



# CUBETORQUER GEN 2

## Interface Control Document



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## Revision History

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A	L. Hobson	2022/07/13	First draft
1.00	L. Hobson	2022/07/15	Formal version after internal review
1.01	L. Hobson	2023/01/12	Updated Resistance and mass values in Table 1. Added tolerances to dimensions in Table 3

## Reference Documents

The following external documents are referenced in this document.

[1] Molex 503763-0291 Datasheet (Available [here](#))

## List of Acronyms/Abbreviations

PWM	Pulse-Width Modulated
RMS	Root-Mean Square
ADCS	Attitude Determination and Control System
CVCM	Collected Volatile Condensable Materials
ID	Identification
LEO	Low Earth Orbit
PCB	Printed Circuit Board



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## 1 Introduction

This document provides a brief functional description of CubeTorquer and details all external interfaces to and from it. The interfaces discussed include electrical, mechanical, and environmental.

CubeTorquers are magnetic torquer rods, intended as actuators used for controlling the orientation of satellites in Low Earth orbit. These rods generate a magnetic field when current is passed through them, which generates a torque through interaction with the earth's magnetic field. Typically, three rods are used per satellite, placed in the three principal axes of the satellite.

The CubeTorquer product has been refined over eight years of use in orbit and offers excellent performance, is robust, user friendly, and comes in a range of sizes for satellites ranging in sizes from 2U to 27U. These rods are manufactured in a production facility that, through innovation and automation, is geared for mass manufacturing, and can be repeatedly delivered in high quantities, on short lead-times, at affordable prices.



Handling Warning: Please handle all magnetic rods with extreme caution and avoid hard, high-frequency mechanical shocks. Such impacts can in extreme cases notably influence the magnetic properties of the cores, which impacts the linearity and magnetic remanence of the rods. Examples of unwanted impacts include dropping the rod onto hard surfaces and bumping the rod against hard surfaces or objects. It is recommended that rods always be placed onto padded surfaces while on the bench. Note however that shocks and vibrations experienced during typical satellite qualification campaigns, and during launch, would not degrade the performance of the product at all.



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## 2 Functional Description

### 2.1 Functions and Features

The main function of a CubeTorquer is to generate a magnetic moment when, and only when, current is passed through it. Electrically conductive wire is wound around a special ferrous core. The core is made from heat-treated ferrous material, which has a high saturation magnetic flux and ensures a low remnant magnetic moment after exciting the core.

Torquer rods are typically driven using PWM control and in some cases, through variable current drivers. CubeTorquer's special heat-treated ferrous core provides a highly linear relationship between coil-current and magnetic moment, with total linearity >98%. This significantly simplifies magnetic torquer controllers since linearity can be assumed.

A crucially important factor about torquer rods is their remnant magnetic moment. This is the magnetic moment left on the coil after it has been excited, and then switched off. Remnant magnetic moments remain in the core material of the rod after it has been magnetized when magnetic flux has flown through it. If this remnant magnetic field is too large once current to the rod is stopped, it may interfere with magnetometer measurements on satellites, causing undesired disturbance torques on the satellite, and may interfere with sensitive payloads. CubeTorquer, through the special heat-treated core, has a negligible remnant magnetic moment.

CubeTorquer can be mounted on three sides and features a compact connector which is polarized. Also, the CubeTorquer is offered with short lead-times and global availability. This makes it very simple to integrate CubeTorquer into any satellite mission.



## 2.2 Characteristics

The characteristics of the different sizes CubeTorquer are shown in Table 1.

Table 1: Characteristics

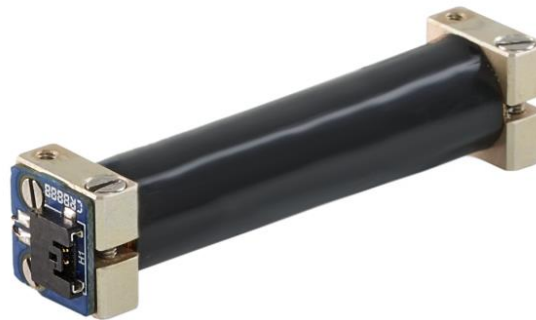
No	Characteristic	CR0002	CR0003	CR0004	CR0006	CR0008	CR0010	CR0012	CR0020	Unit
Performance										
1.	Max Voltage	5								[V]
2.	Minimum Guaranteed Magnetic Moment @ 5V	0.2	0.3	0.4	0.63	0.80	1.00	1.20	2.00	[Am <sup>2</sup> ]
3.	Magnetic Gain	2.3	4.3	3.3	5.8	7.0	7.8	9.5	13.6	[Am <sup>2</sup> /A]
4.	Linearity	> 98								[%]
5.	Nominal Resistance	51.0	66.5	39.5	45.0	44.5	37.5	36.5	32.5	[Ω] ± 1.0
6.	Inductance	0.26	0.45	0.26	0.34	0.32	0.38	0.31	0.37	[H]
7.	Time Constant	5	6.7	6.5	7.6	7.2	10.1	8.4	11.4	[ms]
Physical										
8.	Mass	16.5	23	23	31	28	37	45	54	[g]
9.	Dimensions [H x W x L]	10.5x 10.5x 47	10.5x 10.5x 59	10.5x 10.5x 59	10.5x 10.5x 77	10.5x 10.5x 92	10.5x 10.5x 92	13.0x 13.0x 122	13.0x 13.0x 152	[mm]
Qualification Level										
10.	Random Vibration	14.16								g RMS
11.	Thermal Vacuum	-20 to 80								°C
12.	Thermal Cold & Hot Start	-35 to 70								°C
13.	Radiation	24								kRad



## 3 Electrical Interface

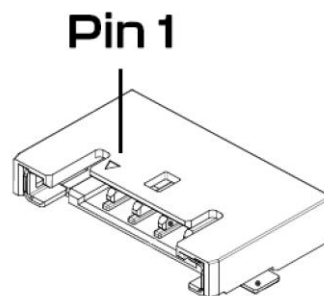
### 3.1 Connector

All CubeTorquer sizes use a 2-way Molex Picolock connector (Mfr Part: 503763-0291). Figure 1 shows an image of CubeTorquer CR0002 with the connector. Please refer to [\[1\]](#) for more information on the Molex Picolock series connectors, and all resources available for it.



*Figure 1: CubeTorquer Molex connector*

The connectors have a triangular marker at pin 1, as illustrated in Figure 2.



*Figure 2: Pin 1 marker on Picolock connector*

The pin assignments of the connector are shown in Table 2.

*Table 2: CubeTorquer connector pin assignments*

Pin Number	Pin Name
1	V+
2	V-



## 3.2 Polarity

Applying a positive voltage on Pin V+ relative to Pin V-, will cause current to flow into pin 1: V+ and out of pin 2: V-, and will generate a magnetic moment in the Z+ coordinate direction as illustrated in Figure 3. The coordinate system is defined in Figure 7, in Section 4.3.

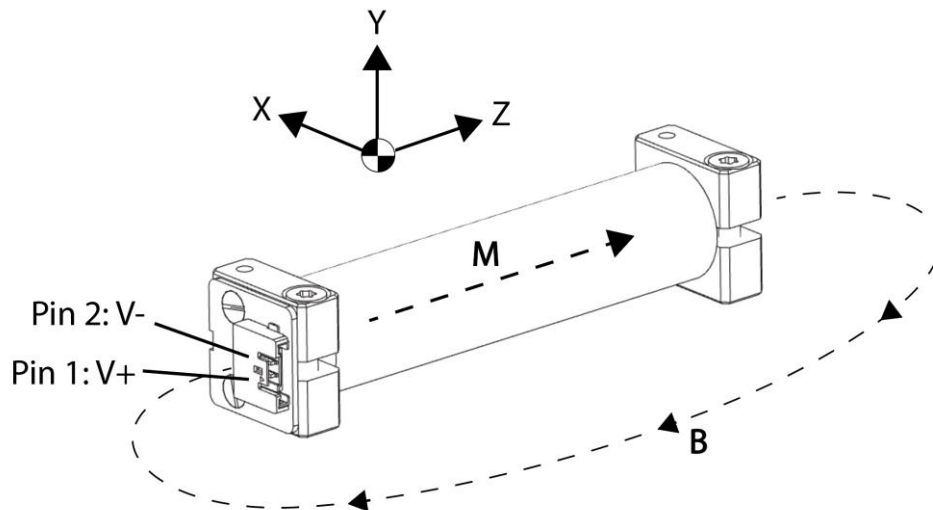


Figure 3: CubeTorquer magnetic moment polarity

## 3.3 Electrical Model

CubeTorquer can be modelled as a resistor and inductor connected in series. The full theoretical model of a magnetic torquer includes both an electric- and magnetic resistance and inductance, but for rods of the sizes in the CubeTorquer range, the simplified model is sufficiently accurate. The simplified model is illustrated in Figure 4.

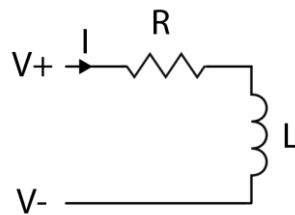


Figure 4: Electrical model of torquer rod

The R and L values for the various sizes rods can be found in Table 1. As expected for an R-L series combination, a torquer rod has a time constant ( $\tau = L/R$ ), also shown in Table 1.





## 4 Mechanical Interface

### 4.1 Dimensions, Mounting Holes, and Connector Placement

All CubeTorquers have the same basic layout as shown in Figure 5. The torquers are composed of two aluminium mounting brackets on either end of a magnetic core over which copper wire is wound. The copper windings are finally protected with non-outgassing black Kapton tape. Each torquer is equipped with a 2-pin Molex Pico-Lock connector for electrical interfacing. The physical size and mounting points for the various CubeTorquers are given in Table 3, where measurements correspond to the dimension definitions in Figure 5. CubeTorquers can be mounted on three of the four sides of the square mounting brackets. Please note that each mounting bracket contains a potted screw that holds the bracket onto the core. This screw should never be removed.

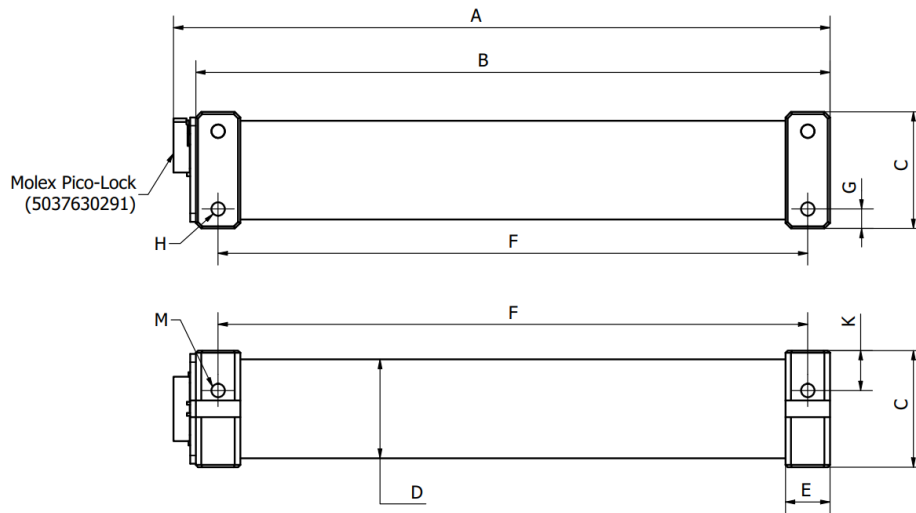


Figure 5: Indicative dimensions of CubeTorquer

Table 3: CubeTorquer dimensions for each variant

Model	A (mm)	B (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)	H	K (mm)	M	
CR0002	47.0	45.0±0.2	10.5±0.1	9.3	4.0	41.0	1.75±0.05	M1.6x0.35 Through hole	3.60±0.05	M1.6x0.35 3.2 Deep	
CR0003	59.0	57.0±0.2		9.3		53.0					
CR0004	59.0	57.0±0.2		9.0		53.0					
CR0006	77.0	75.0±0.2		9.1		71.0					
CR0008	92.0	90±0.2		8.4		86.0					
CR0010	92.0	90±0.2		8.4		86.0					
CR0012	122.0	120.0±0.3	13.0±0.1	8.3	5.0	115.0			4.8±0.05		
CR0020	152.0	150.0±0.3		8.0		145.0					



## 4.2 Placement of CubeTorquers in a satellite

Magnetic torque rods must be placed strategically inside the satellite to ensure that neighbouring rods do not interfere with each other. Figure 6 shows some valid and invalid placement options of two rods with respect to each other. Each combination of two rods within the set of 3 rods must adhere to these placement rules.

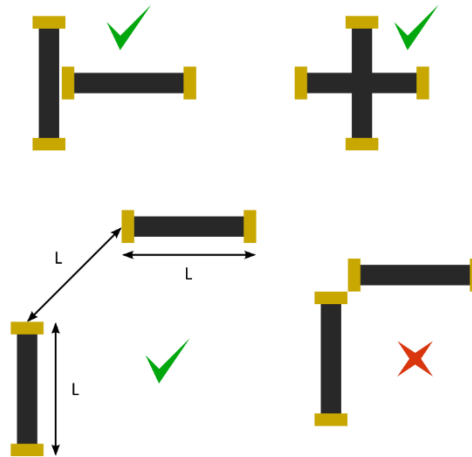


Figure 6: Placement of CubeTorquers with respect to each other

## 4.3 Coordinate System

The coordinate system for CubeTorquer is illustrated in Figure 7. The centre of mass of the rod can be assumed to be at the centre of volume, due to the symmetry of the heavy mechanical components, and the low mass of the connector and PCB. If a more accurate model is required, this can be requested from CubeSpace.

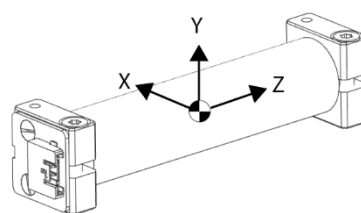


Figure 7: Coordinate definition of CubeTorquer



## 5 Materials used

Table 4 shows the materials used in CubeTorquers.

*Table 4: Materials used in CubeTorquer*

Part	Material
Covering	Polyamide with Acrylic adhesive (Black Kapton tape)
Epoxy	EC 2216
Copper Wire	Polyesterimide Enamel Coating
PCB	High Temp FR4
Solder	60EN (60%Tin, 40% Lead)
Solder Mask	CARAPACE EMP110 / PSR-4000 BLUE
Connector	High Temperature Thermoplastic
Brackets	Alodined Aluminium 6082 T6
Screws	A4 Stainless Steel (316)