Electro-Mechanical-Actuator for UAV's

Overview

Figure 1 Actuator

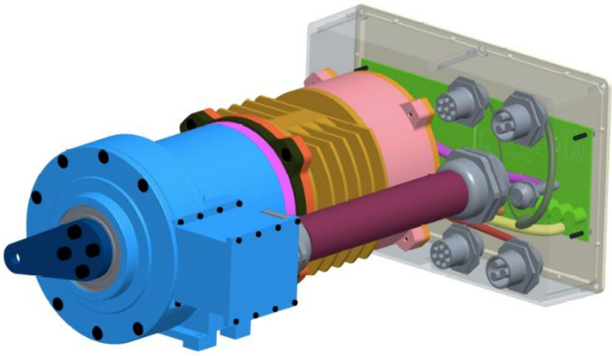


Figure 2 Complete Actuator Assembly

The depicted actuator allows fault tolerant position control using two independent operation lanes (A and B). Each lane consists of a high-resolution output position sensor, power-, control- and communication electronics, motor commutation sensors, a three-phase synchronous motor and inherent fault detection indicators to achieve an optimal power density and fault tolerant capability. The specification for the electro-mechanical actuator applicable for use in heavy **u**nmanned **a**erial **v**ehicles (UAVs) is listed in the following table

Weight (complete actuator incl. electronics, gearbox etc. as in Fig. 1)	8.65 kg
Nominal main supply voltage[1]	**28 Vdc**
Minimum steady state main supply voltage[1]	**20 Vdc**
Maximum steady state main supply voltage[1]	**29 Vdc**
Nominal Motor Phase Currents (**active**/**active** operation)	8Arms resp. **10Apeak** (block commutation)
Nominal Motor Phase Currents (**active**/**passive** operation)	11Arms resp. **14Apeak** (block commutation)
Cooling Method	**Passive Cooling** (no additional cooling plate required)
Backlash	**<0.1°**
Maximum mechanical hysteresis	**<0.02°**
Position Accuracy	**< 0.1°**
Ambient Operation Temperature Range	**-40°C to +70°C** (at full load range: 0Nm to 40Nm resp. 65Nm)

[1] No power is allowed to be fed back into the main electrical power system. Generated power from electrical motors must be dissipated within each lane by a braking chopper. The main power supply unit must have a protection to prevent reverse polarity connections of a battery unit.

Nominal Output Torque[2]	**65Nm** (40Nm load + 25Nm acceleration Torque) (full temperature range)
Continuous Load Torque[2]	**40Nm** (full temperature range)
Minimum Position Bandwidth[2]	**>3Hz** (at full load range: 0Nm to 40Nm resp. 65Nm and full temperature range)
Environmental protection	**IP54**

Table 1 System Specification (based on MIL-STD 704F)

The main components of the actuator are listed in Table 2 and illustrated in Fig. 3, 4 and 5

Note #	Component
1	Output lever
2	Output position encoder of lane A (rotor + stator)
3	Output position encoder of lane B (rotor + stator)
4	Spline-shaft
5	Spline-hub
6	Connection box of the output encoders
7	Gearbox, gear ratio of 1/50 (Harmonic Drives)
8	Cable tube of the output encoders
9	Motor (stator, main rotor (9.1), passive cooling)
10	Rotor for the digital position hall sensor
11	Digital hall sensor circuit board of lanes A and B (electrically isolated)
12	Motor encoder (rotor + stator)
13	Actuator control unit (ACU) of lanes A and B (two circuit boards)
14	Actuator connectors of lanes A and B (communication and power supply)

Table 2 Actuator Components

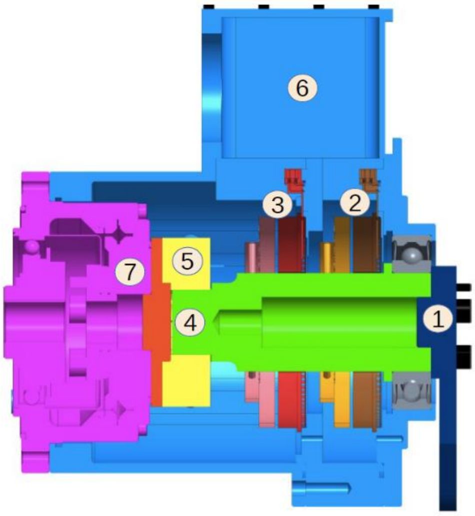


Figure 3 Output parts of the actuator.

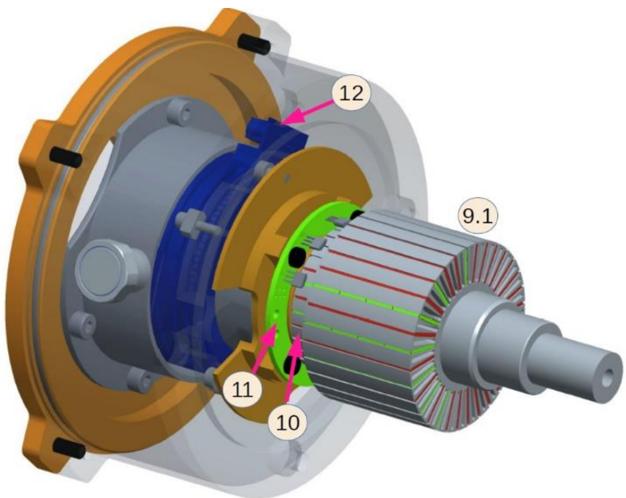


Figure 4 Sensor concept and the main motor rotor

[2] For an active/active operation of lane A and B (both lanes in operation). If only one lane operates, then 70% of nominal rating are applicable.

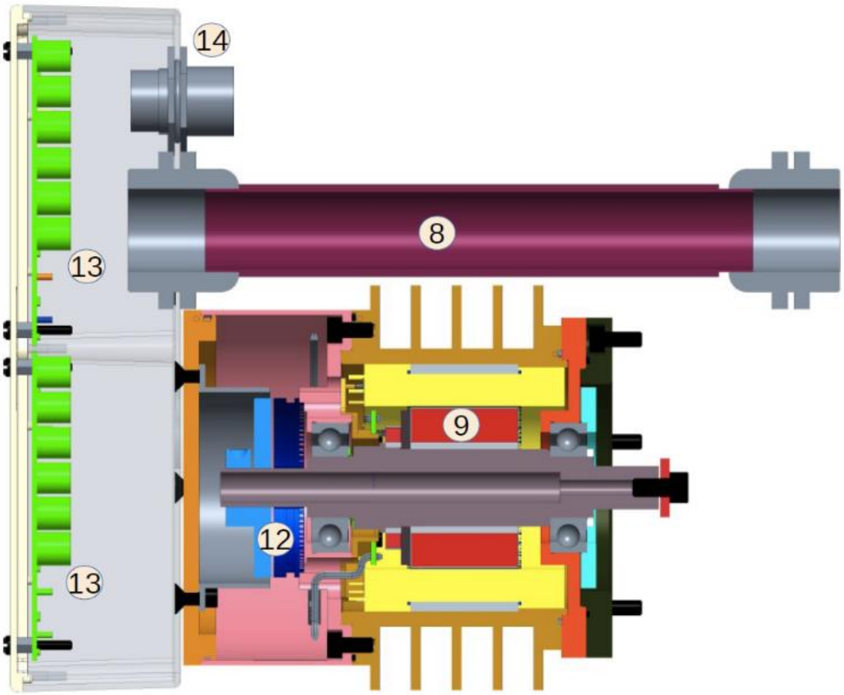


Figure 5 Motor-side parts of the actuator.

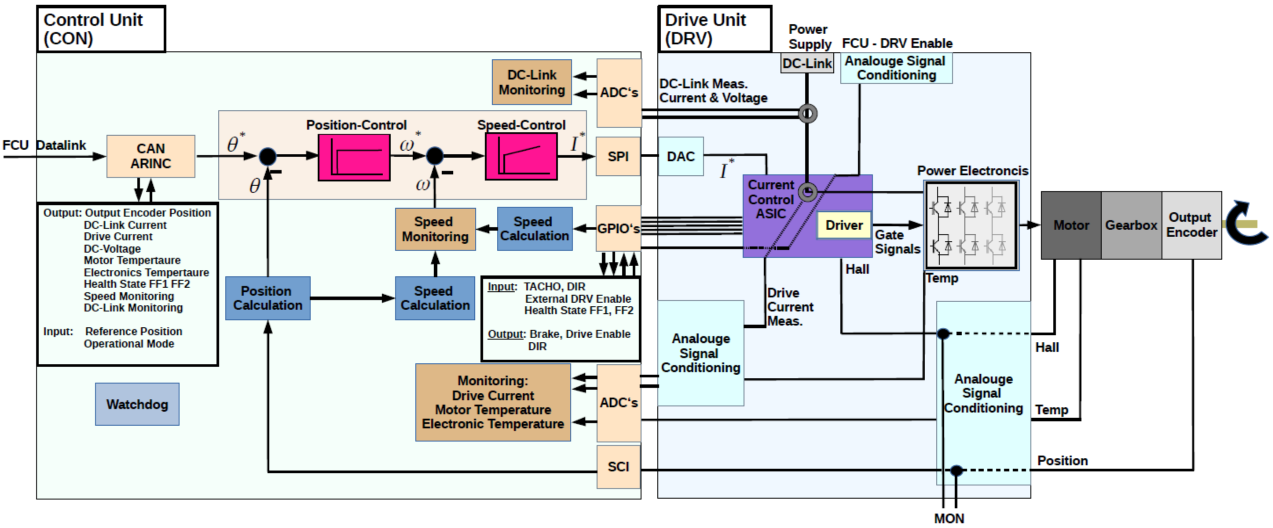


Figure 6 Overview of the electronic and software architecture (one of two identical lanes).

As shown in Fig. 6, lane A and B include a drive unit (DRV) and a control unit (CON), forming together the actuator control unit (ACU). The main purpose of the ACU is to control the motor currents in such a way that the output lever follows a commanded reference position given by the **f**light **c**ontrol **u**nit (FCU) and to provide monitoring data for **mon**itoring lanes (MONs). Both, the DRV and the CON are located on one ACU circuit board, which is shown in Fig. 5. The CON mainly represents a safety microcontroller, and the DRV consists of electronic components, including the power MOSFETs of the half bridges which are connected to the motor terminals. The motor is controlled by means of three cascaded loops to control the position, speed and current of the motor. It can be seen that only the position and speed control is implemented in software, whereas the current control is located externally in an ASIC to reduce the software complexity of the system. The utilised current control ASIC features the following functionalities, for simplicity divided into input and output related tasks:

Input: reference current from the microcontroller, drive enabled from the FCC and microcontroller, hall signals, power supply, reference direction (DIR)

Output: drive current measurement, digital hall sensor commutation status (TACHO), direction (DIR), health status bits (FF1 and FF2). The health status of the ASIC indicates several faults, which are listed in the following table

FF1 Signal	FF2 Signal	Status DRV_Health	Fault	Action to Drive
0	0	(0,0)	Undervoltage	Disable
0	0	(0,0)	Overtemperature	No Action
0	0	(0,0)	Logic Fault	Disable
1	0	(1,0)	Short to ground	Disable
1	0	(1,0)	Short to supply	Disable
1	0	(1,0)	Shorted motor winding	Disable
0	1	(0,1)	Low load current	No Action
1	1	(1,1)	None	No Action

DRV status bits (Functional decoding of DRV_Health status)

The motor speed is calculated by means of the ASIC TACHO bit and through the rate of change of the output position encoder signal. Additional fault detection relevant signals such as the temperature of the power electronics and motor windings as well as the DC-link voltage and current are processed within the microcontroller and transmitted via the datalink to the MON. Abnormal functionality such as software lock-ups or hardware faults of the microcontroller can be detected by a watchdog to recover back to a healthy state. The information of a watchdog event is also transmitted via the datalink to the FCU. Due to the external current control, the functionality of the microcontroller is reduced to the control of the output position lever by means of the position and speed control

loop and to the communication of measurement data such as:

• CAN: communication with FCU

• SPI: communication with DAC for the generation of a current reference voltage for the ASIC.

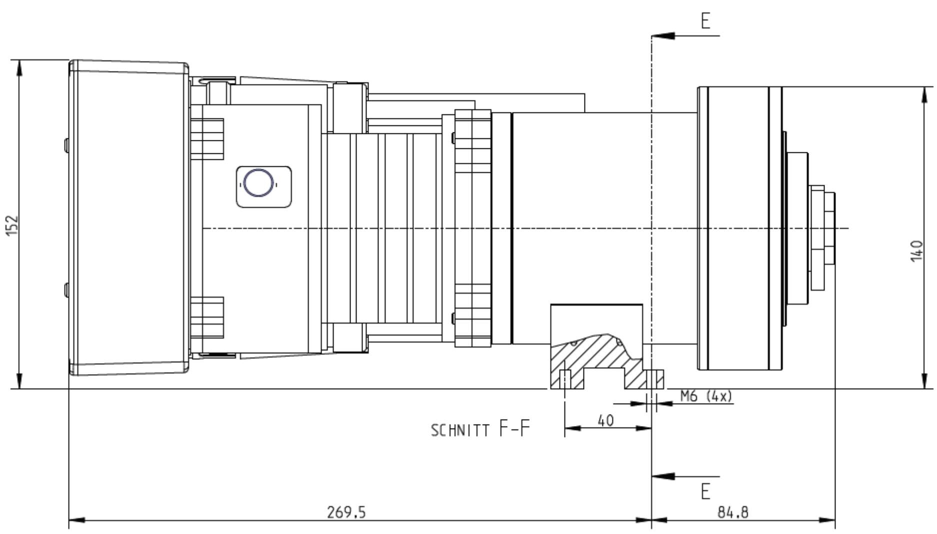
• SCI: reading of the output encoder serial communication protocol

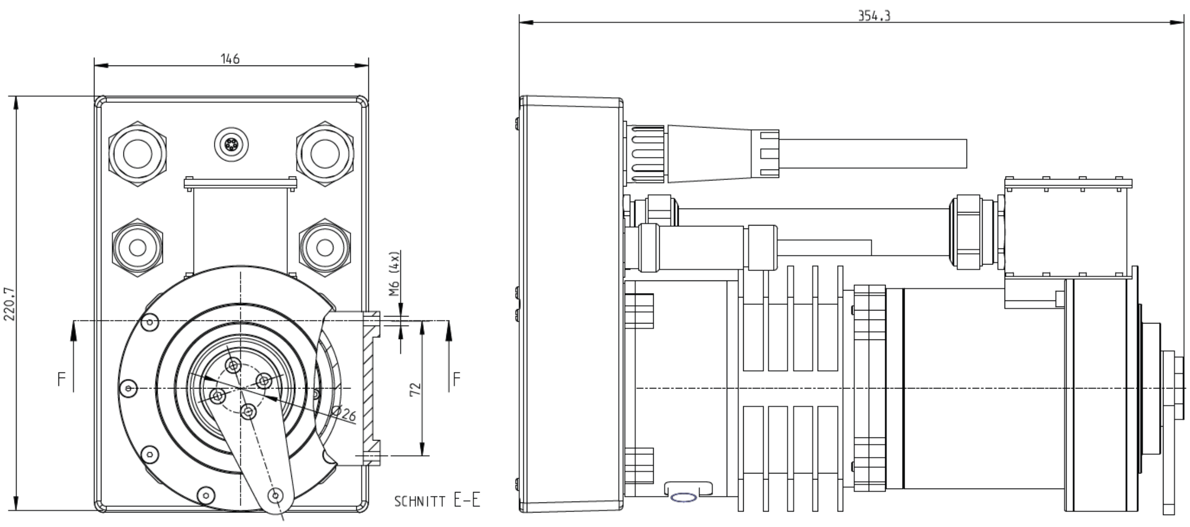
• ADC: temperature sensor measurement of the power electronics and motor windings,

ASIC drive current, DC-link current and voltage

• GPIOS Input: ASIC fault diagnoses bits (FF1, FF2), TACHO, DIR, external drive enable (FCU),

GPIOS Output: BRAKE, drive enabled, DIR.

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