREA**

in

- name of the course -

**$\LaTeX$ -Template for Student Theses at  
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CANDIDATO:

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**TITLE AND CO****SUPERVISOR**

**NAME**

ANNO ACCADEMICO 2020/2021

SESSIONE DI LAUREA I



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# Preface

Bla bla ... ciao



# Abstract

Bla bla bla ...





# Symbols

## Symbols

$\phi, \theta, \psi$	roll, pitch and yaw angle
$b$	gyroscope bias
$\Omega_m$	3-axis gyroscope measurement

## Indices

$x$	x axis
$y$	y axis

## Acronyms and Abbreviations

EKF	Extended Kalman Filter
IMU	Inertial Measurement Unit
UAV	Unmanned Aerial Vehicle
UKF	Unscented Kalman Filter



# Capitolo 1

## Introduction

Bla bla bla ...

Future developments: add Latex tutorial here...



# Capitolo 2

## Chapter

Bla bla bla ...

### 2.1 Section

[1] and [2] and [3] say ...



# Bibliografia

- [1] A. Hilal, M. Dust, and S. Norris, “A cited article in a latex bibliography,” *Random Journal*, 1995.
- [2] M. Spencer, *A cited book in a Latex bibliography*. Cambridge, MA: MIT Press, 1986.
- [3] G. A. Scott and W. M., “Series elastic actuators,” in *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 1981, pp. 3137–3181.





# **Appendice A**

## **Code**

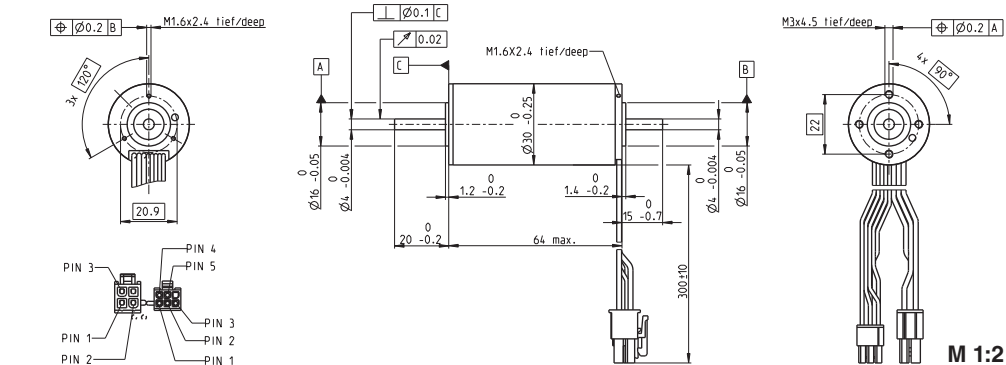
Bla bla bla ...



# **Appendice B**

## **Datasheets**

Bla bla bla ...

**EC-max 30** Ø30 mm, brushless, 60 Watt

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

**Part Numbers**

272762 272763 272764 272765

**Motor Data**

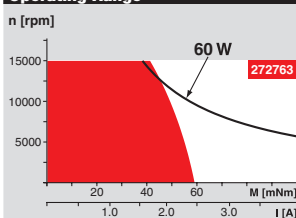
Values at nominal voltage					
1 Nominal voltage	V	12	24	36	48
2 No load speed	rpm	7980	9340	9490	9350
3 No load current	mA	302	191	130	95.4
4 Nominal speed	rpm	6590	8040	8270	8130
5 Nominal torque (max. continuous torque)	mNm	63.6	60.7	63.7	64.1
6 Nominal current (max. continuous current)	A	4.72	2.66	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 <sup>2</sup>	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**

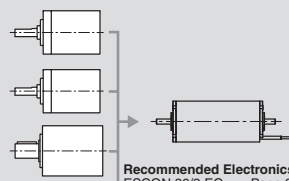
29	Number of pole pairs	
30	Number of phases	
31	Weight of motor	
Values listed in the table are nominal.		
<b>Connection motor</b> (Cable AWG 20)		
red	Motor winding 1	Pin 1
black	Motor winding 2	Pin 2
white	Motor winding 3	Pin 3
	N.C.	Pin 4
<b>Connector</b> <b>Part number</b>		
Molex	39-01-2040	
<b>Connection Sensors</b> (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 <sub>DD</sub> 3...24 VDC	Pin 5
	N.C.	Pin 6
<b>Connector</b> <b>Part number</b>		
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  
 Page 268  
 Planetary Gearhead  
 Ø42 mm  
 3 - 15 Nm  
 Page 271



**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

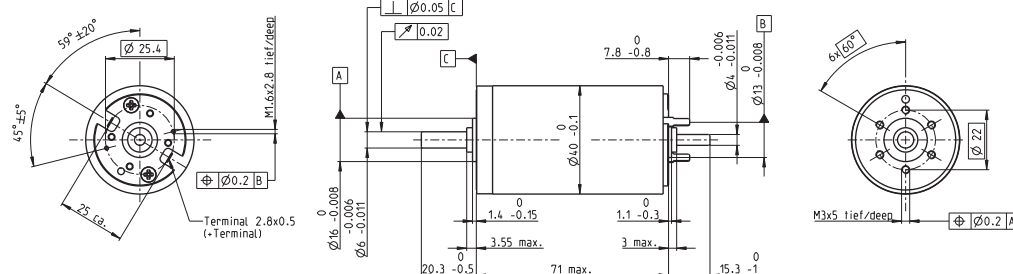
**Overview on page 20 - 25**

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

# 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
<b>Values at nominal voltage</b>						
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
<b>Characteristics</b>						
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 <sup>2</sup>	142	137	119	121	120

## Specifications

<b>Thermal data</b>	
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

<b>Mechanical data (ball bearings)</b>	
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

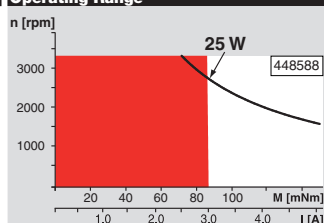
<b>Other specifications</b>	
29 Number of pole pairs	1
30 Number of commutator segments	13
31 Weight of motor	480 g

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

