ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Autonomous Systems Lab
Prof. Roland Siegwart

Semester Thesis

Design and Control of a Bicopter UAV

Spring Term 2018

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Declaration of Originality

I hereby declare that the written work I have submitted entitled

Your Project Title

is original work which I alone have authored and which is written in my own words.[1]

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[1] Co-authored work: The signatures of all authors are required. Each signature attests to the originality of the entire piece of written work in its final form.

Contents

Preface

This semester project was proposed by Autonomous System Lab that interested me to study on it.

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

1.1 Goals

The purpose of this project was to create a bicopter that could flight in each direction and changed the yaw angle.

1.2 Workflow

Worked every weeks on it. Present my pregress and advancement each week to my supervisors

1.3 Timeline

TODO: Timeline

Chapter 2

Design

2.1 Related works

2.2 Specifications

2.3 Ideas and First Drawings

2.4 Needs for the Bicopter

2.5 The Choice of Components

2.6 Final Design Prototyped

Chapter 3

Prototype Building

3.1 Ordered componants

3.2 Mechanical Construction

3.3 3D printing

3.4 Assembly

Chapter 4

System Modelling and Control

4.1 Allocation matrix

Chapter 5

Simulation

5.1 Introduction to ROS

5.2 Model Description

5.3 Nodes

5.4 Control

5.5 Results

Chapter 6

Real flight

?????? NOTHING

Appendix A

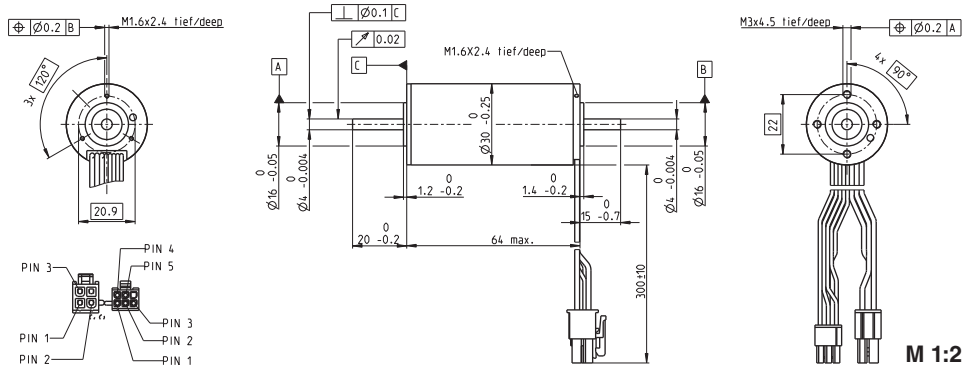
Irgendwas

Bla bla ...

Appendix B

Datasheets

EC-max 30 ∅30 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	gcm²	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)		98 N
	(static, shaft supported)		1300 N
28	Max. radial loading, 5 mm from flange		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.	Pin 4

Connector	**Part number**
Molex	39-01-2040

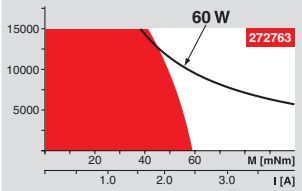
Connection Sensors (Cable AWG 26)

yellow	Hall sensor 1	Pin 1
brown	Hall sensor 2	Pin 2
grey	Hall sensor 3	Pin 3
blue	GND	Pin 4
green	V_{Hall} 3…24 VDC	Pin 5
	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

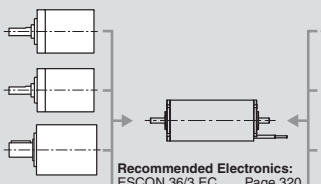
maxon Modular System

Overview on page 20 - 25

Planetary Gearhead
∅32 mm
8.0 Nm
Page 266

Koaxdrive
∅32 mm
1.0 - 4.5 Nm
Page 268

Planetary Gearhead
∅42 mm
3 - 15 Nm
Page 271



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

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
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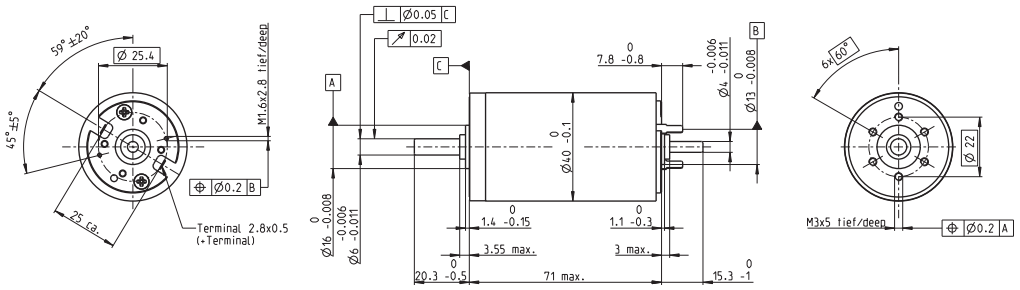
RE 40 ∅40 mm, Precious Metal Brushes, 25 Watt

NEW

maxon DC motor



M 1:2

Stock program
Standard program
Special program (on request)

Motor Data		Part Numbers						
		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	0.0824	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	gcm²	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)	110 N
	(static, shaft supported)	1200 N
28	Max. radial loading, 5 mm from flange	28 N

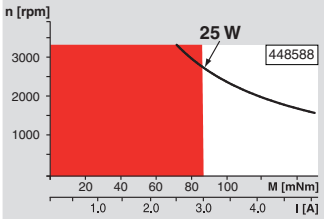
Other specifications

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



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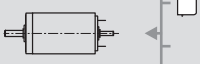
maxon Modular System

Overview on page 20 - 25



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500 CPT,
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