Datasheet for TensorADCS-10m and TensorADCS-10m-D

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Date	06/2025
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Approved By	T. Yen, S. Lee

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List of Abbreviations

ADCS	Satellite Attitude Determination and Control System
ADCS-MCB	ADCS Main Control Board
FOV	Field Of View
GEVS	General Environmental Verification Standard
IMU	Inertial Measurement Unit
LEO	Low Earth Orbit
MTQ	Magnetorquer / Magnetic Torquer
OBC	Onboard Computer on a satellite
PCB	Printed Circuit Board
RPM	Revolution per Minute
SWaP	Size, Weight, and Power Consumption
TLE	Two-Line Element
VSCMG	Variable-speed Single-gimbal Control Moment Gyroscope

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1. OVERVIEW

TensorADCS series represents an extensive range of **Attitude Determination and Control Systems (ADCS)** for nano and microsatellite missions. Central to our design is a **Variable-speed, Single-gimbal Control Moment Gyroscope (VSCMG)**, enhancing the system's torque-to-power ratio. Our user-intuitive interfaces, onboard attitude determination, and automated modes ensure streamlined satellite operations. Whether for earth observation or precise maneuvering, TensorADCS series provides enhanced agility for mission success. Custom configurations are available upon consultation for specialized needs.

- TensorADCS-10m

TensorADCS-10m is our flagship ADCS model, with proven flight heritage since 2022. This highly self-contained system features an optimized single tuna can configuration, requiring merely 0.25U of satellite volume while incorporating a comprehensive suite of components: one **ADCS-Main Control Board (ADCS-MCB)**, six TensorFSS-15M Fine Sun Sensors, and one integrated Control Moment Gyroscope (CMG) model, TensorCMG-10m-N.

- TensorADCS-10m-D

TensorADCS-10m-D is our versatile ADCS-10m solution, specifically designed for flexibility and ease of integration across a wide range of satellite configurations. This model includes one ADCS-MCB, six TensorFSS-15M Fine Sun Sensors, one TensorCMG-10m-S (CMG with embedded skew-angle), and an external driving module, DMCMG-10m. The built-in skew-angle configuration simplifies the satellite design process, making it ideal for customers requiring customized angular mounting setups.

Table 1-1. Part List of TensorADCS-10m Series

Model	TensorADCS-10m	TensorADCS-10m-D
Component	QTY	QTY
ADCS-MCB	1	1
TensorMTQ-200m (integrated with ADCS-MCB)	2	2
Air-Coil (integrated with ADCS-MCB)	1	1
TensorCMG-10m-N	1	0
TensorCMG-10m-S/SF/V/VF	0	1
DMCMG-10m	0	1
TensorFSS-15M	6	6
GNSS receiver	Optional	Optional
Star tracker	Optional	Optional

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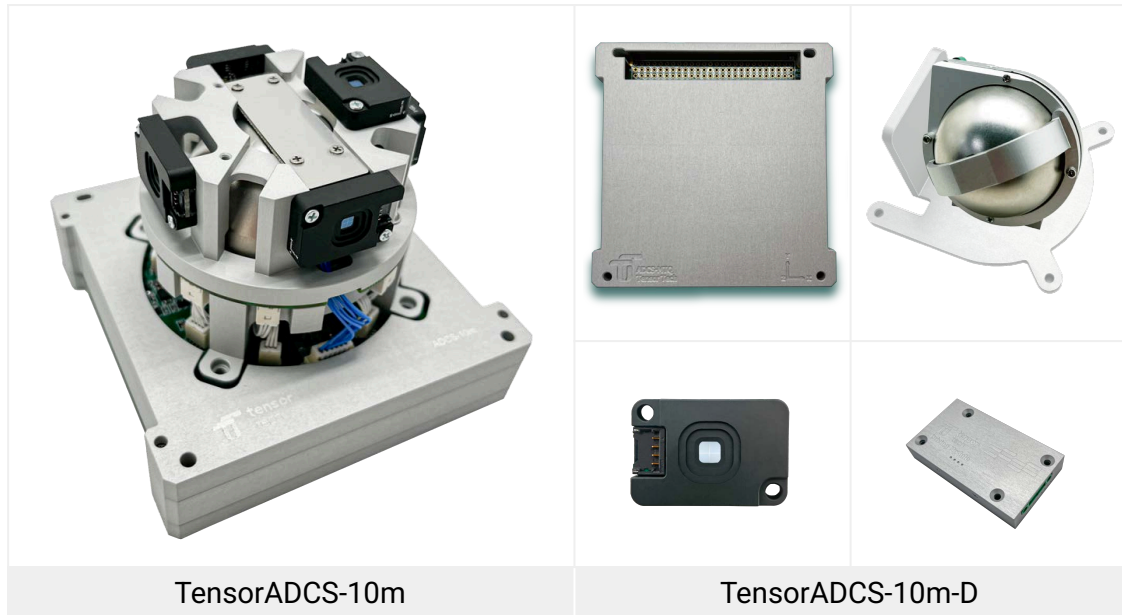
1

| TensorADCS-10m | TensorADCS-10m-D |

Figure 1-1. TensorADCS-10m and TensorADCS-10m-D

TensorADCS-10m and TensorADCS-10m-D utilize two distinct CMG configurations. The standard TensorADCS-10m, our compact integrated ADCS, is exclusively compatible with one TensorCMG-10m-N unit. Meanwhile, the enhanced TensorADCS-10m-D, our versatile ADCS solution, operates solely with one TensorCMG-10m-S unit for optimal performance.

- **TensorCMG-10m-N**

  TensorCMG-10m-N is optimized for integration within standard satellite frames or tuna-can spaces. This configuration provides a compact yet powerful solution, ideal for tightly constrained satellite architectures.

- **TensorCMG-10m-S/V**

  Designed for maximum adaptability, TensorCMG-10m-S/V incorporates a predefined skew angle to streamline mounting across various satellite structural designs. Its integrated skew configuration significantly reduces complexity and enhances integration flexibility.

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2. APPLICATIONS and FEATURES

2.1 Applications

- Attitude Determination and Control
- Guidance and Navigation

2.2 Features

Highly Integrated
- Minimum external component required
- Compact hardware design fit in tuna can

Modularize and Flexible
- Multiple modes for most satellite applications
- Configurable hardware for balanced Size, Weight, and Power Consumption (SWaP)
- Dual communication interfaces, including RS-485 and UART

Robust
- Fault detection and error handling
- Environment tests follow NASA General Environmental Verification Standard (GEVS)
- Factory-calibrated and quality-controlled

Ship with Support Software
- Firmware update
- Parameter setting
- Testing and health check

Flight Proven

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3. SPECIFICATIONS

3.1 Common Specifications

Parameter	Description	Min	Typ	Max	Unit
Pointing Knowledge	Standard Configuration at Sunlit	-	0.3	-	deg
	Configuration with Star Tracker[1]	-	2 or 3	-	arcsec
	Control Accuracy	-	0.4	-	deg
Voltage	V_{BAT} Bus, operating	6	8	14	V
Power	V_{BAT} = 6V, steady state at TensorCMG, Ω = 3000RPM, τ_s = 0	-	0.83	-	W
	V_{BAT} = 6V, maximum power at transient[2]	-	-	5.36	
Inrush Current	V_{BAT} Bus at motor max command, within 300us	-	0.68	-	A
Angular Momentum Storage (on x,y-axis)		-	-	13	mNms
Torque	Output Torque	-	-	1	mNm
Slew Rate		5	-	-	deg/s
Magnetic Dipole Moment	Generate by MTQ-200m on X/Y Axis	-	-	0.2	Am^2
	Generate by air coil on Z Axis	-	-	0.1	
Temperature	Non-operational (survival range when power-off)	-40	-	85	°C
	Operational (allowable flight temperature, AFT)	-25	-	70	
Rotor Speed	Operating TensorCMG-10m Inner Rotor Speed	2000	-	8000	RPM
Random Vibration Susceptibility, 20-2000 Hz		-	14	-	Grms
CMG-10m Rotor Speed Error		-	-	0.5	%

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[1] Typical value, performance might vary according to the configuration selected.
[2] The CMG operates at τ_s = 0.9 mNm, wheel momentum = 14.2 mNm-s, Ω = 10500RPM, τ_t = 16.3 mNm, and $\dot{\gamma}$ = 28.98 RPM

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Parameter	Description	Min	Typ	Max	Unit
CMG-10m Gimbal Angle Error		-	0.5	-	deg
Update Rate		-	-	10	Hz
Radiation Hardness (Si)		-	24	-	krad

- Communication Interface: RS485 and UART
- PCB Production Standard: IPC-6012C Class 3
- PCB Assembly Standard: IPC-A-610 Class 3
- Static and Dynamic imbalance of the rotor: ISO1940 G0.4 calibration to the rotor of the CMG
- Design Life : 3 years in Low Earth Orbit (LEO)

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3.2 TensorADCS-10m

Parameter	Description	Min	Typ	Max	Unit
Mass	Total mass	-	495	-	gram
Length	Dimensions	92[3]	94[4]	-	mm
Width		86.5[1]	92[2]	-	mm
Height		70[1]	73.5[2]	-	mm
Volume	Installed inside satellite	-	-	0.7	U
	Installed at tuna can	-	-	0.25	

3.3 TensorADCS-10m-D

Parameter	Description	Min	Typ	Max	Unit
Mass	with 1 x TensorCMG-10m-S	-	485	-	gram
	with 1x TensorCMG-10m-SF	-	500	-	
Volume	Configuration dependent, see ICD and CAD for details				

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[3] Dimension without radiation protection shroud
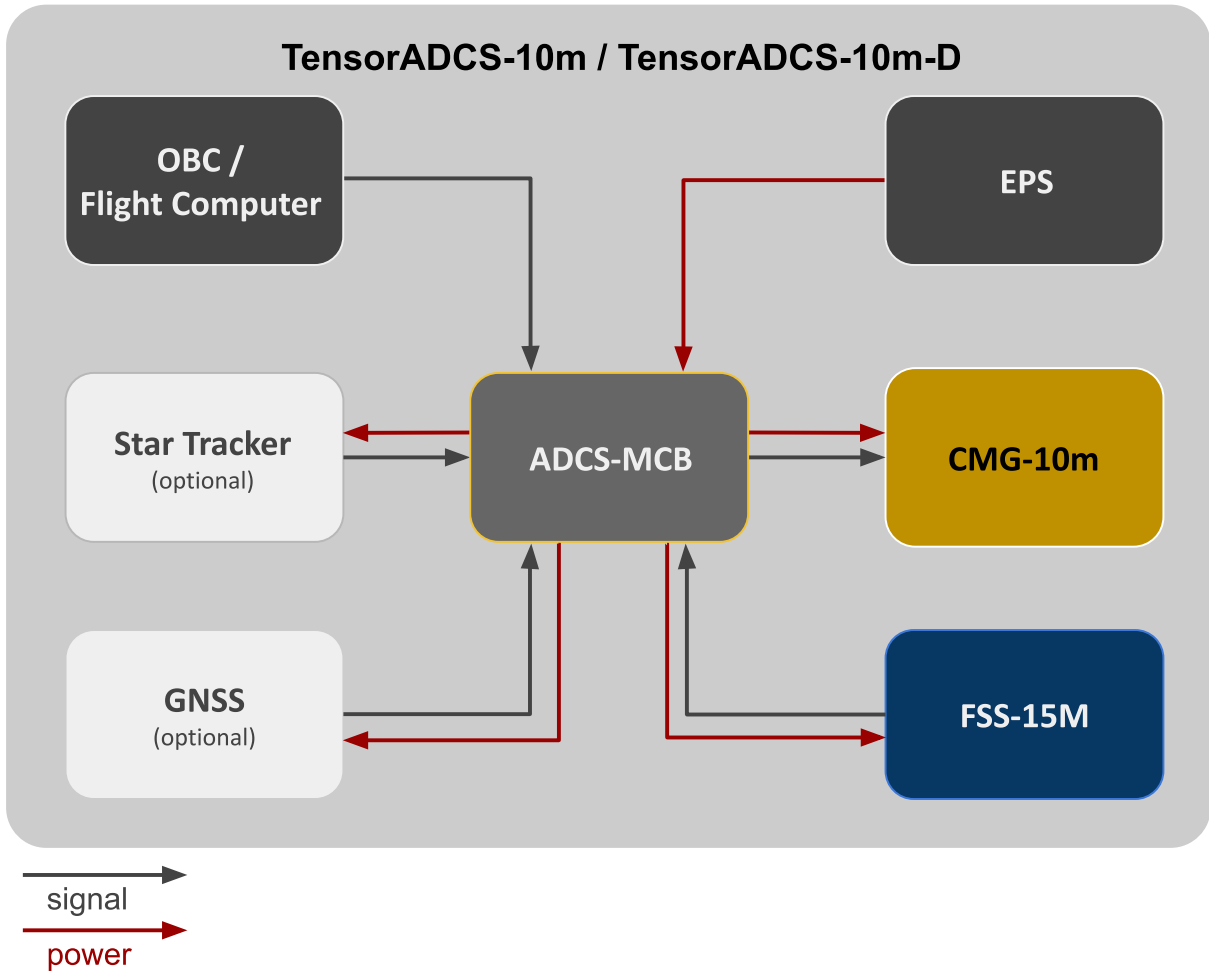[4] Dimension with radiation protection shroud

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3.4 Block Diagram

Figure 3-1. Standard Configuration Diagram of TensorADCS-10m
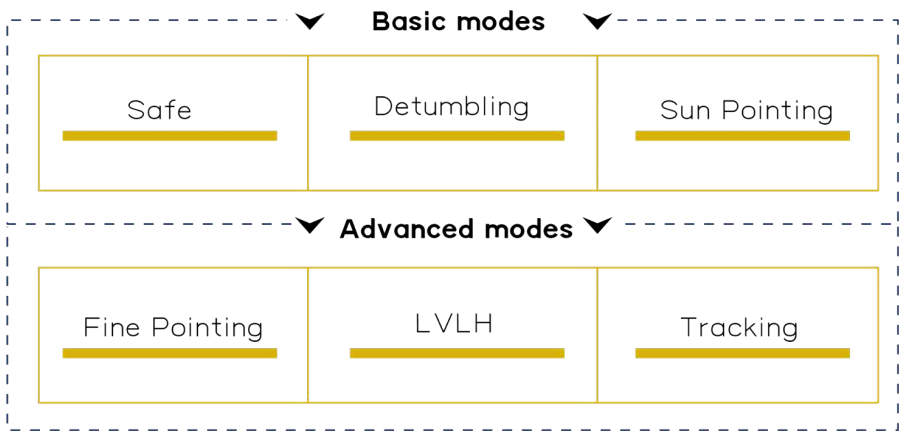
Figure 3-2. Operating Modes of TensorADCS-10m

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4. PARTS

4.1 ADCS-MCB

ADCS-MCB serves as the primary control computer for attitude estimation, control, and communication. It is diversely compatible with all Tensor Tech nanosatellite products and selected third-party components through a straightforward register-based interface. The On-Board Computer (OBC) primarily undergoes mode transitions to effectively execute its mission on orbit, establishing ADCS-MCB as a robust offloading engine.

Figure 4-1. ADCS-MCB

ADCS-MCB is integrated with an **Inertial Measurement Unit (IMU)** for rate measurement, temperature sensor, and magnetorquer driver.

In standard ADCS configurations, the integrated control algorithms consist of tumbling handling, attitude controller, steering controller for VSCMG, **Extended Kalman Filter (EKF)**-based estimator, fault detection, and fault handling.

Incorporating the GNSS receiver as the optional module, the OBC can access the information at the current position and time from the ADCS-MCB by connecting the GNSS antenna with the IPEX connector. In advanced mode operations, the data of positioning and timing is essential for ADCS-MCB, except for TensorADCS-MTQ configuration. The user is required to update the GNSS or **Two-Line Element (TLE)** data, along with time information, through their OBC in the absence of selecting the GNSS module provided by Tensor Tech. The ADCS parses the data of positioning and timing from the raw string, subsequently updating its estimator.

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4.2 TensorCMG-10m

TensorCMG-10m serves as the primary attitude actuator for precise pointing with high slew rates. The design of TensorCMG series offers the optimized solution for satellite ADCS performance in terms of weight, volume, and power consumption. TensorCMG-10m is designed to fit in a tuna can, providing the best volume utilization for most nanosatellites. Static and dynamic imbalance calibration of TensorCMG-10m rotor adheres to ISO1940 G0.4 standards.

$$\tau_s = I_s \dot{\omega}_s$$

$$\tau_t = I_s \omega_g \omega_s$$
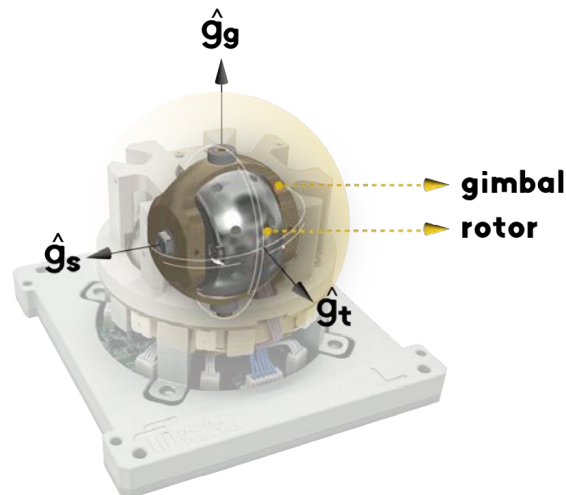
$$\tau_g = I_g \dot{\omega}_g$$

Figure 4-2. Simplified System Dynamics of CMG and the Definition of the Gimbal Frame

As shown in Figure 4-2, TensorCMG-10m is a Variable-speed, Single-gimbal CMG (VSCMG) boasting enhanced SWaP performance over conventional CMGs. This advantage is attributed to the utilization of spherical motor technology.

To understand the system dynamics of a CMG, simplified torque output formulas are illustrated in Figure 4-2. The $\hat{g}_s$, $\hat{g}_t$, and $\hat{g}_g$ axes are attached to the motor gimbal (the brown component) and controlled to spin in the $\hat{g}_s$ -direction. The $\hat{g}_g$ -axis is the tilting axis; the $\hat{g}_s$ -axis is referred to as the inner rotor rotational axis, and the speed upon $\hat{g}_s$ -axis is the inner rotor speed.

The control algorithm inside TensorADCS-10m utilizes 2 axes torque, τ_s and τ_t , in TensorCMG-10m. The CMG controls the satellite's attitude on the xy-plane, while magnetorquers are used for the z-axis attitude control.

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4.2.1 TensorCMG-10m-N

Integrated within either a tuna-can space or a standard satellite frame (as shown in Figure 4-3), TensorCMG-10m-N integrated in TensorADCS-10m is equipped with a high magnetic permeability shell to prevent magnetic interference. The rotor undergoes strict dynamic unbalance calibration in line with ISO1940 G0.4. While TensorCMG-10m-N does not include 3-axis magnetorquers, Tensor Tech recommends and provides them for comprehensive attitude control.
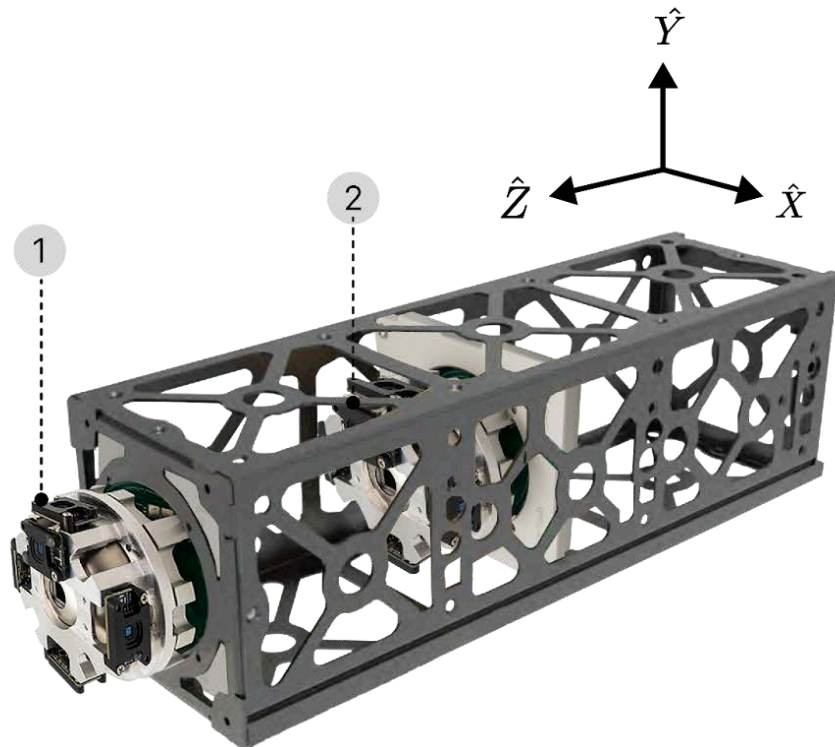

Figure 4-3. Installation Suggestions (Configuration 1 and Configuration 2) of TensorADCS-10m and the Definition of Satellite Frame (black arrows)

4.2.2 TensorCMG-10m-S/V/SF/VF

TensorCMG-10m-S/V is designed for versatility, enabling seamless integration into satellite structures of various configurations. It offers two main configurations: a skew version featuring an embedded skew angle, TensorCMG-10m-S, and a vertical mounting version for standard installation, TensorCMG-10m-V for the control moment gyroscope, optimized for easy mounting within diverse satellite designs.

TensorCMG-10m-S/V offers innovative control moment gyroscope technology with separated mechanics and electronics, optimized for seamless CMG cluster integration.

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| TensorCMG-10m-S | TensorCMG-10m-V |

Figure 4-4. TensorCMG-10m-S and TensorCMG-10m-V

TensorCMG-10m-S/V also provides one variant model called TensorCMG-10m-SF/VF, which includes the TensorFSS-15M mounting bracket if you select to have the FSS units pre-mounted with the CMG by the factory.

Table 4-5. Features of TensorCMG-10m-S/SF

Model	Feature (Y: Equipped, N: Not Equipped)		
	skewed mechanical interface	DMCMG-10m	FSS mounting bracket
TensorCMG-10m-S	Y	Y	N
TensorCMG-10m-SF	Y	Y	Y
TensorCMG-10m-V	N	Y	N
TensorC<G-10m-VF	N	Y	Y

DMCMG-10m (Driving Module) is designed to work in tandem with TensorCMG-10m-S/V/SF/VF, forming a critical paired system. TensorCMG-10m and DMCMG-10m must be integrated into the satellite or spacecraft system to ensure proper functionality.

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Figure 4-5. DMCMG-10m

4.3 Magnetorquer (MTQ)

Figure 4-6. TensorMTQ-200m installed on ADCS-MCB

TensorMTQ series are 3-axis magnetorquers with features of de-tumbling, de-saturation, and serving as backups for CMG failures. TensorMTQ-200m is directly mounted on ADCS-MCB. The resultant torque allows the satellite to rotate precisely around one or more of its axes, facilitating accurate attitude control.

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4.4 TensorFSS-15M

Figure 4-7. TensorFSS-15M

TensorADCS-10m series incorporates six Fine Sun Sensors, TensorFSS-15M, units with complete cable assemblies for precise attitude determination. Each TensorFSS-15M provides dual-axis sun angle measurement capabilities. For detailed TensorFSS specifications, please consult the dedicated TensorFSS-15M datasheet.

Mounting Configurations
Configuration 1: Integrated Assembly
Direct FSS integration within the CMG tuna can housing (See Figure 4-3)
> Benefits:
> - Enhanced Field of View (FOV) coverage
> - Minimized cable harness requirements

Configuration 2: Distributed Placement
Recommended placement of five TensorFSS-15M units on user-specified spacecraft structural surfaces
> Optimal placement guidelines:
> - Mount sensors across six CubeSat faces
> - Ensure partial **FOV (Field of View)** overlap between adjacent sensors
> - Maintain complete 4π steradian coverage

While standard-length cables (P/N: E1302002) are supplied, the user may have to make adjustments to ensure that the cables fit perfectly in their satellite.

4.5 Magnetometer

TensorFSS-15M features configuration magnetometer functionality. When implementing this function, proper installation planning is essential for integration with ADCS-MCB.

Installation Requirements
1. Placement Considerations
   - Select appropriate structural location for TensorFSS-15M installation
   - The installed location of TensorFSS-15M with magnetometer function must be positioned at least **10 cm away** from sources of magnetic interference, such as TensorCMG units, motors, and high-current wiring harnesses.
   - Establish proper communication routing to ADCS-MCB
2. Environmental Precautions, avoid proximity to:

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- Areas of residual magnetic fields
- Materials with high magnetic permeability
- High-current conducting paths

Magnetic Field Characteristics
- The maximum magnitude of the leakage magnetic flux density of ± 3 μT can be detected by the magnetic probe if it is placed **10 cm away** from the TensorCMG-10m.
- The frequency of this leakage magnetic flux density depends on the inner rotor speed, which ranges from 33Hz (2000 rpm) to 133Hz (8000 rpm).

Signal Processing
- ADCS-MCB provides integrated magnetic interference filtering
- Additional filtering may be required for magnetically sensitive payloads

Note: The user must implement appropriate filtering solutions for any auxiliary payloads sensitive to the specified magnetic field levels.

5. ENVIRONMENTAL TEST

Table 5-1. Environmental Test Summary for TensorADCS-10m

	QM	EM	FM
CPT	●	●	●
TID Radiation Test[5]	●	-	-
SEE Radiation Test[6]	●	-	-
Sine Vibration (SV) Test	●	-	-
Random Vibration Test	●	-	●
Thermal Cycling Test[7]	-	-	●
Thermal Vacuum Cycling Test	●	-	-

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[5] For TID and SEE tests, LPT is executed while the DUT is exposed to radiation.
[6] SEE tests on critical electronic components only, including MCU, motor driver, current sensors, etc.
[7] LPT is executed in every hot/cold plateau.

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REVISION HISTORY

Date	Editor	Version	Contents
2023.08.10	S. Lee, Z. Liu	1.0.0	Initial release, update all chapters.
2023.09.27	T. Yen	1.0.1	Revise the descriptions of the usages of the product
2023.10.02	T. Yen	1.0.2	Revise the style of the document and add a list of abbreviations
2023.10.11	A. Huang	1.0.3	Change the package of ADCS-MTQ Suite to: 1. one ADCS-MCB with MTQ1 2. one FSS-15M
2023.10.12	T. Yen	1.0.4	Modify the description of the dimension of ADCS-10m by excluding the ADCS-MCB. Also updating Figure 3-1 and Figure 3-2 for a clearer definition of the gimbal frame.
2023.10.19 | 2024.03.26	T. Yen, A. Huang, D. Hsieh, Z. Liu	1.0.5a | 1.0.5g	1. Added updated placement suggestion for FSS-15M and CMG-10m magnetic flux leakage note. 2. Updated with latest MTQ model information. 3. Introduced the new 4-digit document revision naming rule. 4. Applied 4-digit revision policy for technical documents. 5. Corrected ADCS-40m EXT TQR typical wiring diagram. 6. Updated GNSS size details. 7. Revised ADCS-MTQ wiring diagram. 8. Updated TID radiation test results; changed copyright to 2024. 9. Updated common specs in Table 3-1 and ADCS-10m specs in Table 3-2. 10. Merged Sections 1 (Applications) and 2 (Features); sections now span 1 to 4.
2024.05.21 | 2024.02.23	A. Huang, D. Hsieh, C. Hu	1.0.6a | 1.0.6c	1. Revised content for ADCS-10m and ADCS-20m/40m-Discrete only, and take out the content of ADCS-MTQ, ADCS-20m/40m-Integrated content. ADCS-MTQ will have a separate datasheet. 2. Renamed all product references from ADCS to TensorADCS across documentation. 3. Separated TensorADCS-10m into its own datasheet; TensorADCS-20m/40m-Discrete will have a separate datasheet. 4. Updated Figure 3-1 – Simplified system dynamics and gimbal frame definition. 5. Revised Sections 3.5 and 3.6 for FSS description. 6. Updated Table 4-1 – Environmental tests summary.

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2025.02.24	A. Huang	1.1.0a	Replace existing fine sun sensor content with updated TensorFSS-15M V2.0 specifications and features.
2025.03.10	D. Hsieh, A. Huang	1.1.0b	Update Figures 3-1 and 3-3
2025.03.11	H. Cheng, C. Hu, A. Huang	1.1.0c	Revised minimum clearance requirement between TensorFSS-15M (with magnetometer functionality) and CMG unit to 20 cm to prevent interference in Section 2.2.
2025.03.25	S. Lee, A. Huang	1.1.0d	Update the minimum distance requirement between the TensorFSS-15M (with magnetometer functionality) and sources of magnetic interference to 10 cm to prevent signal disruption.
2025.05.09	T. Yen, Z. Liu, C. Hu, C. Huang, A. Huang	1.2.0a	1. Added material for new variant model TensorADCS-10m-D and renamed as Datasheet for TensorADCS-10m and TensorADCS-10m-D 2. Updated information (voltage, current, power) in Table 3-1. 3. Inserted Overview as Section 1 and renumbered subsequent sections. 4. Updated the block diagram in Figure 3-1.
2025.05.23	A. Huang	1.2.0b	1. Updated the TensorCMG-10m-S product photo 2. Corrected and aligned the font of "Inrush Current"
2025.06.10	C. Hu, A. Huang	1.2.1a	Updated environmental test specifications for FM models.

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