Attitude Determination and Control System with Variable-Speed Single-Gimbal Control Moment Gyroscopes for Nanosatellites

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Abstract

This paper presents a novel Attitude Determination and Control System (ADCS) utilizing Variable-Speed Control Moment Gyroscopes (VSCMG) tailored explicitly for nanosatellites. The VSCMG was realized by spherical motor technology, in which a patented magnetic field design controls the inner rotor and gimbal. Because of the characteristics of the control moment gyroscope, the proposed ADCS offers improved attitude maneuverability and reduced power consumption, addressing the limitations of traditional ADCS solutions for nanosatellites. Furthermore, the adoption of spherical motor technology shrinks the VSCMG into a smaller form factor, which allows the VSCMG to be fitted into a nanosatellite. This research paper introduces the specifications of the integrated ADCS family based on VSCMG, as well as the components used in the system.

ADCS-10m Integrated ADCS with CMG

ADCS-10m is a highly self-contained configuration designed for 3 to 6U nanosatellites with one tuna-can, which utilizes one VSCMG for attitude control. The compact design allows for easy integration and improved volume utilization, requiring only 0.2U of volume within the satellite structure and one tuna-can for the VSCMG. Figure 1 presents the photograph of the ADCS-10m, while Table 1 shows its specifications.

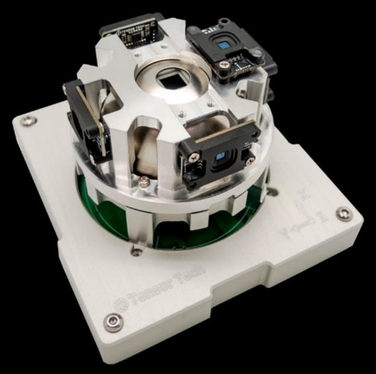

Fig. 1. Photograph of the ADCS-10m module.

Table 1. The specification of the ADCS-10m

Parameter	Description	Typ.	Max.	Unit
Mass	Total mass		450	grams
Length		91.7		mm
Width	Including CMG, MCB, and MTQ	86.0		mm
Height		51.4		mm
Volume	Installed within the satellite structure		0.5	U
	Installed at tuna-can		0.2	
Pointing accuracy		1		deg
Current	5V bus	0.25	0.8	A
	3.3V bus	0.3	0.6	
	5V bus inrush current in 100 μs	0.04	0.1	
	3.3V bus inrush current in 400 μs	0.4	1	
Angular momentum storage			10	mNms
Torque	Output torque		1	mNm^2
Slew rate	3U or smaller		10	deg/s
	6U		5	
Magnetic dipole moment	Generate by MTQ on the x/y-axis		0.2	Am^2
	Generate by MTQ on the z-axis		0.1	

ADCS-20m & ADCS-40m Integrated ADCS

ADCS-20m is an optimized configuration designed for 6 to 12U nanosatellites, utilizing two tuna-cans and incorporating two Variable-Speed Control Moment Gyroscopes (VSCMG) in a modified scissored-pair configuration. This configuration offers a higher angular momentum storage capability compared to the ADCS-10m. Along with the volume utilization inside the tuna-cans, it requires the installation of a main control board, three Magnetorquer (MTQ) rods, and sun sensors. On the other hand, ADCS-40m employs four VSCMG to maximize momentum storage and output torque, forming a modified pyramid cluster CMG configuration. This configuration is specifically designed for 12U nanosatellites or larger microsatellites. It is important to note that the ADCS-10m, ADCS-20m, and ADCS-40m modules can be installed either within the deployer's tuna-can, optimizing volume utilization for most nanosatellites, or within the satellite structure, depending on the mission requirements.

ADCS-MTQ Integrated ADCS driven by Three-Axis Magnetorquers

Despite not using VSCMGs for attitude control, it is worth noting that the main control board of ADCS is capable of solely driving the MTQs to present an MTQ-based ADCS, which is a minimal configuration for less than 3U nanosatellite that requires sun-pointing and de-tumbling capabilities as shown in Figure 2.

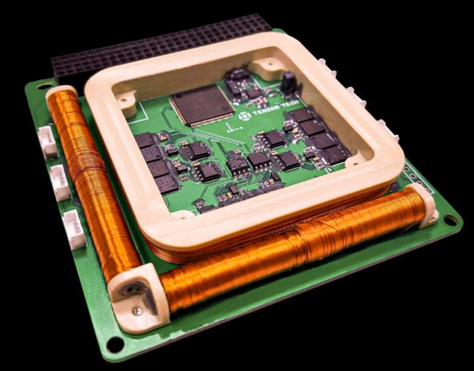

Fig. 2. Photograph of the ADCS-MTQ module.

Conclusion

The Variable-Speed Control Moment Gyroscope (VSCMG) presents a promising hybrid actuator solution for spacecraft attitude control. Combining the features of reaction wheels (RWs) and Control Moment Gyroscopes (CMGs) and minimizing them with spherical motor technology, the VSCMG offers enhanced control flexibility, improved performance, and reduced singularity concerns. Moreover, the complete ADCS product family offers the attitude sensors and the embedded control firmware, allowing the user to adopt the VSCMG technology easily without the need to develop their own control algorithms.