APPLICATION		REVISIONS			
NEXT ASSY	USED ON	LTR	DESCRIPTION	DATE	APPROVED
-	68904934-BA60	B	SEE ECN-6116295	2022-02-09	KJE/MTA

REVISION STATUS OF SHEET 1 APPLICABLE TO ALL SHEETS

THIRD ANGLE PROJECTION	DRAFTER	L. PRIEBE	2020/07/28
	CHECKER	D. PFEIFER	2020/07/28
	DEV ENGR	D. HORKHEIMER	2020/07/28
UNLESS NOTED OTHERWISE	ENGRG MGT	C. VISKER	2020/07/28
DIMENSIONS ARE IN INCHES TOLERANCES ON: ∠ ± - .XX ± - .XXX ± -	CONTRACT NO. HONEYWELL FUNDED		
MATERIAL -			

Honeywell

HONEYWELL INTERNATIONAL INC.
AEROSPACE – Minneapolis, MN USA

PRODUCT SPECIFICATION 68904934-BA60 RATE SENSOR

SIZE	CAGE CODE	DRAWING NUMBER	
A	94580	DS36134-60	
SCALE NONE	WT -	SHEET 1 OF 54	

MSWORD

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1. Scope

This specification establishes the requirements and operational guidelines for the 68904934-BA60 Rate Sensor Unit (RS).

2. Applicable Documents

The following documents of the exact issue shown form a part of this specification to the extent specified in the applicable paragraphs. In case of conflict, this specification has precedence.

2.1. Non-Honeywell Documents

Document Number	Document Title
ANSI/ESD S20.20	Standard for the Development of Electrostatic Discharge Control Program
IPC/J-STD-001	Requirements for Soldered Electrical and Electronic Assemblies
ANSI/TIA/EIA-422-B	Electrical Characteristics of Balanced Voltage Differential Interface Circuits
ASTM D3951	Standard Practice for Commercial Packaging
ASTM E595-15	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
DO-160D	Environmental Conditions and Test Procedures for Airborne Equipment
ECSS-E-ST-20-06C	Space Engineering - Spacecraft Charging
ECSS-Q-ST-60-15C	Radiation Hardness Assurance – EEE components
IPC-4101	Specification for Base Materials for Rigid and Multilayer Printed Boards
ISO-9001	Quality Management
MIL-HDBK-814	Ionizing Dose and Neutron Hardness Assurance Guidelines for Microcircuits and Semiconductor Devices
MIL-STD-461F	Department of Defense Interface Standard: Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-810E	Environmental Engineering Considerations and Laboratory Tests
MIL-STD-882	Department of Defense Standard Practice System Safety
NASA-HDBK-4002A	Mitigating In-Space Charging Effects - A Guideline
NASA-HDBK-4006	Low Earth Orbit Spacecraft Charging Design Handbook
NASA-STD-6016 Rev A	Standard Materials and Processes Requirements for Spacecraft

2.2. Honeywell Documents

Document Number	Document Title
68904934	HG4934 Installation Drawing
DS36031-01	Block E Systems Requirements and Design Document
HAQM	Honeywell Aerospace Quality Manual
2.1.3.G.R&CE101PSMP	DSES Minneapolis Part Selection and Management Plan (PSMP)

Document Number	Document Title
EB53000249-560	Electrical, Electronic, Electro-optical & Electromechanical (EEEE) Parts Control Plan (PCP) for Commercial Space Programs
2.3.2.W.R&CE207OSHA	Operating and Support Hazard Analysis
2.3.2.W.R&CE202Derate	Parts Derating
2.1.3.W.R&CE107Uprating	Part Uprating
2.3.2.W.R&CE208Stress	Parts Stress Analysis
2.3.2.W.R&CE201BIT	Built-In-Test Effectiveness Analysis
2.3.2.W.R&CE204FMECA	Failure Mode, Effects and Criticality Analysis

3. Requirements

The 68904934-BA60 Space Rate Sensor (RS) is a specific configuration of the common inertial sensor product specified in DS36031-01, characterized by its unique functional and environmental requirements and inertial performance. The following paragraphs establish the unique requirements for the 68904934-BA60 Space Rate Sensor.

In addition, the 68904934-BA60 Space Rate Sensor must satisfy all requirements of DS36031-01 that are applicable to “Commercial RS” configurations intended for use in low Earth polar orbit space applications.

3.1. Item Definition

The 68904934-BA60 is a device which measures angular rates in a body mounted strap down configuration. It provides compensated summed incremental angle for navigation as well as angular rates for control. The data is reported in user defined coordinates through a digital serial interface bus. The unit contains three gyroscopes as well as the electronics and software necessary to implement the requirements specified herein. The input axes form a right handed frame aligned with the Rate Sensor mounting frame. The angular rotation input axes follow the right hand rule.

3.2. Electrical Interface

3.2.1. External System Connector Type and Location

The Rate Sensor’s hardware input/output (I/O) interfaces with the external system shall be through a 14-pin connector. [RS_SRS_10036]

The location and physical dimensions of the external system connector shall be as defined in the Rate Sensor installation drawing. [RS_SRS_10037]

3.2.2. External Connector Pin Assignments

The pin assignments of the external system connector shall be as defined in Table 1 - System Connector Pin Out. [RS_SRS_10039]

Table 1 - System Connector Pin Out

Pin Number	Signal Name	Signal Function
1	DGND	Digital Power and Signal Return
2	+5VDC	+ 5 VDC Power
3	Reserved	Floating (Note 1)
4	Reserved	User No Connect
5	Reserved	User No Connect

Pin Number	Signal Name	Signal Function
6	RESET	Reset Input discrete - Active High (CMOS compatible input)
7	Reserved	User No Connect
8	Reserved	User No Connect
9	SER_DATA_OUT_H	Serial Data High Output (RS-422/485)
10	SER_DATA_OUT_L	Serial Data Low Output (RS-422/485)
11	Reserved	Floating (Note 1)
12	Reserved	Floating (Note 1)
13	Reserved	User No Connect
14	Reserved	User No Connect

Note 1: This pin should be tied to DGND by the user. Internally this pin is floating and not connected to any circuit.

3.2.3. External Electrical Inputs/Outputs

3.2.3.1. Input Power

3.2.3.1.1. Characteristics

Input power requirements are specified in Table 2 - Input Power Requirements. NOTE: Maximum start-up current draw is highly dependent on the rise time of the user's power supplies. The Max Start-up Current Transient value listed in Table 2 - Input Power Requirements is valid only for external power supplies where the rise times are ≥2 ms.

Note: It is recommended that the Rate Sensor be powered up with the RESET Input Discrete applied (logic 1, +3.3V) and then once the external power supply voltage has stabilized within Rate Sensor requirements the RESET Input Discrete can be de-asserted (logic 0, GND).

If the rise time is longer than 75 msec then the application of the RESET Input Discrete upon power up is required until the external power supply voltage has stabilized.

The 5V power application to the Rate Sensor should monotonically increase from 1 to 5 volts to ensure proper Rate Sensor start-up.

Table 2 - Input Power Requirements

Voltage (VDC)	Tolerance	Maximum Ripple (mV p-p)	Max Start-up Current Transient (Amp)	Max Run Current (Amp)	Typical Current (mA)
+5	±10%	50	2	1.1	600

Note: Tolerance is inclusive of the contribution of maximum ripple.

3.2.3.1.2. Power Connection Equivalent Circuits

Figure 1 - +5 VDC Equivalent Circuit represents the equivalent circuit and should be used during the design process to determine actual current sourcing requirements for the system. Rapid rise times on power supplies may cause temporarily excessive current draw due to the nature of the filters present in the Rate Sensor.

Equivalent circuit is given for reference only:

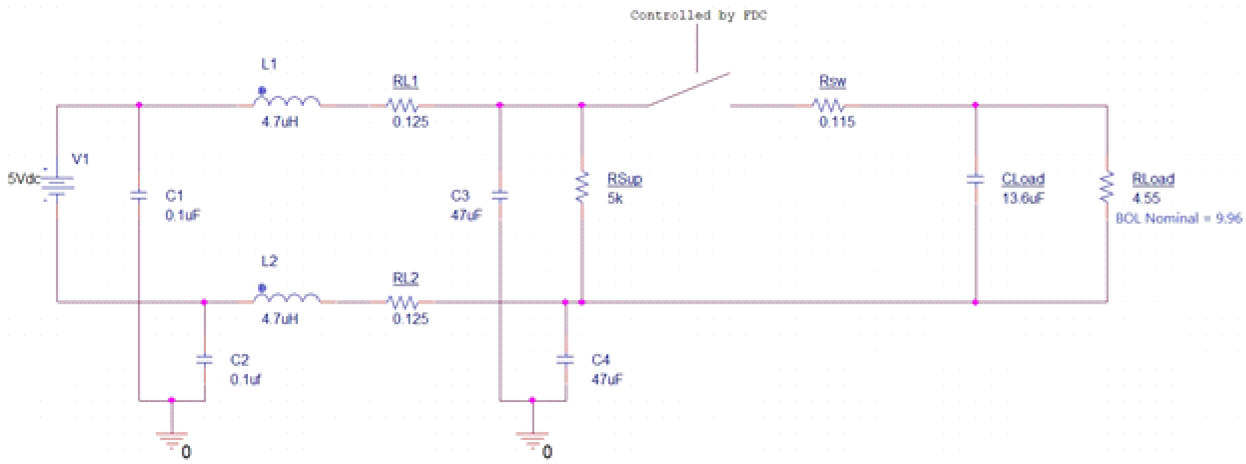


Figure 1 - +5 VDC Equivalent Circuit

To support customer evaluation of this equivalent circuit model, the following worst case tolerances are suggested for components in this model:

Table 3 - Worst Case Component Tolerances

Component	BOL	Temperature	Aging
C1	± 10%	-25%/15%	± 21%
C2	± 10%	-25%/15%	± 21%
C3	± 10%	± 11%	± 10%
C4	± 10%	± 11%	± 10%
L1	± 20%	± 10%	± 1%
L2	± 20%	± 10%	± 1%

Worst case FDC linearly transitioning switch characteristics are as follows:

Table 4 - Worst Case Switch Timing

Switch Characteristics	Time (µs)
On to Off Time	7
Off to On Time	2500

No damage to the Rate Sensor FDC switch shall result from a signal over voltage totaling (DC+AC Ripple+Transient) of less than +5.85V for time intervals not exceeding 1.0ms as measured after the EMI filter. [RS_SRS_12908]

3.2.3.1.3. Isolation

The isolation resistance between the +5 Volt Power Return and chassis ground shall be greater than 10K Ohms. [RS_SRS_13128]

3.2.3.1.4. Chassis Ground Connection

Chassis ground is provided by the customer via direct electrical connection to the Rate Sensor housing. See the Rate Sensor installation drawing for recommended chassis ground connection.

3.2.3.2. Receive Clock

Not applicable in this configuration.

3.2.3.3. Serial Data Output

The Rate Sensor shall transmit a RS-422 compatible serial data output signal on the SER_DATA_OUT_H and SER_DATA_OUT_L pins of the Rate Sensor external interface connector defined in Section 3.2.2 - External Connector Pin Assignments. [RS_SRS_10128]

3.2.3.4. Reset Input Discrete

The system shall accept a 3.3 Volt LVCMOS compatible discrete input for hardware reset on the RESET pin of the Rate Sensor external interface connector defined in Section 3.2.2 - External Connector Pin Assignments. [RS_SRS_10131]

The RESET input shall tolerate 5 Volt logic input levels. [RS_SRS_10132]

The application of logic 1 (+3.3 VDC) on the RESET input shall cause the Rate Sensor to halt all processes. The Rate Sensor remains halted for the duration of logic 1 on the RESET input. Upon restoration of logic 0 (0 VDC) or open on the RESET input, the Rate Sensor restarts the power-up initialization process and transitions to normal operation. Note: When the Rate Sensor is in the RESET state all electronic components remain powered. [RS_SRS_10133]

To ensure a reset command is successfully captured and executed by the Rate Sensor, the RESET signal should be asserted for a minimum of 15 ms. Note that holding RESET at logic 1 during power application does not reduce the in-rush current.

The RESET input discrete signal is internally pulled to a logic 0 (0 VDC) to allow a no connect (open) at the system level.

3.2.4. Serial Data Output Protocol

3.2.4.1. Serial Communications Controller (SCC) Interface

The Rate Sensor shall transmit a compatible data signal, in accordance with RS-422, on the Serial Data signal pins, SER_DATA_OUT, of the sensor external interface connector as specified in Section 3.2.2 - External Connector Pin Assignments. [RS_SRS_10138]

Note: The Rate Sensor utilizes Resistor-Capacitor (RC) source termination on the RS-422 transmitter before the external interface for signal integrity and EMI reasons. Contact Honeywell for details on source termination implementation.

The decision to implement a parallel termination resistor at the User’s RS-422 receiver should be informed by User evaluation of application specific details that influence signal integrity, e.g. cable length, cable construction, and receiver component capabilities. Honeywell’s Factory and Qualification testing utilized a conventional 120Ω nominal parallel termination resistor placed between SER_DATA_OUT_H and SER_DATA_OUT_L at the input to the test equipment’s receiver in accordance with TIA-422.

3.2.4.2. Asynchronous Protocol

3.2.4.2.1. General Requirements

Each Asynchronous output frame shall open with a Rate Sensor address byte that can be used as a synching byte, followed by the information that includes control and data fields. [RS_SRS_10142]

The frame checksum shall follow the data message.

[RS_SRS_10143]

The checksum shall be computed by using a simple 16-bit unsigned integer sum of all bytes included in the message prior to the checksum itself, with overflows of the 16-bit value being ignored. Twenty-six (26) bytes are summed as thirteen (13) 2-byte words, including one (1) byte for the address, one (1) byte for the message ID and twenty-four (24) bytes for the data and status words.

[RS_SRS_11398]

The format for the Asynchronous message shall be as shown in Figure 2 - Asynchronous Message. [RS_SRS_10144]

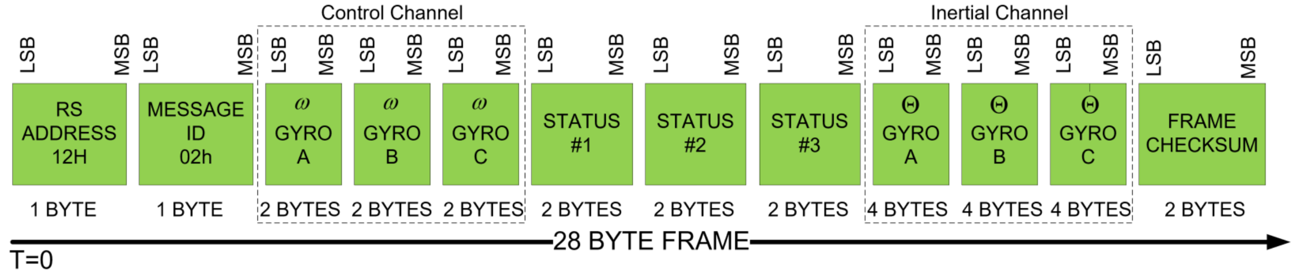


Figure 2 - Asynchronous Message

The order of transmission shall be Least Significant (LS) bit first; LS byte first; LS 16 bit word first. [RS_SRS_10147]

Each asynchronous data byte shall be transmitted in the following order: 1 start bit, 8 data bits, 1 parity bit, and 1 stop bit. Parity bit is set for odd parity. Between the 28 byte messages the line is idle (high). [RS_SRS_10148]

Data representation shall be two's complement [RS_SRS_11404]

The bit transmission (baud) rate shall be 1 MHz ± 3% [RS_SRS_11405]

The address field contains a unique hex number to identify the Rate Sensor model.

The message ID contains a unique hex number to identify the content of the message.

The information field includes data as specified in the following sections for each message format.

The message characteristics shall be as shown in Table 5 - Asynchronous (UART) Message Characteristics [RS_SRS_10151]

Table 5 - Asynchronous (UART) Message Characteristics

Field Description	Number of Bytes	Value / Paragraph
Address	1	12h
Message ID	1	02h
Information	24	See Table 6 - Message Information Field Contents
Checksum	2	Defined in requirement above

3.2.4.2.2. Asynchronous 600 Hz Message Format

Message shall contain angular rates, summed incremental angle and Rate Sensor status words as defined in Table 6 - Message Information Field Contents. NOTE: Summed incremental is allowed to overflow. Increasing the summed angle past full scale positive will result in wrap around to full scale negative. Similarly, increasing past full scale negative results in wrap around to full scale positive. [RS_SRS_10171]

The Rate Sensor shall limit the delta angles to ± 0.8166667 deg prior to summing.

[RS_SRS_11417]

The Rate Sensor status words shall contain the bit-mapped information defined in Table 7 - Message Information Status Word 1, Table 8 - Message Information Status Word 2, and

Table 9 - Message Information Status Word 3. [RS_SRS_10172]

The start of sequential message transmissions shall be on the average 1/600 seconds ± 0.01%. [RS_SRS_10173]

Table 6 - Message Information Field Contents

Data Field	Parameter	Bytes	LSB Weighting	Units/Value
1	Angular Rate X (Body) (Control Channel)	2	600×2^{-23} (7.152557 E-05)	rad/sec/LSB
2	Angular Rate Y (Body) (Control Channel)	2	600×2^{-23} (7.152557 E-05)	rad/sec/LSB
3	Angular Rate Z (Body) (Control Channel)	2	600×2^{-23} (7.152557 E-05)	rad/sec/LSB
4	Status 1	2	N/A	See Table 7 - Message Information Status Word 1
5	Status 2	2	N/A	See Table 8 - Message Information Status Word 2
6	Status 3	2	N/A	See Table 9 - Message Information Status Word 3
7	Summed Incremental Angle X (Body) (Inertial Channel)	4	2^{-27} (7.450581E-09)	rad/LSB
8	Summed Incremental Angle Y (Body) (Inertial Channel)	4	2^{-27} (7.450581E-09)	rad/LSB
9	Summed Incremental Angle Z (Body) (Inertial Channel)	4	2^{-27} (7.450581E-09)	rad/LSB
		Total 24		

Table 7 - Message Information Status Word 1

Bit	Definition	Notes
Bit 0-1	2 Bit Counter	00 01 10 11...
Bit 2-3	2 bit BIT-mode indicator	0=Power-up BIT 1=Continuous BIT 2=Initiated BIT 3=not defined
Bit 4	Rate Sensor Failed (Latched)	0=OK, 1=Failed
Bit 5	Gyro Failed (Latched)	0=OK, 1=Failed
Bit 6	Reserved	
Bit 7	AGC Voltage	0=OK, 1=Failed

Bit	Definition	Notes
Bit 8	Gyro A Start/Run	0=Start, 1=Run
Bit 9	Gyro B Start/Run	0=Start, 1=Run
Bit 10	Gyro C Start/Run	0=Start, 1=Run
Bit 11	Gyro A FDC	0=OK, 1=Failed
Bit 12	Gyro B FDC	0=OK, 1=Failed
Bit 13	Gyro C FDC	0=OK, 1=Failed
Bit 14	FDC Failed	0=OK, 1=Failed
Bit 15	RS OK	0=OK, 1=Failed

Note: Reserved bits are always 0.

Note: Bit 0 is the LSB.

Note: See Section 3.2.7 - Fault Detection and Correction (FDC) for details on the Fault Detection and Correction (FDC) process.

The RS failed (Latched) bit shall be set by the faults defined in Table 11 - BIT Definition. [RS_SRS_12695]

The Gyro failed (Latched) bit shall be set by the faults defined in Table 11 - BIT Definition. [RS_SRS_12696]

The memory bit shall be set by the logical OR function of the Normal Mode CRC, Configuration Table CRC, Coefficient Table CRC and Random Access Memory (RAM) tests. [RS_SRS_12697]

Table 8 - Message Information Status Word 2

Bit	Definition	Notes
Bit 0-7	Gyro Temperature A	LSB=1°C (NOTE Temperature sensors are not calibrated.)
Bit 8	Motor Bias Voltage	0=OK, 1=Failed
Bit 9	Start data flag	0=sensor data, 1=5555h data transmitted for synchronization
Bit 10	Processor	0=OK, 1=Failed
Bit 11	Memory	0=OK, 1=Failed
Bit 12	ASIC	0=OK, 1=Failed
Bit 13	Gyro Health	0=OK, 1=Failed
Bit 14	ATP Indicator	0=Mode 1, 1=Mode 2 (NOTE used by factory)
Bit 15	Reserved	

Note: Reserved bits are always 0.

Note: Bit 0 is the LSB.

Table 9 - Message Information Status Word 3

Bit	Definition		Notes
Bit 0-7	Gyro Temperature B		LSB=1°C (NOTE Temperature sensors are not calibrated.)
Bit 8-15	Gyro Temperature C		LSB=1°C (NOTE Temperature sensors are not calibrated.)

Note: Bit 0 is the LSB.

3.2.5. Activation Timing and Built In Test (BIT)

The Rate Sensor power up sequence is illustrated in Figure 3 - Power Up Sequence.

The power-on processor reset supervisory circuit shall have a turn on time < 65 ms. [RS_SRS_13139]

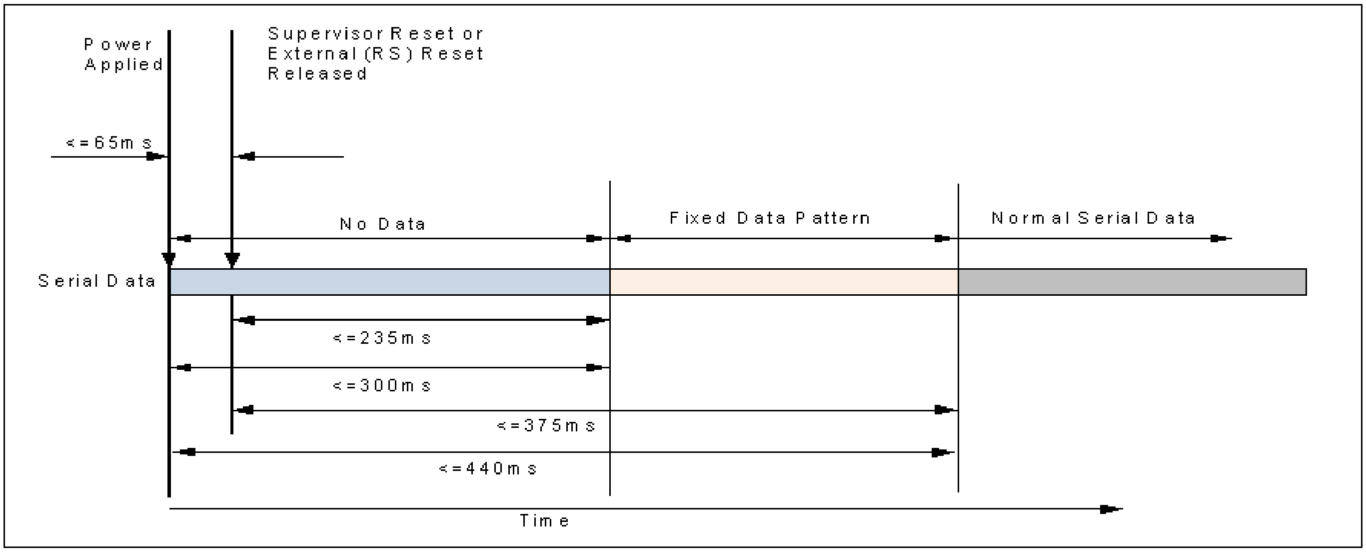


Figure 3 - Power Up Sequence

3.2.5.1. Serial Data Interface Activation

The serial data interface shall be available within 300 ms after the last applied power form is within the specified tolerances and the reset line is inactive. [RS_SRS_10805]

The Rate Sensor transmits a fixed pattern 5555h in place of Control sensor data and 55555555h in place of inertial sensor data until the completion of Power-Up BIT.

3.2.5.2. BIT

The Rate Sensor shall perform BIT in two functional areas defined to be Power Up and Continuous as specified in Table 11 - BIT Definition and defined in the following paragraphs. [RS_SRS_13624]

Configurable BIT tests shall be independently enabled via the configuration table for each BIT mode. [RS_SRS_13625]

BIT coverage for any of the BIT modes shall be determined with all available tests enabled. [RS_SRS_13626]

BIT results shall be annunciated for only those tests that are enabled in that BIT mode. [RS_SRS_13627]

BIT annunciation shall be cleared upon transition to a different BIT mode except for the latched BTI annunciation. [RS_SRS_13628]

Mission Critical failures shall be defined as a failure resulting in severity levels I, II, III as defined in Table 10 - FMECA Severity Classification [RS_SRS_13629]

Table 10 - FMECA Severity Classification

Severity Classification	**Level**	**Description**
Catastrophic	I	A failure which may cause death or weapon system loss (i.e., aircraft, tank, missile, ship, etc.).
Critical	II	A failure which may cause severe injury, major property damage or major system damage which will result in mission loss.
Marginal	III	A failure which may cause minor injury, minor property damage or minor system damage which will result in delay or loss of availability or mission degradation.
Minor	IV	A failure not serious enough to cause injury, property damage or system damage, but which will result in unscheduled maintenance or repair.

The Rate Sensor performs BIT during power-up and normal operation. The following table shows the BIT performed.

Table 11 - BIT Definition

Description	FDC	CBIT Power Up BIT	RS OK	Latched: Gyro Fail RS Fail
Gyro Run/Start: Test that the PLL is locked.	x	C	x	G
Gyro AGC Voltage: Test that AGC voltage is within range.	x	C	x	G
Gyro Motor Bias: Test that motor bias voltage is within range.	x	P, C	x	G
Gyro Output Statistics Test: Compute estimate of standard deviation of sequential overlapping frames. Check for stddev in range.	x	C	x	G
Normal Mode CRC Test: Compute cyclic redundancy check (CRC) and compare against pre-computed value.		P, C	x	RS
Configuration Table CRC Test: Compute CRC and compare against value in the table.		P, C	x	RS
Coefficient Table CRC Test: Compute CRC and compare against value in the table.		P, C	x	RS
Processor Test: Perform sample calculation and compare with known answer.		P, C	x	RS
WDT Test: Check if the WDT hardware reset the processor.		P	x	RS

Description	FDC	CBIT Power Up BIT	RS OK	Latched: Gyro Fail RS Fail
Stack Overflow Test: Check integrity of known data pattern at waterline location in stack memory.		P, C	x	RS
Loop Completion Test: Check for processing frame overrun and reset processor. At power-up check for cause of reset.		P, C	x	RS
Comprehensive RAM Test: Perform Space MultiFunction ASIC processor and peripheral memory BISTs. Destructive test.		P	x	RS
Non-comprehensive RAM Test: Write known data patterns to fixed locations in RAM, read from those locations in RAM, and compare.		P, C	x	RS
Gyro Temp: Check that each temperature is in range. Compare each gyro temp against the other two and fail channel that is out of range.		P, C	x	G
Gyro NVREF Test: Test that the gyro reference voltage is in range.	x	P, C	x	G
Gyro ASIC Register Read-back Test: Read back the gyro ASIC registers and compare their values to the expected values.		P	x	G
SPI Bus Transfer Test: Verify timing of SPI bus operations.		P, C	x	RS
Power Monitor: Test that the regulated +3V3 internal rail is valid, the +5V_COMM Power Good pin is valid, and the +5VA internal rail and its Power Good pin are valid.	x	C	x	G, RS
Gyro FDC: Checks the internal registers for incorrect values and checks BIT marked in the “FDC” column for a failure condition.		C	x	

Note: See Section 3.2.7 - Fault Detection and Correction (FDC) for details on the FDC process.

3.2.5.2.1. Power-Up BIT

The Rate Sensor shall complete Power-Up BIT (PBIT) and report the results within 440 milliseconds after power is within specified tolerances and Rate Sensor Reset is inactive. [RS_SRS_10808]

The PBIT function within the Rate Sensor shall be capable of detecting 42% of all mission critical failures as defined in Section 3.2.5.2 - BIT. The Power-Up BIT shall evaluate the functionality of all gyros, ASICs, memory and data conversion devices. Verification of this requirement shall be by analysis only per ISO 9000 2.3.2.W.R&CE201BIT and 2.3.2.W.R&CE204FMECA. [RS_SRS_13631]

3.2.5.2.2. Continuous BIT

The normal operation mode shall perform Continuous BIT (CBIT) and report the results in the Rate Sensor status words. [RS_SRS_10810]

When a fault is no longer detected, the fault indication shall be cleared with the exceptions of the Gyro Failed and RS Failed status bits which shall be latched on any applicable BIT failure. [RS_SRS_10811]

All enabled CBIT functions shall be active within 1.2 seconds following Serial Data Interface Activation as specified in Section 3.2.5.1 - Serial Data Interface Activation. [RS_SRS_10812]

The CBIT function with the Rate Sensor shall be capable of detecting 95% of all mission critical failures as defined in Section 3.2.5.2 - BIT. The CBIT shall evaluate the functionality of all gyros, ASICs, memory and data conversion devices. Verification of this requirement shall be by analysis only per ISO 9000 2.3.2.W.R&CE201BIT and 2.3.2.W.R&CE204FMECA. [RS_SRS_13634]

3.2.5.3. Time to Performance

The Rate Sensor shall meet all performance specifications as stated in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables within the time specified in Table 12 - Time to Performance. [RS_SRS_11406]

Table 12 - Time to Performance

Performance Level	**Time to Performance (sec)**
Full Performance	5

3.2.6. Rate Sensor Operational Modes

The Rate Sensor has two operational modes: Initialization Mode and Normal Mode. The transition between modes is shown in Figure 4 - Mode Transition Diagram.

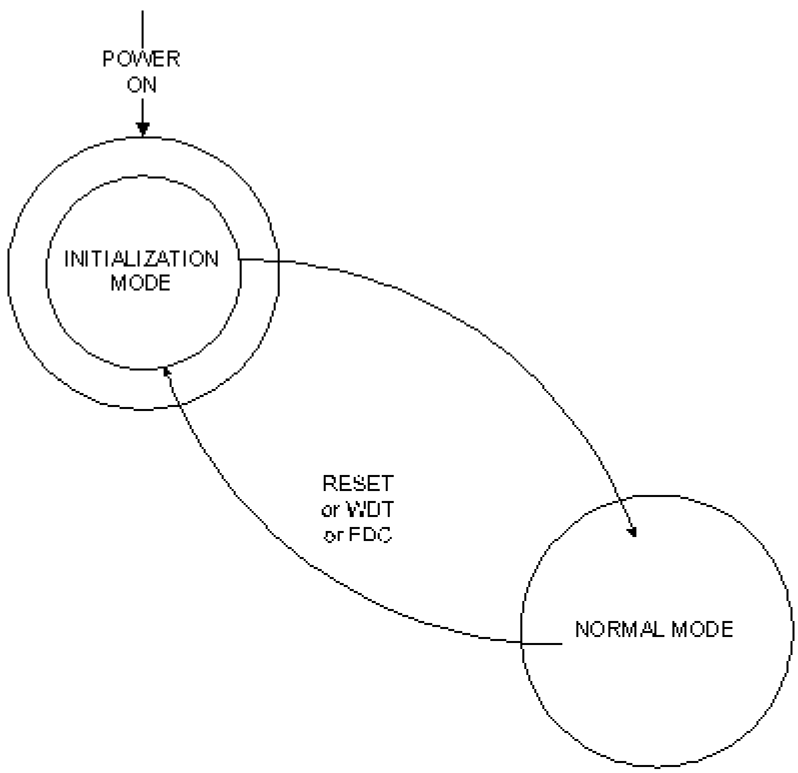


Figure 4 - Mode Transition Diagram

3.2.6.1. Watchdog Timer

A Watchdog Timer (WDT) shall be implemented in the hardware. [RS_SRS_11764]

3.2.7. Fault Detection and Correction (FDC)

The Rate Sensor provides functionality to detect and recover from radiation induced single event upsets or other non-radiation related fault conditions. This process, referred to as Fault Detection and Correction (FDC), continuously reads and compares internal register values against their expected values and monitors BIT results for failed conditions. If an unexpected register value is discovered or a BIT is failed, the Rate Sensor performs a soft reset to correct the condition and resume normal Rate Sensor operation. The FDC detection process takes typically 1-10 milliseconds; the timing for reset and recovery is described below.

The Fault Detection and Correction supervisory circuit shall have a turn on time < 1.5ms [RS_SRS_13144]

The Rate Sensor shall detect corrupted internal register values and/or failed BIT and set the *Gyro (A/B/C) FDC* bit of Status Word 1 (see Table 7 - Message Information Status Word 1, bit 11, 12, or 13) to annunciate the fault condition for the affected channel. [RS_SRS_11475]

The *RS OK* bit of Status Word 1 (see Table 7 - Message Information Status Word 1, bit 15) shall be set when a corrupted register value or failed BIT is detected. [RS_SRS_11476]

The Rate Sensor shall attempt to recover the corrupted register value or failed BIT by performing an internal soft reset. [RS_SRS_11477]

If a reset does not correct the corrupted register value or failed BIT, the Rate Sensor shall set the *FDC Failed* bit of Status Word 1 (see Table 7 - Message Information Status Word 1 bit 14) and stop the FDC process for that channel. [RS_SRS_11478]

Upon restart, the *Gyro (A/B/C) FDC* bit shall remain set for 1.6 seconds after reaching continuous mode. [RS_SRS_11479]

Once set, the *FDC Failed* bit shall persist until the Rate Sensor is soft reset for a separate channel or a separate cause (e.g. user power cycles the Rate Sensor manually). [RS_SRS_11480]

Once *FDC Failed* is set, *Gyro (A/B/C) FDC* shall also persist indicating the failed channel. [RS_SRS_12805]

Note: During a soft reset, there will be a negligible reduction in current consumption and transmission of the Output Message (see Table 6 - Message Information Field Contents) will temporarily cease. When a soft reset is performed the Summed Incremental Angles in the output message (see Table 6 - Message Information Field Contents) reset back to 0. The user will need to update their attitude calculations accordingly.

3.2.7.1. FDC Timing Diagrams (For Reference Only)

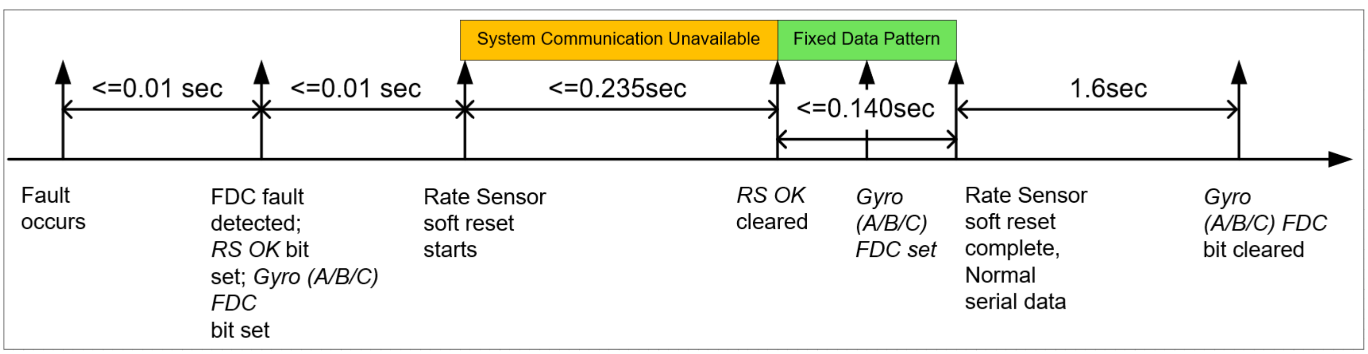


Figure 5 - Soft Reset with Recovery - Example Timing

Figure 6 - RESERVED

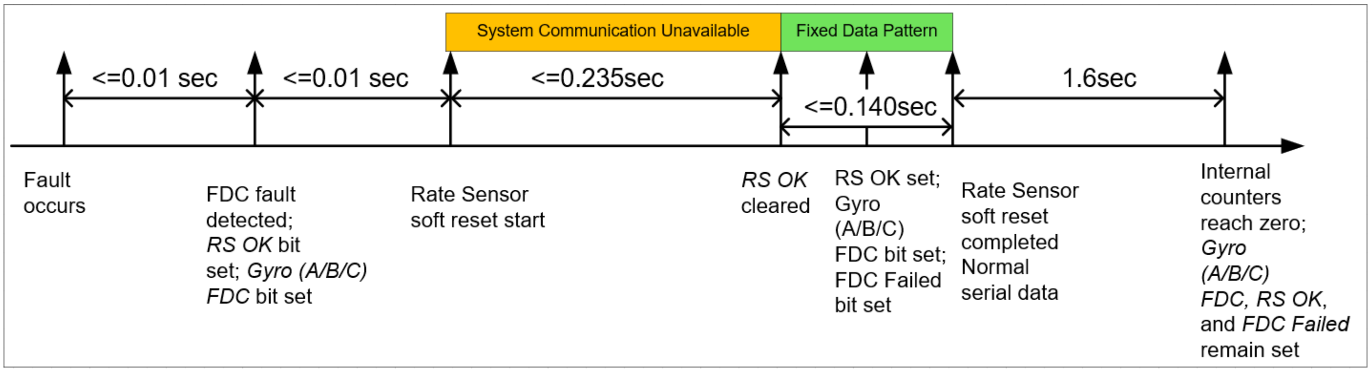


Figure 7 - FDC Failed (No Recovery) - Example Timing

The peak time loading of any cyclic processing frame shall not exceed 90% [RS_SRS_13149]

The memory usage for RAM and Read Only Memory (ROM) in support of the processor shall not exceed 75% for each memory type [RS_SRS_13150]

3.3. Inertial Performance Specifications

The performance specifications for the gyro channels are tabulated and referenced in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables.

3.3.1. Angular Rate Channel Performance

The following performance specifications apply to each angular rate output channel for the operating environments specified in Section 3.5 - Environmental Specifications.

3.3.1.1. Angular Rate Channel Inertial and Control Tables

Table 13 - Angular Rate Inertial Performance Requirements

Parameter	**Inertial Req.**	**Units**
Operating Rate Range	±115	°/s, minimum
Scale Factor Repeatability	3000	ppm, 3σ
Scale Factor In-Run Stability	525	ppm, 3σ
Scale Factor Static g Sensitivity	300 (Note 1)	ppm/g 3σ
Scale Factor Linearity	0.15	% of FS, 3σ
Bias Repeatability	225	°/hr, 3σ
Bias (In Run Stability)	3.0	°/hr, 3σ
Bias Static g Sensitivity	90 (Note 1)	°/hr/g, 3σ
Output Noise (standard deviation)	30	μrad, maximum
Angular Random Walk	0.200	deg/rt-hr, maximum
Frequency Response Bandwidth	10 Hz ≤ BW ≤ 25 Hz	as defined
Frequency Response Phase Limit	-90° from 10-25 Hz	as defined

Note 1: g-sensitivity is valid over a ±20 g linear acceleration range.

Table 14 - Angular Rate Control Performance Requirements

Parameter	Control Req.	Units
Scale Factor Repeatability	3000	ppm, 3σ
Bias Repeatability	225	°/hr, 3σ
Output Noise (standard deviation)	0.45	mrad/sec, maximum
Frequency Response Bandwidth	10 Hz ≤ BW ≤ 25 Hz	as defined
Frequency Response Phase Limit	-90° from 10-25 Hz	as defined

Table 15 - Angular Rate Alignment Performance Requirements

Parameter	Requirement	Units
Gyro Axes Non-orthogonality Stability	2250	μrad 3σ
Axes Alignment Stability to Case	2250	μrad 3σ
Mount to Mount Repeatability	3.5 (with pins)	mrad max

3.3.1.2. Operating Rate Range

The Rate Sensor shall meet the performance requirements listed in this specification for input rates up to the maximum value specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_11483]

3.3.1.3. Output Scale Factor

The output scaling adjustments shall be capable of a multiply operation. (i.e. not limited to a power of 2). [RS_SRS_11485]

The output scale factor (LSB weighting) of the angular rate words shall be as listed in Section 3.2.4 - Serial Data Output Protocol. [RS_SRS_11486]

3.3.1.4. Scale Factor Linearity

The angular rate scale factor linearity error shall be as specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_14023]

3.3.1.5. Scale Factor Repeatability

The angular rate scale factor repeatability error including all sources except those defined independently shall be as specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_11488]

3.3.1.6. Scale Factor In-Run Stability

The angular rate scale factor in-run stability error including all sources except those defined independently shall be as specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_11490]

3.3.1.7. Scale Factor g Sensitivity

The sensitivity of angular rate scale factor to static g loading shall be as specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_11492]

3.3.1.8. Bias Repeatability

The angular rate bias repeatability error including all sources except those defined independently shall be as specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_11494]

3.3.1.9. Bias In-Run Stability

The angular rate bias in-run stability error including all sources except those defined independently shall be as specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_11496]

3.3.1.10. Bias Static g Sensitivity

The sensitivity of angular rate bias to static g loading shall be as specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_11498]

3.3.1.11. Output Noise

The Rate Sensor flight control output noise shall be as specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_11502]

The Rate Sensor inertial output noise shall be as specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_13783]

3.3.1.12. Angular Random Walk

The angular random walk of the inertial output shall be as specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_11508]

3.3.1.13. Frequency Response

The Rate Sensor's bandwidth shall be as specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_11512]

3.3.1.14. Angular Rate Control & Inertial Channel Transfer Functions

This diagram is provided for reference only:

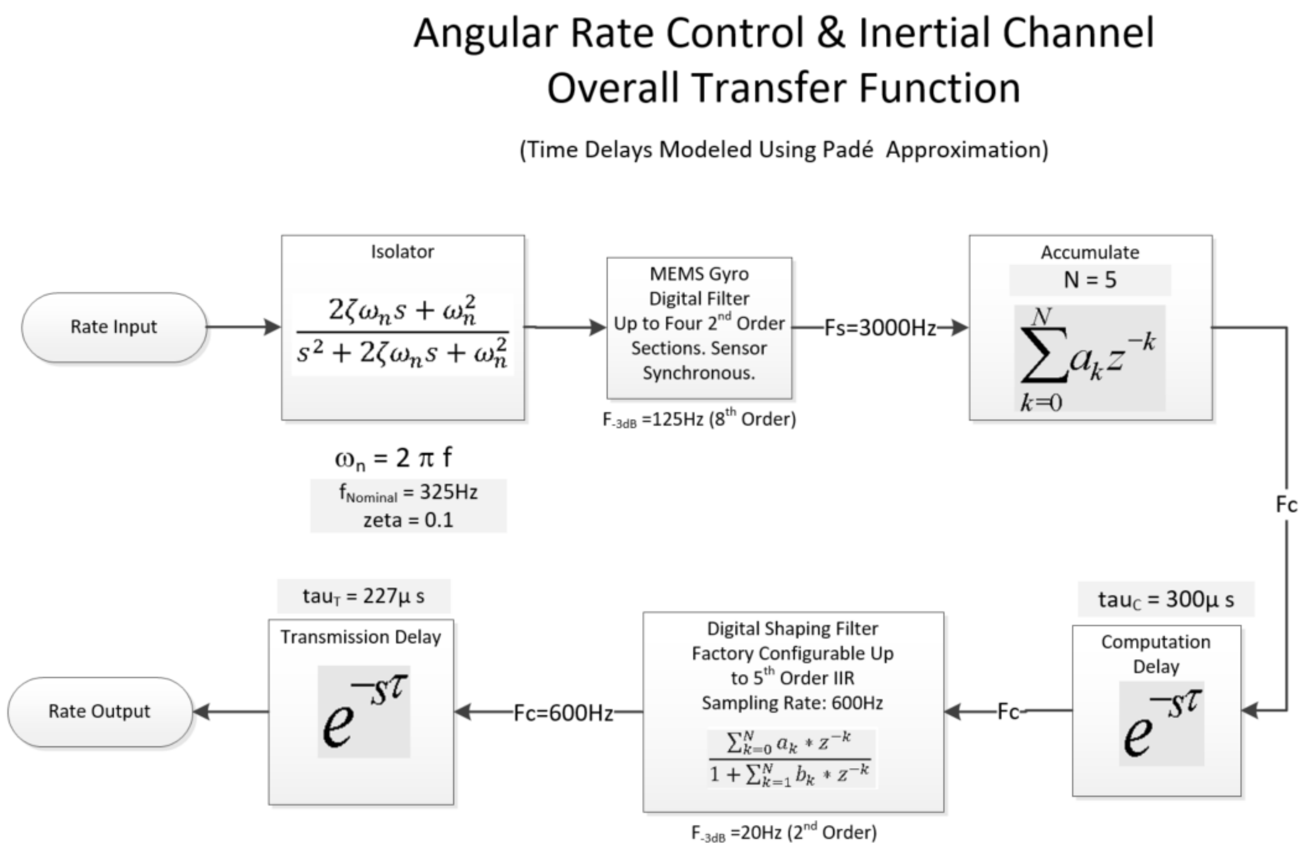


Figure 8 - Angular Rate Control & Inertial Channel Transfer Function

3.3.1.15. Axes Alignment Stability

The residual misalignment stability (total vector) between the Rate Sensor case - defined input axes and the Rate Sensor's sensor input axes shall be no greater than that specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_11504]

3.3.1.16. Axes Alignment Stability (Non-Orthogonality)

The compensated variation in orthogonality among the angular rate input axes relative to each other shall be as specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_11506]

3.3.1.17. Mount to Mount Repeatability

The Rate Sensor shall have a mounting alignment repeatability as specified in Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables when installed per the Rate Sensor installation drawing. This variation assumes the use of alignment pins as called for in the Rate Sensor installation drawing. [RS_SRS_11510]

3.4. Physical Characteristics

3.4.1. Weight

The Rate Sensor weight shall be 0.312 ±0.031 lbs. [RS_SRS_10924]

3.4.2. Size

The Rate Sensor shall not exceed the envelope shown in the Rate Sensor installation drawing. [RS_SRS_10926]

3.4.3. Input Axis and Rate Sensor Mounting Provisions

The Rate Sensor mounting configuration, mechanical alignment, orientation and polarity of the input axes for the Rate Sensor shall be as defined in the Rate Sensor installation drawing. [RS_SRS_10928]

3.4.4. Environmental Seal

The Rate Sensor package shall be environmentally sealed to less than 5E-7 cc/s He_4 leak rate at 1 atmosphere differential total pressure using a 5% He_4 gas mix. [RS_SRS_13026]

The user should not subject the Rate Sensor to contact with any fuels, lubricants, solvents, or their vapors.

3.4.5. Center of Gravity and Center of Navigation

The Rate Sensor Center of Gravity (CG) and Center Of Navigation (CON) are defined with respect to the Rate Sensor mounting surface. The location of the CG and CON are shown in the Rate Sensor installation drawing.

3.4.6. ESD

Identification, handling and shipping of electrostatic discharge sensitive devices shall be in accordance with PC29100-04. The Rate Sensor is a Class 2 device as defined in ANSI/ESD S20.20. [RS_SRS_10936]

3.5. Environmental Specifications

The minimum Rate Sensor operating and non-operating environmental specifications are shown in Table 16 - Table of Environmental Conditions.

Table 16 - Table of Environmental Conditions

Environment	Operating	Non-Operating	Units
Acceptance Temperature (at Atmospheric Pressure)	-54 to +85	-54 to +95	°C
Flight (Baseplate) Temperature in Vacuum	-40 to +70	-54 to +85	°C
Temperature Shock	±3 (Angular Rate) ±0.8 (Inertial)	±15	°C/minute
Random Vibration	Figure 11 - Operating Random Vibration	Figure 9 - Non-Operating Random Vibration	---
Shock	Figure 12 - Operating Shock Profile	Figure 10 - Non-Operating Shock	---
Thermal Vacuum	Space (Low Earth Orbit)	Space (Low Earth Orbit)	---
Magnetic Field	±10	---	Gauss
Electromagnetic Effects	Section 3.5.2.8 - Electromagnetic Environmental Effects	---	---
Acoustic Noise	Section 3.5.2.9 - Acoustic Noise	---	---
Humidity	---	DO-160D Section 6, Category B	---

3.5.1. Non-Operating Environments

3.5.1.1. Temperature at Atmospheric Pressure

The Rate Sensor shall meet the requirements of this specification after exposure to the non-operating temperature at atmospheric pressure specified in Section 3.5 - Environmental Specifications. [RS_SRS_11519]

3.5.1.2. Baseplate Temperature in Vacuum

The Rate Sensor shall meet the requirements of this specification after exposure to the non-operating temperature, as measured at the baseplate, in a vacuum specified in Section 3.5 - Environmental Specifications. [RS_SRS_11521]

3.5.1.3. Temperature Shock

The Rate Sensor shall meet the requirements of this specification after exposure to 3 thermal shocks to the temperature specified in Section 3.5 - Environmental Specifications. [RS_SRS_11523]

3.5.1.4. Vibration

The Rate Sensor shall meet the requirements of this specification after exposure to the vibration profile defined in Figure 9 - Non-Operating Random Vibration for four minutes on each orthogonal axis at room temperature. [RS_SRS_11525]

Frequency (Hz)	Amplitude (G^2/Hz)
20	0.282
25	0.282
40	0.8
78	0.8
80	1
250	1
258	0.8
500	0.8
565	0.282
1000	0.282
2000	0.05
Total: 26.78 G_{RMS}	

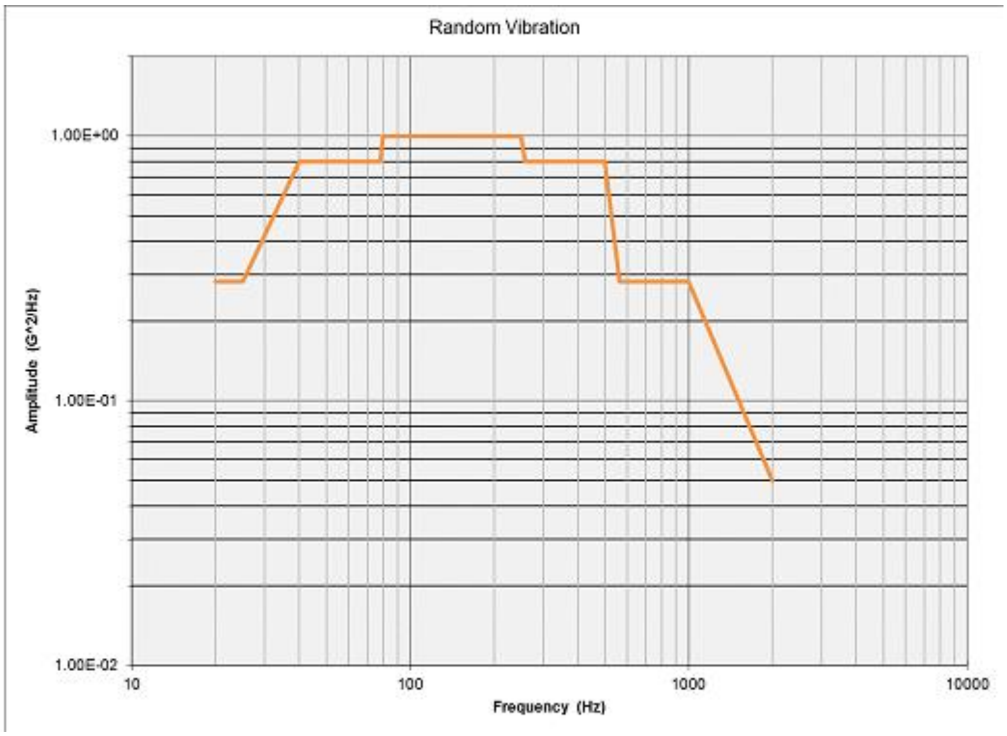
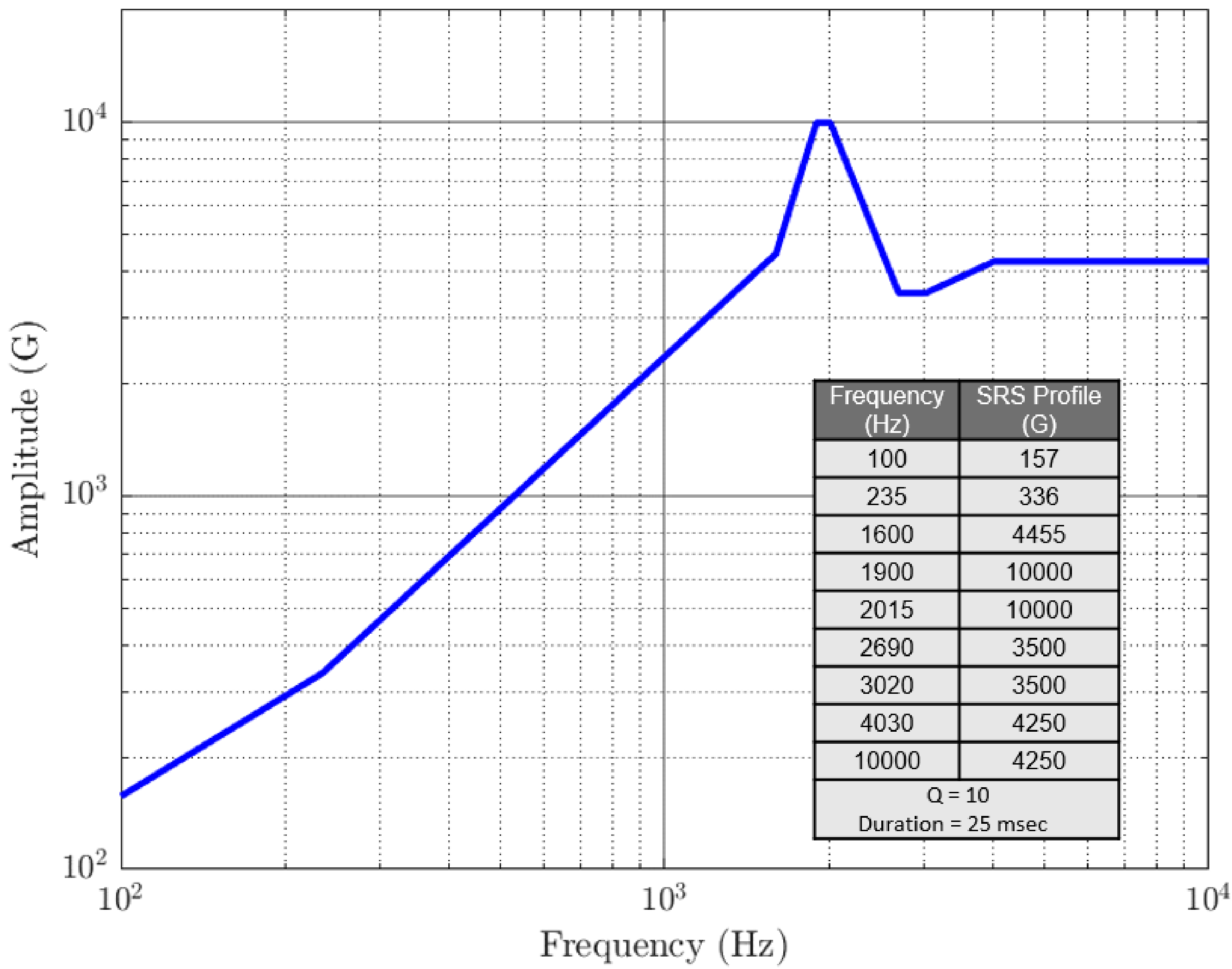


Figure 9 - Non-Operating Random Vibration

3.5.1.5. Shock

The Rate Sensor shall meet the requirements of this specification after exposure to the shock pulse of Figure 10 - Non-Operating Shock at room temperature. Three shocks shall be applied along each of the three major Rate Sensor axes for a total of nine shocks.

[RS_SRS_11527]



Frequency (Hz)	SRS Profile (G)
100	157
235	336
1600	4455
1900	10000
2015	10000
2690	3500
3020	3500
4030	4250
10000	4250
Q = 10 Duration = 25 msec	

Figure 10 - Non-Operating Shock

3.5.1.6. Thermal Vacuum

The Rate Sensor shall meet the requirements of this specification after exposure to the thermal vacuum defined in Section 3.5 - Environmental Specifications. [RS_SRS_11529]

3.5.1.7. Humidity

The RS shall meet the performance requirements of this specification after exposure to the relative humidity environment specified in Table 16 - Table of Environmental Conditions. [RS_SRS_13542]

3.5.2. Operating Environments

3.5.2.1. Temperature at Atmospheric Pressure

The Rate Sensor shall meet the performance requirements of this specification during and after indefinite operation at all temperatures specified in Section 3.5 - Environmental Specifications with no forced convection, while operating at atmospheric pressure. The operating temperature of the Rate Sensor is defined as the ambient surrounding air temperature. [RS_SRS_11532]

3.5.2.2. Baseplate Temperature in Vacuum

The Rate Sensor shall meet the performance requirements of this specification during and after indefinite operation at the baseplate temperatures specified in Section 3.5 - Environmental Specifications while operating in a vacuum. [RS_SRS_11534]

3.5.2.3. Temperature Shock

The Rate Sensor shall meet the performance requirements of this specification during and after thermal ramp rate specified in Section 3.5 - Environmental Specifications as measured at the Rate Sensor mounting flange. [RS_SRS_11536]

3.5.2.4. Random Vibration

The Rate Sensor shall operate continuously and without failure during exposure and meet the requirements of this specification after exposure to the vibration profile shown in Figure 11 - Operating Random Vibration for four minutes per orthogonal axis at room temperature. [RS_SRS_11538]

Frequency (Hz)	Amplitude (G^2/Hz)
20	0.282
25	0.282
40	0.8
78	0.8
80	1
250	1
258	0.8
500	0.8
565	0.282
1000	0.282
2000	0.05
Total: 26.78 G_{RMS}	

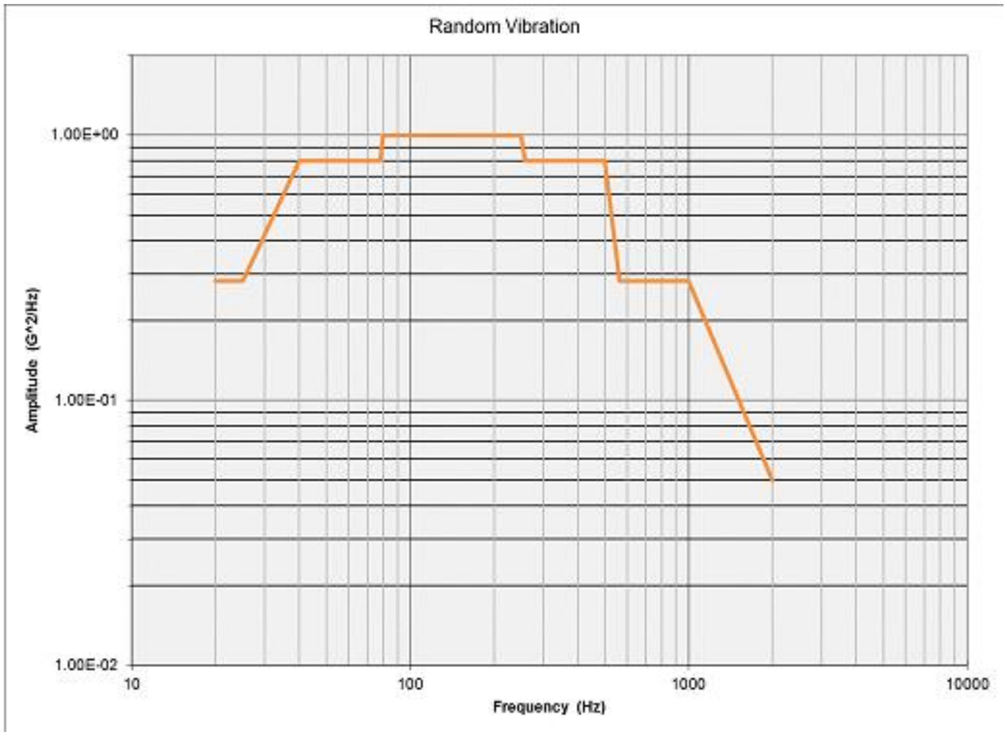
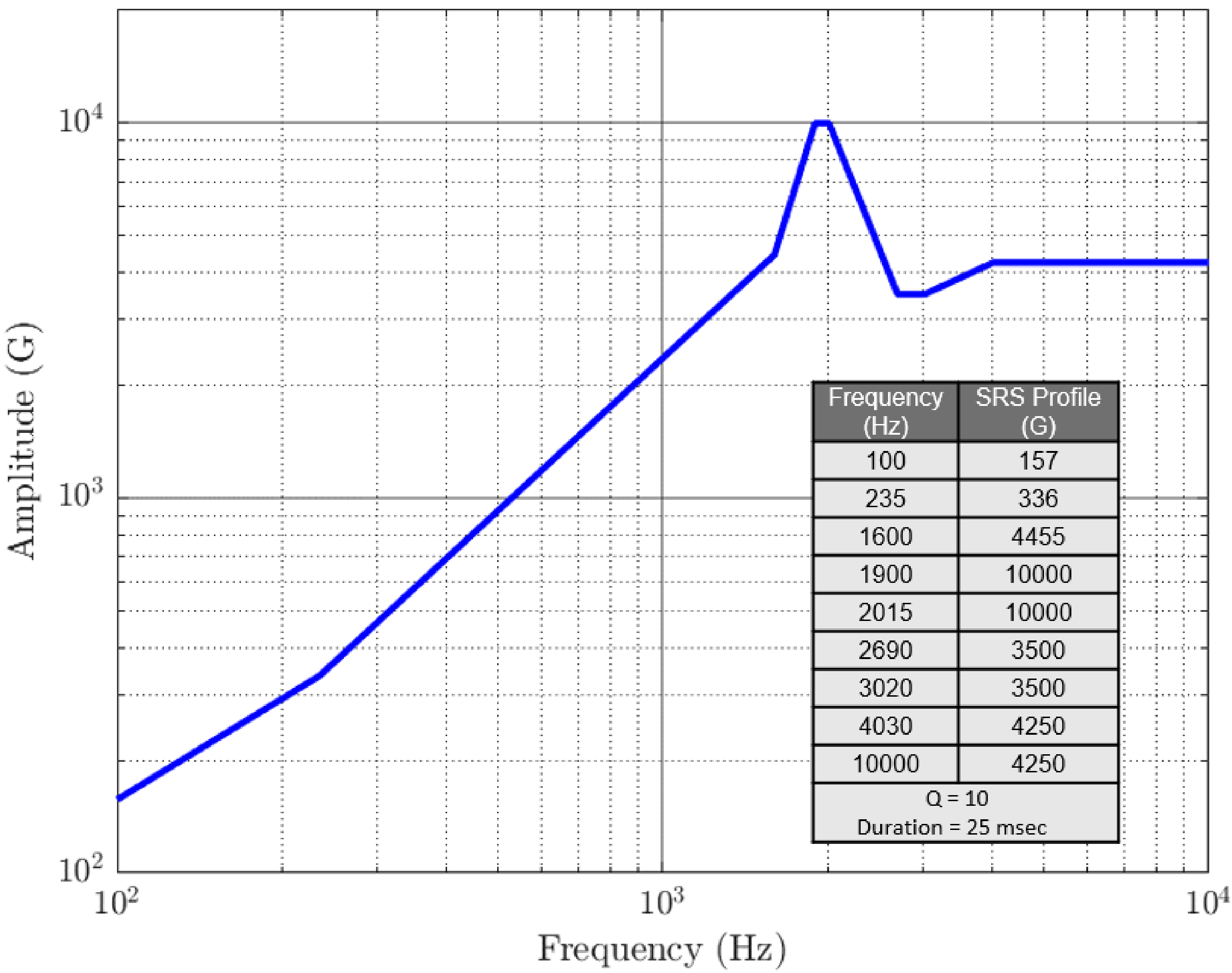


Figure 11 - Operating Random Vibration

3.5.2.5. Shock

The Rate Sensor shall operate continuously and without failure through the shock event and meet the requirements of this specification after exposure to the shock pulse of Figure 12 - Operating Shock Profile at room temperature. Three shocks shall be applied along each of the three major Rate Sensor axes for a total of nine shocks.

[RS_SRS_11540]



Frequency (Hz)	SRS Profile (G)
100	157
235	336
1600	4455
1900	10000
2015	10000
2690	3500
3020	3500
4030	4250
10000	4250
Q = 10 Duration = 25 msec	

Figure 12 - Operating Shock Profile

3.5.2.6. Thermal Vacuum

The Rate Sensor shall meet the requirements of this specification during and after exposure to the thermal vacuum defined in Section 3.5 - Environmental Specifications. [RS_SRS_11542]

3.5.2.7. Magnetic Field

The RS shall meet the performance requirements of this specification during and after exposure to static magnetic fields along any axis as specified in Table 16 - Table of Environmental Conditions. [RS_SRS_13526]

3.5.2.8. Electromagnetic Environmental Effects

The tailored requirements of MIL-STD-461F applicable to the Rate Sensor are listed below. To meet electromagnetic environmental effects requirements, the user should shield the I/O cabling and provide chassis ground connection to the IMU housing per Section 3.2.3.1.4 - Chassis Ground Connection.

Note: All EMI testing is performed with a nominal +5V input supply voltage.

Table 17 - Tailoring of MIL-STD-461F EMI Requirements

Requirement Description	Tailoring
CS101 - Conducted Susceptibility	5V: Curve 2 with the following relaxation: 30Hz to 10kHz – 26dB 10kHz to 14.5kHz – 41dB 14.5kHz to 150kHz – 26dB
CS115 – Conducted Susceptibility, Impulse excitation	500 mA peak transient
CS116 - Conducted Susceptibility damped sinusoidal transients	Imax = 250 mA peak
RS103 - Radiated Susceptibility	100 V/M 2 MHz - 40 GHz
CE102 - Conducted Emissions	Basic curve with 20 dB relaxation
RE102 - Radiated Emissions	Fixed external wing with 20dB relaxation

3.5.2.8.1. Conducted Susceptibility

The Rate Sensor shall comply with the CS101, CS114 Curve 3, CS115 and CS116 requirements of MIL-STD-461F with tailoring per Table 17 - Tailoring of MIL-STD-461F EMI Requirements for systems using secondary regulated power. [RS_SRS_13059]

3.5.2.8.2. Radiated Susceptibility

The Rate Sensor shall comply with the RS103 requirements of MIL-STD-461F with tailoring per Table 17 - Tailoring of MIL-STD-461F EMI Requirements. [RS_SRS_13061]

3.5.2.8.3. Conducted Emissions

The Rate Sensor shall comply with the CE102 requirement of MIL-STD-461F as applied to the +5VDC power line with tailoring per Table 17 - Tailoring of MIL-STD-461F EMI Requirements. [RS_SRS_13063]

3.5.2.8.4. Radiated Emissions

The Rate Sensor shall comply with the RE102 requirements of MIL-STD-461F with tailoring per Table 17 - Tailoring of MIL-STD-461F EMI Requirements. [RS_SRS_13065]

3.5.2.9. Acoustic Noise

The RS shall survive and meet the performance requirements of this specification after exposure to the acoustic environment specified in Figure 13 - Acoustic Noise for 6 minutes. [RS_SRS_13511]

Frequency (Hz)	SPL (dB)
16	125.6
31.5	125.9
63	125.3
125	133.7
250	131.8
500	143
1000	141.6
2000	140.2
4000	133.8
8000	128.5
OASPL	147.24

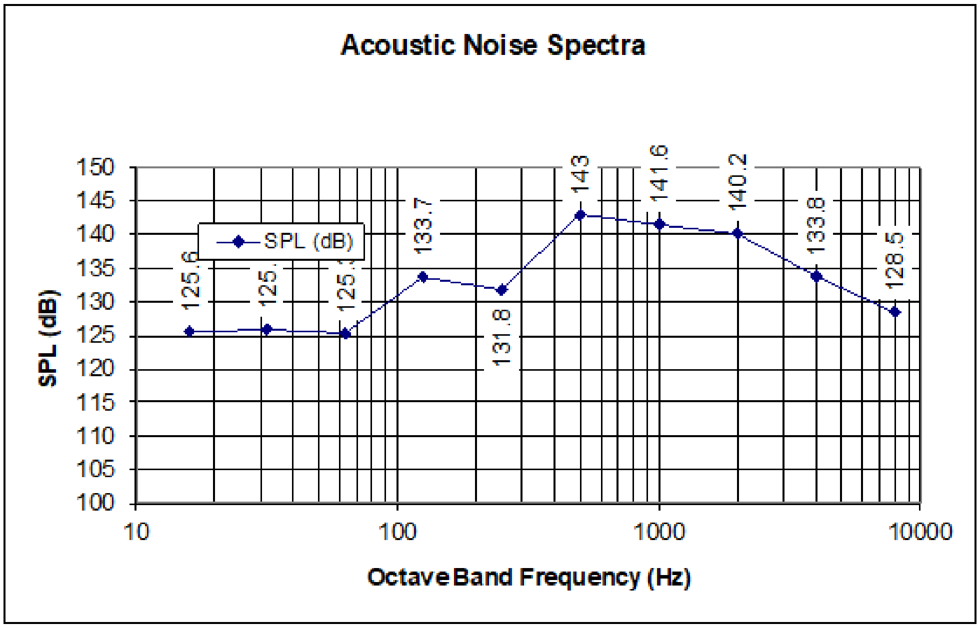


Figure 13 - Acoustic Noise

3.5.3. Radiation Effects

3.5.3.1. Mission Environment

The unit shall be designed to survive the mission exposure and to meet all performance requirements when operating in the natural space radiation environment defined in Table 18 - Natural Space Radiation Environment for Unit Design [RS_SRS_13316]

Table 18 - Natural Space Radiation Environment for Unit Design

Mission	
Mission Type:	Low Earth Orbit (LEO), polar
Orbital Parameters:	1100km circular x 87.9°
Mission life:	6 years
Dose Models	
Trapped electron fluence:	AE8, solar minimum
Trapped proton fluence:	AE8, solar minimum
Solar proton fluence:	ESP, 90% confidence
Single Event Effects (SEE) Models	
Galactic cosmic ray flux:	CREME96, solar minimum
Solar flare flux, average:	CREME96, worst day
Solar flare flux, peak:	CREME96, peak 5-minutes
Trapped proton flux:	AE8, solar minimum

The spacecraft structure shall provide a minimum of 2mm aluminum shielding (isotropic). [RS_SRS_13358]

3.5.3.2. Total Ionizing Dose (TID) and Displacement Damage (DD)

The Mission Deposited Dose for a component shall be defined as the cumulative dose deposited within the component's semiconductor die. [RS_SRS_13392]

Mission Deposited Dose shall be predicted for all semiconductor components using a ray-trace or Monte-Carlo shielding analysis and the mission radiation environment(s) of Table 18 - Natural Space Radiation Environment for Unit Design [RS_SRS_13393]

Radiation Tolerance shall be defined as the radiation exposure level at which a component or assembly's degraded parameters remain within the design's established End of Life (EOL) limits. [RS_SRS_13394]

Radiation Design Margin (RDM) shall be calculated using the formula

RDM = Radiation Tolerance / Mission Deposited Dose [RS_SRS_13395]

Note: Displacement Damage is also referred to as Total Non-Ionizing Dose (TNID).

3.5.3.2.1. Component Radiation Tolerance Rating and Degraded Parameters

Component Radiation Tolerance shall be established for all semiconductor part types via radiation testing. [RS_SRS_13401]

Industry accepted generic radiation tolerance levels based on process technology may be substituted for test data if the resulting RDM is not less than 10.

The cumulative effects of TID and DD degradation at the rated Radiation Tolerance level shall be evaluated to ensure that system End of Life (EOL) performance and reliability requirements are maintained. [RS_SRS_13402]

Degraded parameter endpoint limits shall be calculated using the one-sided lot tolerance method of MIL-HDBK-814 with a ≥90% survival probability at 90% confidence. [RS_SRS_13403]

3.5.3.2.2. Component Radiation Design Margin

All active semiconductor components shall possess a minimum RDM of 1.2. [RS_SRS_13404]

All active semiconductor components with 1.2 ≤ RDM < 2.0 shall be subject to Radiation Lot Acceptance Testing (RLAT) on the flight lot, unless the flight lot and qualification lot share the same manufacturer date code. [RS_SRS_13405]

Active semiconductor devices with RDM ≥ 2.0 shall be exempted from RLAT, regardless of flight lot date code. [RS_SRS_13406]

All other materials (non-EEE components) shall possess a RDM ≥ 1.0. [RS_SRS_13407]

3.5.3.3. Single Event Effects (SEE)

3.5.3.3.1. Component SEE

All semiconductor components shall be evaluated for SEE to a linear energy transfer (LET) of ≥60 MeV-cm^2/mg. [RS_SRS_13409]

Single Event Effects (SEE) hardening is accomplished through a combination of component selection and control and circuit/system design such that compliance to the unit functionality, performance, and reliability requirements is maintained.

All component single event effects shall be assessed to determine their impact to system performance. [RS_SRS_13411]

Component SEE shall be summed for each category listed in Table 19 - Single Event Effects RMTTF and MTBU Requirements to produce a total system SEE rate prediction. [RS_SRS_13412]

Predicted SEE rates shall comply with the minimum Radiation Mean Time To Failure (RMTTF) and recoverable Mean Time Between Upset (MTBU) requirements Table 19 - Single Event Effects RMTTF and MTBU Requirements [RS_SRS_13413]

Table 19 - Single Event Effects RMTTF and MTBU Requirements

Title	Description	Requirement	Units
RMTTF	Unrecoverable events caused by destructive SEE; or non-destructive SEE which render the unit nonfunctional (Category 1 SEE)	>100	years
MTBU, Recoverable SEE, Category 2	Persistent functional interruption requiring external intervention for recovery	>100	days
MTBU, Recoverable SEE, Category 3	Temporary functional interruption or out-of-specification unit performance with autonomous recovery	>1	days

The SEE analysis shall consider the worst day solar flare environment to ensure that error mitigation cannot be overwhelmed under worst-case particle flux conditions. [RS_SRS_13437]

3.5.3.3.2. Component Single Event Latchup (SEL) and Destructive SEE

Components susceptible to SEL, or damaging or destructive SEE shall not be used unless the unit reliability requirements can be met with the system total RMTTF incorporated into the unit reliability mean time to failure (MTTF) prediction [RS_SRS_13438]

If a component does not have sufficient test data to demonstrate SEL immunity to at least 40MeV-cm^2/mg, a worst-case bounding SEL rate shall be calculated and included in the analysis. [RS_SRS_13439]

3.5.3.3.3. Component Non-Damaging SEE

Non-damaging single event effects (e.g. SEU, SET, SEFI, etc.) which may result in unrecoverable effects to the unit (damage or failure) shall comply with the radiation mean time to failure (RMTTF) requirement of Table 19 - Single Event Effects RMTTF and MTBU Requirements. RMTTF predictions shall be calculated based on 6 years of exposure to the nominal solar minimum GCR and trapped proton flux. [RS_SRS_13440]

Non-damaging single event effects (e.g. SEU, SET, SEFI, etc.) which may cause recoverable performance degradation or functional interruption of the unit shall comply with the mean time between upset (MTBU) requirements of Table 19 - Single Event Effects RMTTF and MTBU Requirements. MTBU predictions shall be calculated based on 6 years of exposure to the nominal solar minimum GCR and trapped proton flux. [RS_SRS_13441]

3.5.3.4. Internal Charging

All conductive elements shall be assessed for internal charging per the guidelines of NASA-HDBK-4002A, NASA-HDBK-4006, or ECSS-E-ST-20-06C. [RS_SRS_13443]

The preferred approach for mitigating internal charging is establishing either a permanent electrical connection to DC ground or a conductive bleed path to DC or AC ground. If this approach is not feasible and the element must remain electrically floating, analysis shall be used to demonstrate that charging flux at the component complies with the maximum charging flux guidelines of NASA-HDBK-4002A, NASA-HDBK-4006, or ECSS-ET-ST-20-06C. [RS_SRS_13444]

3.6. Hardware Requirements

3.6.1. Identification and Marking

3.6.1.1. Non-Interference

Labels shall not interfere with equipment installation requirements as specified in the Rate Sensor drawing. [RS_SRS_11444]

3.6.1.2. Content

The information, as shown in accordance with Table 20 - Label Content, shall be marked on the exterior of the equipment using materials and/or processes that will ensure legibility during the life span of the Rate Sensor. [RS_SRS_11446]

Table 20 - Label Content

Equipment title
Supplier's Name
Supplier's Part Number
Supplier's serial number * - assigned in ascending order and non-repetitive for each article. Once assigned, serial numbers never change and are never reassigned. If an article goes out of existence (scrapped) the serial number goes out of existence as well
Year and month of manufacture*
ESD label
NOTE: * The date of manufacture and the supplier number may be combined into an eight digit serial number of the year, month and serial number. (i.e. 00 for year 2000, 09 for the month and xxxx for the serial number produces 0009xxxx)

3.6.2. Materials

3.6.2.1. PWB Materials

Laminate and prep materials shall conform to IPC-4101 'Specification for Base Materials for Rigid and Multilayer Printed Boards'. [RS_SRS_11788]

3.6.3. Parts

3.6.3.1. Electronic Parts

Selection and management of electronic parts shall be in accordance with Honeywell Aerospace policies and procedures per 2.1.3.G.R&CE101PSMP. Note: EB53000249-560 will be consulted for additional guidance on electronic part selection. [RS_SRS_12699]

3.6.3.2. Printed Wiring Assemblies

Printed wiring assemblies shall be designed to IPC/J-STD-001 class 3. [RS_SRS_12701]

3.6.3.3. Parts Derating

Electrical, electronic, and electromechanical (EEE) parts shall use Honeywell Derating Work Instruction 2.3.2.W.R&CE202Derate as a design goal and results shall be documented through the completion of a Parts Stress Analysis using work instruction 2.3.2.W.R&CE208Stress. [RS_SRS_12703]

If uprating of a part is required, the part shall be uprated per 2.1.3.W.R&CE107Uprating. [RS_SRS_12871]

3.6.3.4. Helium Insensitive Parts

The Rate Sensor shall use parts that are insensitive to direct exposure to Helium gas. [RS_SRS_14153]

Note: A part that is insensitive to Helium is a part that conforms to the requirements of its datasheet during and after direct exposure to Helium.

3.6.4. Build Process

Build processes shall be IAW ISO-9001. [RS_SRS_11790]

3.6.5. Soldering

All soldering shall conform to the requirements of IPC/J-STD-001 class 3. [RS_SRS_11792]

3.6.6. Outgassing

The outgassing of all materials external to the housing seal shall outgas Collected Volatile Condensable Mass (CVCM) of <0.1% when tested in accordance with ASTM E595-15, except the external connector potting material which has an exposed area of <2 square inches and may have a CVCM of 1% maximum. Note: See NASA-STD-6016 Rev. A, Rationale code 403 for reference. [RS_SRS_11794]

3.6.7. Mounting Interface

The Rate Sensor shall meet its requirements when mounted to a surface in contact with the entirety of the Rate Sensor's mounting interface with a contact conductance of at least 1000 W/m^2-°C. [RS_SRS_13460]

3.7. Software Processes and Verification

Software will be developed in accordance with Honeywell software development process.

3.8. Reliability, Maintainability, and Safety

3.8.1. Reliability

3.8.1.1. Mission Life

The Rate Sensor shall meet performance requirements for a minimum of 6.5 years mission life. Where mission life is defined as at least 6 years on-orbit and at least 0.5 year of Rate Sensor ground integration.

[RS_SRS_10983]

3.8.1.2. Probability of Success (Ps)

The Rate Sensor shall have a Probability of Success, Ps, against the 6 year reference mission >0.92 @ Temperature of 30°C in a Space Flight environment. [RS_SRS_13480]

3.8.1.3. FMECA Assessment

The Rate Sensor design shall be evaluated for a Failure Mode, Effect and Criticality Analysis (FMECA) in accordance with 2.3.2.W.R&CE204FMECA [RS_SRS_13155]

3.8.2. Maintainability

3.8.2.1. Testability

The Rate Sensor shall be designed to provide Built In Test hardware and software, test points, test isolation capability, the test connections, test coverage to isolate to a replaceable module and compatibility to interface to an independent test set. [RS_SRS_11777]

3.8.2.2. Periodic Maintenance

No periodic maintenance shall be required. [RS_SRS_11779]

3.8.2.3. Interchangeability

All Rate Sensors bearing the same part number shall be physically and functionally interchangeable with no need for additional calibration or adjustment. [RS_SRS_11781]

3.8.3. System Safety

The Rate Sensor hardware shall comply with controls identified in an Operating & Support Hazard Analysis (O&SHA) prepared using MIL-STD-882 and Honeywell Legacy Work Instruction 2.3.2.W.R&CE207OSHA for guidance and documented in a Safety Assessment Report (SAR). [RS_SRS_13781]

A safety assessment shall be conducted using MIL-STD-882, Honeywell Legacy Work Instruction 2.3.2.W.R&CE211SAR, and Honeywell's latest Standard Processes for guidance and documented in the SAR. [RS_SRS_13780]

The analysis shall also include an assessment and summary of any hazardous materials used in the Rate Sensor design and/or manufacturing process and summarized in the SAR. [RS_SRS_13782]

4. Quality Assurance

The development, build, and test of the Rate Sensors are performed in accordance with the Honeywell Aerospace Quality Manual (HAQM).

This section establishes the requirements for verification and testing of the Rate Sensor performance and design characteristics.

4.1. Methods of Verification

4.1.1. Verification

Compliance with the requirements of this specification shall be verified in accordance with Section 4.5 - Verification Matrix. [RS_SRS_11547]

4.1.2. Methods

All requirements of Section 3 shall be verified by inspection, analysis, demonstration, test, or a combination of these methods. [RS_SRS_11549]

4.1.3. Inspection

Inspection of the specified item includes review of material certifications, engineering or service documentation or visual observation of the unit.

4.1.4. Analysis

Analysis includes examination and interpretation of applicable engineering and/or test data by recognized analytical techniques to establish compliance with design requirements.

4.1.5. Demonstration

Demonstration includes verification by operation, movement and/or adjustment of the item under specified conditions to determine the functional performance of the item in a qualitative manner. The item may be instrumented, qualitative limits of performance may be monitored and data may be recorded, including defined human interaction.

4.1.6. Test

Test consists of repeatable experiments carried out under controlled and traceable conditions. Testing applies to identified performance related and non-performance design requirements that are specified in quantitative terms. This includes verification by systematically exercising an item under all appropriate condition with instrumentation, collection, analysis and evaluation of quantitative data.

4.1.7. Similarity

Compliance with specified requirements may be established using the results of testing performed on previously developed equipment provided that: 1) similarity exists between the previously tested equipment and the equipment described herein; and 2) the tests on the previously tested equipment satisfies the test requirement set forth herein.

Qualification by similarity shall be accomplished by reviewing certified test data to substantiate that: [RS_SRS_11559]

a) An item of equipment similar to the item or its component being evaluated has been successfully tested in accordance with the requirements herein.

b) The item or its components being evaluated does not incorporate differences that would invalidate the criteria of (a) above.

c) Comparison has been limited to a virtually identical item previously qualified by test or analysis. Qualification is to include documentation of the previous qualification and a detailed matrix of all the differences between the compared two (2) articles. Each difference is to be addressed by engineering analysis. Only first generation data is to be acceptable.

4.2. Qualification Test

Qualification tests shall be performed to demonstrate that the design meets the specified functional requirements. The requirements to be verified by qualification testing are identified in Section 4.5 - Verification Matrix. Testing shall be performed in accordance with test plans. [RS_SRS_11565]

4.3. Acceptance Test

Acceptance testing is the final test prior to shipment and completed in the customer protocol. Successful completion of this test constitutes approval and verification that the device has met requirements.

Requirements to be verified as part of the Acceptance Test Procedure (ATP) are listed in Section 4.5 - Verification Matrix.

Acceptance testing shall consist of an approximately 1-hour room temperature test and will be completed in the customer-defined protocol. [RS_SRS_11569]

4.4. Qualification Tests

A qualification verification test shall be performed which demonstrates that the requirements of this specification have been met. The tests shall include: Physical/mechanical requirements, Environmental requirements, software validation. Requirements to be verified as part of the qualification are listed in Section 4.5 - Verification Matrix. Prior to submittal for qualification tests, the Rate Sensor shall have met the acceptance test requirements specified in paragraph Section 4.3 - Acceptance Test and it shall meet those same requirements again after qualification testing. Unless otherwise specified, one Rate Sensor manufactured under the same conditions as those proposed for subsequent production shall be subjected to and pass the qualification tests specified herein. [RS_SRS_11571]

4.4.1. Guidance

This testing shall be performed in accordance with a Honeywell Engineering approved Qualification Test Plan. [RS_SRS_11573]

4.4.2. Reporting

A qualification test report shall be written following the completion of the tests. [RS_SRS_11575]

4.4.3. Non-Operating Environmental Tests

4.4.3.1. High Temperature

The Rate Sensor shall be tested at the high temperature specified in Section 3.5.1.1 - Temperature at Atmospheric Pressure and in accordance with MIL-STD-810, Method 501.3, Procedure I, except that the chamber temperature in step 3 shall be maintained for 24 hours after stabilization, and steps 4 and 5 shall be omitted. Operational performance of step 6 shall be satisfied by the performance test specified in Section 4.3 - Acceptance Test conducted with the Rate Sensor at standard ambient conditions. [RS_SRS_11587]

4.4.3.2. Low Temperature

The Rate Sensor shall be tested at the low temperature specified in Section 3.5.1.1 - Temperature at Atmospheric Pressure and in accordance with MIL-STD-810, Method 502.3, Procedure I, steps 1-3. The chamber temperature in step 3 shall be maintained for 24 hours after stabilization. Operational performance shall be satisfied by the performance test specified in Section 4.3 - Acceptance Test conducted at standard ambient conditions. [RS_SRS_11589]

4.4.3.3. Temperature Shock and Thermal Cycling

The Rate Sensor shall be tested at the high and the low temperatures specified in Section 3.5.1.3 - Temperature Shock in accordance with the MIL-STD-810, Method 503.3, except that the diurnal cycle shall be omitted and the Rate Sensor shall be maintained at the temperature extremes for four hours or until the Rate Sensor has been stabilized. Three cycles shall be used. Operational performance shall be satisfied by the performance test specified in Section 4.3 - Acceptance Test at standard ambient conditions. [RS_SRS_11591]

4.4.3.4. Vibration

The Rate Sensor shall be tested in accordance with MIL-STD-810 Method 514.4, Procedure I except that the test levels and duration used in step 5 shall be as specified in Figure 9 - Non-Operating Random Vibration. Subsequent to the vibration test, operational performance shall be satisfied by the performance test specified in Section 4.3 - Acceptance Test at standard ambient conditions. [RS_SRS_11593]

4.4.3.5. Shock

The Rate Sensor shall be tested in accordance with MIL-STD-810, Method 516.4, Procedure I, except the number of shocks and shock level shall meet the requirements specified in Figure 10 - Non-Operating Shock. Subsequently, operational performance shall be satisfied by the performance test specified in Section 4.3 - Acceptance Test at standard ambient conditions. [RS_SRS_11595]

4.4.3.6. Thermal Vacuum

The Rate Sensor shall be exposed to a thermal vacuum specified in Section 3.5.1.6 - Thermal Vacuum and tested with the profile below. Subsequent to TVAC exposure, operational performance shall be satisfied by the performance test specified in Section 4.3 - Acceptance Test. [RS_SRS_11600]

Table 21 - TVAC Profile

Parameter	Qualification
Minimum operating temperature	-40°C
Minimum (survival) non-operating temperature	-54°C
Maximum operating temperature	70°C
Maximum (survival) non-operating temperature	85°C
Minimum number of non-operating thermal vacuum cycles	1
Minimum number of operating thermal vacuum cycles	6
Temperature rate of change as measured at the baseplate	3°C/min (goal)
Vacuum requirement	$<10^{-4}$ Torr

4.4.3.7. Humidity

The Rate Sensor shall be tested at the humidity levels specified in Table 16 - Table of Environmental Conditions. Subsequent to humidity exposure, operational performance shall be satisfied by the performance test specified in Section 4.3 - Acceptance Test. [RS_SRS_13544]

4.4.4. Operating Environmental Tests

4.4.4.1. High Temperature

The Rate Sensor shall be tested at the high temperature specified in Section 3.5.2.1 - Temperature at Atmospheric Pressure and in accordance with MIL-STD-810, Method 501.3, Procedure II (Constant temperature exposure), except steps 16 and 17 shall be omitted. Step 10, operational checkout, shall be satisfied by a test for compliance with the requirements specified in Section 4.3 - Acceptance Test. [RS_SRS_11598]

4.4.4.2. Low Temperature

The Rate Sensor shall be tested at the low temperature specified in Section 3.5.2.1 - Temperature at Atmospheric Pressure and in accordance with MIL-STD-810, Method 502.3, Procedure II (Constant temperature exposure), except steps 10-12 shall be omitted. Step 4, operational checkout, shall be satisfied by a test for compliance with the requirements specified in Section 4.3 - Acceptance Test. [RS_SRS_11602]

4.4.4.3. Temperature Shock

The Rate Sensor shall be designed to operate in accordance with all requirements in this specification during and after a temperature shock as defined in Section 3.5.2.3 - Temperature Shock. Five temperature shocks shall be applied. Subsequent to thermal shock, operational performance shall be satisfied by the test specified in Section 4.3 - Acceptance Test. [RS_SRS_11604]

Note: Performance during temperature shock is assessed against 3σ limits.

4.4.4.4. Vibration

The Rate Sensor shall be tested in accordance with MIL-STD-810, Method 514.4, procedure I, except that the test levels and duration shall be as specified in the following paragraphs. [RS_SRS_11606]

4.4.4.4.1. Random Vibration

The Rate Sensor shall be vibrated as specified in Figure 11 - Operating Random Vibration. All Rate Sensor outputs shall be monitored for evidence of discontinuities, intermittency, or shorted output as determined by the BIT status. BIT failure shall be cause for rejection. Subsequently, operational performance shall be satisfied by the performance test specified in Section 4.3 - Acceptance Test at standard ambient conditions. [RS_SRS_11608]

4.4.4.5. Shock

The Rate Sensor shall be tested in accordance with MIL-STD-810, Method 516.4, procedure I except the number of shocks and shock level shall meet the requirements specified in Figure 12 - Operating Shock Profile. After all shocks have been performed, operational performance shall be satisfied by the test specified in Section 4.3 - Acceptance Test. [RS_SRS_11610]

4.4.4.6. Thermal Vacuum

The Rate Sensor performance during exposure to the thermal Vacuum specified in Section 3.5.2.6 - Thermal Vacuum shall be verified during TVAC testing with the following profile: [RS_SRS_11612]

Table 22 - TVAC Profile

Parameter	Qualification
Minimum operating temperature	-40°C
Minimum (survival) non-operating temperature	-55°C
Maximum operating temperature	70°C
Maximum (survival) non-operating temperature	85°C
Minimum number of non-operating thermal vacuum cycles	1

Parameter	Qualification
Minimum number of operating thermal vacuum cycles	6
Temperature rate of change as measured at the baseplate	3°C/min (goal)
Vacuum requirement	<10^{-4} Torr

4.4.4.7. Magnetic Field

The Rate Sensor shall be subjected to a magnetic field as defined in Table 16 - Table of Environmental Conditions. Device output shall be monitored during exposure to the magnetic field and verified for proper operation. Subsequent to exposure, the device shall be subjected to the tests as defined in Section 4.3 - Acceptance Test. [RS_SRS_11614]

4.4.4.8. Acoustic Noise

The Rate Sensor shall be designed to operate in accordance with all requirements in this specification during and after being exposed to an acoustic noise such that the sound field as monitored within a 1 inch of the RS case satisfies the levels of Figure 13 - Acoustic Noise. After acoustic noise test is performed, operational performance shall be satisfied by the test specified in Section 4.3 - Acceptance Test. [RS_SRS_13510]

4.4.5. Serial Data Interface

All signals, timing and data format of the serial interface shall be verified at standard ambient conditions. The test methods shall generally employ timing and signal verification using a logic analyzer, and data format validation using basic low-level software tools. [RS_SRS_11616]

4.4.6. Fault Detection and Correction

The Fault Detection and Correction function shall be verified through formal software test, circuit analysis, and system level Single Event Effect induced demonstration. [RS_SRS_13763]

4.4.7. Input Power

The specified maximum and minimum input power supply voltage shall be applied and currents shall be monitored to verify that the requirements specified in Section 3.2.3.1 - Input Power are met.

Verify the electrical isolation of Section 3.2.3.1.3 - Isolation is met. [RS_SRS_11618]

4.4.8. Electromagnetic Interference and Susceptibility Control

4.4.8.1. Electromagnetic Emissions

Verification of the emissions requirements specified in Section 3.5.2.8 - Electromagnetic Environmental Effects shall be by analysis or test in accordance with MIL-STD-461F. [RS_SRS_13068]

4.4.8.2. Electromagnetic Susceptibility

Verification of the susceptibility requirements as specified in Section 3.5.2.8 - Electromagnetic Environmental Effects shall be by analysis or test in accordance with MIL-STD-461F. [RS_SRS_13070]

4.4.9. Frequency Response

The bandwidth of the rate output shall be verified empirically by evaluation of the Power Spectral Density of the rate output while static on a pier. The phase delay will be verified by analysis of the rate the outputs filters. Combined this will verify the requirements specified in Section 3.3.1.13 - Frequency Response. [RS_SRS_11768]

4.4.10. Operating Range - Angular Rate Channels

Each angular rate inertial and flight control channel shall be exercised over its full input range per Section 3.3.1.2 - Operating Rate Range. [RS_SRS_11620]

4.4.11. Angular Rate Channel Scale Factors

The angular rate channel scale-factors shall be verified by applying static angular rates up to and including the specified operating range for both positive and negative inputs along the three principal Rate Sensor axes as shown in the Rate Sensor installation drawing. The data shall be analyzed to verify the rate-dependent requirements of Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables. [RS_SRS_11622]

4.4.12. Angular Rate Channel Random Walk

Using an appropriate test method, verify that the requirement specified in Section 3.3.1.12 - Angular Random Walk is met.

4.4.13. Activation Time

The requirements specified in Section 3.2.5.3 - Time to Performance shall be verified by test. The activation time for each channel is defined as the time after which all subsequent filtered data points fall within 3-sigma repeatability limits. [RS_SRS_11626]

4.4.14. Weight

Verify by measurement that the requirement specified in Section 3.4.1 - Weight is met.

4.4.15. Environmental Seal

Measure the helium leak rate of the environmental seal in a vacuum and demonstrate compliance with Section 3.4.4 - Environmental Seal.

4.4.16. Abbreviated Performance Test

Basic Rate Sensor inertial performance is verified by integrating the inertial angular rate channel outputs for 100 seconds. The Rate Sensor shall be mounted to a stable surface under quiescent conditions for the duration of the test. Earth's rate and one gravity provide the inertial input for the test. The magnitude of the vector sum of the accumulated angles from the three inertial angular rate channels shall be between 0.0 and 0.063 radian. [RS_SRS_11635]

4.4.17. Performance Test

Performance testing consists of a precision tumble test over the operating temperature range of the device. The data is analyzed to verify the applicable requirements of Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables.

4.4.18. Visual and Dimensional Inspections

Verify by inspection that the requirements pertaining to device physical characteristics are met.

4.4.19. High and Low Temperature Performance Test

Rate Sensor performance parameters that are substantially influenced by ambient temperature shall be verified with the device stabilized at the specified temperature limits. [RS_SRS_11642]

4.4.20. Component TID, DD, and SEE Qualification

Construction baseline equivalency shall be based on the die mask revision and component baseline requirements of EB53000249-560 (Electrical, Electronic, Electro-optical & Electromechanical Parts Control Plan for Commercial Space Programs), regardless of the proximity of qualification lot and flight lot manufacturing dates. [RS_SRS_13397]

TID, DD, and SEE qualification shall be performed on components with an equivalent construction baseline to flight material. [RS_SRS_13396]

TID degradation shall be evaluated for all active semiconductor part types. [RS_SRS_13398]

DD degradation shall be evaluated for all active semiconductor part types with cumulative mission fluence of 2E11 n/cm^2 (1 MeV) or greater per industry radiation hardness assurance guideline ECSS-Q-ST-60-15C. [RS_SRS_13399]

DD degradation shall be evaluated for all optical or opto-electronic part types regardless of cumulative mission fluence. [RS_SRS_13400]

SEE shall be evaluated for all semiconductor components. [RS_SRS_13800]

4.4.21. System TID, DD, and SEE Qualification

Note: System or assembly level testing may be used in place of, or as a supplement to, component TID and/or DD and/or SEE testing for verification of TID, DD, and SEE component qualification requirements.

4.4.22. Analytical Verification

Analytical verification should be used to verify Rate Sensor design parameters that are not readily testable.

4.4.23. Demonstration

Rate Sensor functional requirements not related to inertial performance should be verified by demonstration.

4.5. Verification Matrix

Verification Method

T - Test

I - Inspection

A - Analysis

D - Demonstration

Verification Level

ATP - Acceptance Test

Q - Qualification

Table 23 - Verification Table

Requirement	Verification Method (Test, Analysis, Inspection, Demonstration)				Verification Level		Section 4 Verification Requirement Paragraph
	T	A	I	D	Qual	Internal Testing/ATP	
Section 3 - Requirements	Title						
Section 3.1 - Item Definition	Title						
Section 3.2 - Electrical Interface	Title						
Section 3.2.1 - External System Connector Type and Location			X		X		Section 4.4.18 - Visual and Dimensional Inspections
Section 3.2.2 - External Connector Pin Assignments			X		X		Section 4.4.18 - Visual and Dimensional Inspections
Section 3.2.3 - External Electrical Inputs/Outputs	Title						

Requirement	Verification Method (Test, Analysis, Inspection, Demonstration)				Verification Level		Section 4 Verification Requirement Paragraph
Section 3.2.3.1 - Input Power	Title						
Section 3.2.3.1.1 - Characteristics	X				X		Section 4.4.7 - Input Power
Section 3.2.3.1.2 - Power Connection Equivalent Circuits		X			X		Section 4.4.22 - Analytical Verification
Section 3.2.3.1.3 - Isolation	X				X		Section 4.4.7 - Input Power
Section 3.2.3.1.4 - Chassis Ground Connection	Title						
Section 3.2.3.2 - Receive Clock	Title						
Section 3.2.3.3 - Serial Data Output	X			X	X		Section 4.4.5 - Serial Data Interface
Section 3.2.3.4 - Reset Input Discrete	X				X	A	Section 4.4.5 - Serial Data Interface
Section 3.2.4 - Serial Data Output Protocol	Title						
Section 3.2.4.1 - Serial Communications Controller (SCC) Interface	X	X	X	X	X		Section 4.4.5 - Serial Data Interface, Section 4.4.22 - Analytical Verification
Section 3.2.4.2 - Asynchronous Protocol	Title						
Section 3.2.4.2.1 - General Requirements	X	X			X		Section 4.4.5 - Serial Data Interface, Section 4.4.22 - Analytical Verification
Section 3.2.4.2.2 - Asynchronous 600 Hz Message Format	X				X		Section 4.4.5 - Serial Data Interface
Section 3.2.5 - Activation Timing and Built In Test (BIT)	X	X			X		Section 4.4.5 - Serial Data Interface, Section 4.4.22 - Analytical Verification
Section 3.2.5.1 - Serial Data Interface Activation	X				X	I	Section 4.4.5 - Serial Data Interface
Section 3.2.5.2 - BIT	Title						
Section 3.2.5.2.1 - Power-Up BIT	X	X			X		Section 4.4.22 - Analytical Verification

Requirement	Verification Method (Test, Analysis, Inspection, Demonstration)				Verification Level		Section 4 Verification Requirement Paragraph
Section 3.2.5.2.2 - Continuous BIT	X	X			X		Section 4.4.16 - Abbreviated Performance Test,
Section 3.2.5.3 - Time to Performance	X				X	I	Section 4.4.5 - Serial Data Interface
Section 3.2.6 - Rate Sensor Operational Modes	Title						
Section 3.2.6.1 - Watchdog Timer	X	X			X		Section 4.4.22 - Analytical Verification, Section 4.4.23 - Demonstration
Section 3.2.7 - Fault Detection and Correction (FDC)	X	X			X		Section 3.2.7 - Fault Detection and Correction (FDC)
Section 3.3 - Inertial Performance Specifications	Title						
Section 3.3.1 - Angular Rate Channel Performance	Title						
Section 3.3.1.1 - Angular Rate Channel Inertial and Control Tables	Title						
Section 3.3.1.2 - Operating Rate Range	X				X		Section 4.4.10 - Operating Range - Angular Rate Channels
Section 3.3.1.3 - Output Scale Factor	X	X			X	A	Section 4.4.11 - Angular Rate Channel Scale Factors, Section 4.4.17 - Performance Test, Section 4.4.19 - High and Low Temperature Performance Test, Section 4.4.22 - Analytical Verification
Section 3.3.1.4 - Scale Factor Linearity	X	X			X		Section 4.4.17 - Performance Test, Section 4.4.19 - High and Low Temperature Performance Test, Section 4.4.22 - Analytical Verification

Requirement	Verification Method (Test, Analysis, Inspection, Demonstration)				Verification Level		Section 4 Verification Requirement Paragraph
Section 3.3.1.5 - Scale Factor Repeatability	X	X			X	I	Section 4.4.17 - Performance Test, Section 4.4.19 - High and Low Temperature Performance Test, Section 4.4.22 - Analytical Verification
Section 3.3.1.6 - Scale Factor In-Run Stability	X	X			X		Section 4.4.11 - Angular Rate Channel Scale Factors, Section 4.4.17 - Performance Test, Section 4.4.19 - High and Low Temperature Performance Test, Section 4.4.22 - Analytical Verification
Section 3.3.1.7 - Scale Factor g Sensitivity		X			X		Section 4.4.22 - Analytical Verification
Section 3.3.1.8 - Bias Repeatability	X	X			X	I	Section 4.4.17 - Performance Test, Section 4.4.19 - High and Low Temperature Performance Test, Section 4.4.22 - Analytical Verification
Section 3.3.1.9 - Bias In-Run Stability	X	X			X	I	Section 4.4.17 - Performance Test, Section 4.4.19 - High and Low Temperature Performance Test, Section 4.4.22 - Analytical Verification
Section 3.3.1.10 - Bias Static g Sensitivity	X	X			X	I	Section 4.4.17 - Performance Test, Section 4.4.19 - High and Low Temperature Performance Test, Section 4.4.22 - Analytical Verification
Section 3.3.1.11 - Output Noise	X	X			X	A	Section 4.4.17 - Performance Test, Section 4.4.22 - Analytical Verification
Section 3.3.1.12 - Angular Random Walk	X				X	I	Section 4.4.11 - Angular Rate Channel Scale Factors, Section 4.4.17 - Performance Test, Section 4.4.19 - High and Low Temperature Performance Test,

Requirement	Verification Method (Test, Analysis, Inspection, Demonstration)				Verification Level		Section 4 Verification Requirement Paragraph
Section 3.3.1.13 - Frequency Response	X	X			X		Section 4.4.9 - Frequency Response, Section 4.4.22 - Analytical Verification
Section 3.3.1.15 - Axes Alignment Stability	X	X			X	I	Section 4.4.22 - Analytical Verification
Section 3.3.1.16 - Axes Alignment Stability (Non-Orthogonality)	X	X			X	I	Section 4.4.22 - Analytical Verification
Section 3.3.1.17 - Mount to Mount Repeatability		X			X		Section 4.4.22 - Analytical Verification
Section 3.4 - Physical Characteristics	Title						
Section 3.4.1 - Weight	X		X	X	X		Section 4.4.14 - Weight, Section 4.4.18 - Visual and Dimensional Inspections, Section 4.4.23 - Demonstration
Section 3.4.2 - Size			X	X	X		Section 4.4.18 - Visual and Dimensional Inspections, Section 4.4.23 - Demonstration
Section 3.4.3 - Input Axis and Rate Sensor Mounting Provisions	X		X	X	X	A	Section 4.4.18 - Visual and Dimensional Inspections, Section 4.4.23 - Demonstration
Section 3.4.4 - Environmental Seal	X	X			X	I	Section 4.4.15 - Environmental Seal, Section 4.4.22 - Analytical Verification
Section 3.4.5 - Center of Gravity and Center of Navigation	Title						
Section 3.4.6 - ESD	Title						
Section 3.5 - Environmental Specifications	Title						
Section 3.5.1 - Non-Operating Environments	Title						
Section 3.5.1.1 - Temperature at Atmospheric Pressure	X				X		Section 4.4.3.1 - High Temperature, Section 4.4.3.2 - Low Temperature

Requirement	Verification Method (Test, Analysis, Inspection, Demonstration)				Verification Level		Section 4 Verification Requirement Paragraph
Section 3.5.1.2 - Baseplate Temperature in Vacuum	X				X		Section 4.4.3.1 - High Temperature, Section 4.4.3.2 - Low Temperature
Section 3.5.1.3 - Temperature Shock	X				X		Section 4.4.3.3 - Temperature Shock and Thermal Cycling
Section 3.5.1.4 - Vibration	X				X		Section 4.4.3.4 - Vibration
Section 3.5.1.5 - Shock	X				X		Section 4.4.3.5 - Shock
Section 3.5.1.6 - Thermal Vacuum	X				X		Section 4.4.3.6 - Thermal Vacuum
Section 3.5.1.7 - Humidity	X				X		Section 4.4.3.7 - Humidity
Section 3.5.2 - Operating Environments	Title						
Section 3.5.2.1 - Temperature at Atmospheric Pressure	X				X		Section 4.4.4.1 - High Temperature, Section 4.4.4.2 - Low Temperature
Section 3.5.2.2 - Baseplate Temperature in Vacuum	X				X		Section 4.4.4.1 - High Temperature, Section 4.4.4.2 - Low Temperature
Section 3.5.2.3 - Temperature Shock	X				X		Section 4.4.4.3 - Temperature Shock
Section 3.5.2.4 - Random Vibration	X				X		Section 4.4.4.4 - Vibration
Section 3.5.2.5 - Shock	X				X		Section 4.4.4.5 - Shock
Section 3.5.2.6 - Thermal Vacuum	X				X		Section 4.4.4.6 - Thermal Vacuum
Section 3.5.2.9 - Acoustic Noise	X				X		Section 4.4.4.8 - Acoustic Noise
Section 3.5.3 - Radiation Effects	Title						
Section 3.5.3.1 - Mission Environment		X			X		Section 4.4.22 - Analytical Verification
Section 3.5.3.2 - Total Ionizing Dose (TID) and Displacement Damage (DD)	X	X			X		Section 4.4.22 - Analytical Verification, Section 4.4.20 - Component TID, DD, and SEE Qualification, Section 4.4.21 - System TID, DD, and SEE Qualification

Requirement	Verification Method (Test, Analysis, Inspection, Demonstration)				Verification Level		Section 4 Verification Requirement Paragraph
Section 3.5.3.2.1 - Component Radiation Tolerance Rating and Degraded Parameters	X	X	X		X		Section 4.4.20 - Component TID, DD, and SEE Qualification, Section 4.4.21 - System TID, DD, and SEE Qualification
Section 3.5.3.2.2 - Component Radiation Design Margin	X	X			X		Section 4.4.20 - Component TID, DD, and SEE Qualification, Section 4.4.21 - System TID, DD, and SEE Qualification
Section 3.5.3.3 - Single Event Effects (SEE)	Title						
Section 3.5.3.3.1 - Component SEE	X	X			X		Section 4.4.20 - Component TID, DD, and SEE Qualification, Section 4.4.21 - System TID, DD, and SEE Qualification, Section 4.4.22 - Analytical Verification
Section 3.5.3.3.2 - Component Single Event Latchup (SEL) and Destructive SEE		X			X		Section 4.4.20 - Component TID, DD, and SEE Qualification, Section 4.4.21 - System TID, DD, and SEE Qualification, Section 4.4.22 - Analytical Verification
Section 3.5.3.3.3 - Component Non-Damaging SEE		X			X		Section 4.4.20 - Component TID, DD, and SEE Qualification, Section 4.4.21 - System TID, DD, and SEE Qualification, Section 4.4.22 - Analytical Verification
Section 3.5.3.4 - Internal Charging		X			X		Section 4.4.22 - Analytical Verification
Section 3.5.2.7 - Magnetic Field	X				X		Section 4.4.4.7 - Magnetic Field
Section 3.5.2.8 - Electromagnetic Environmental Effects	Title						
Section 3.5.2.8.1 - Conducted Susceptibility	X				X		Section 4.4.8.2 - Electromagnetic Susceptibility

Requirement	Verification Method (Test, Analysis, Inspection, Demonstration)				Verification Level		Section 4 Verification Requirement Paragraph
Section 3.5.2.8.2 - Radiated Susceptibility	X				X		Section 4.4.8.2 - Electromagnetic Susceptibility
Section 3.5.2.8.3 - Conducted Emissions	X				X		Section 4.4.8.1 - Electromagnetic Emissions
Section 3.5.2.8.4 - Radiated Emissions	X				X		Section 4.4.8.1 - Electromagnetic Emissions
Section 3.6 - Hardware Requirements	Title						
Section 3.6.1 - Identification and Marking	Title						
Section 3.6.1.1 - Non-Interference			X		X		Section 4.4.18 - Visual and Dimensional Inspections
Section 3.6.1.2 - Content			X		X		Section 4.4.18 - Visual and Dimensional Inspections
Section 3.6.2 - Materials	Title						
Section 3.6.2.1 - PWB Materials			X		X		Section 4.4.18 - Visual and Dimensional Inspections
Section 3.6.3 - Parts	Title						
Section 3.6.3.1 - Electronic Parts			X		X		Section 4.4.18 - Visual and Dimensional Inspections
Section 3.6.3.2 - Printed Wiring Assemblies			X		X		Section 4.4.18 - Visual and Dimensional Inspections
Section 3.6.3.3 - Parts Derating			X		X		Section 4.4.18 - Visual and Dimensional Inspections
Section 3.6.4 - Build Process			X		X		Section 4.4.18 - Visual and Dimensional Inspections
Section 3.6.5 - Soldering			X		X		Section 4.4.18 - Visual and Dimensional Inspections
Section 3.6.6 - Outgassing			X		X		Section 4.4.18 - Visual and Dimensional Inspections
Section 3.6.7 - Mounting Interface		X			X		

Requirement	Verification Method (Test, Analysis, Inspection, Demonstration)				Verification Level		Section 4 Verification Requirement Paragraph
Section 3.7 - Software Processes and Verification		X			X		Section 4.4.22 - Analytical Verification
Section 3.8 - Reliability, Maintainability, and Safety	Title						
Section 3.8.1 - Reliability	Title						
Section 3.8.1.1 - Mission Life		X			X		Section 4.4.22 - Analytical Verification
Section 3.8.1.2 - Probability of Success (Ps)		X			X		Section 4.4.22 - Analytical Verification
Section 3.8.1.3 - FMECA Assessment		X			X		Section 4.4.22 - Analytical Verification
Section 3.8.2 - Maintainability	Title						
Section 3.8.2.1 - Testability		X			X		Section 4.4.22 - Analytical Verification
Section 3.8.2.2 - Periodic Maintenance		X			X		Section 4.4.22 - Analytical Verification
Section 3.8.2.3 - Interchangeability		X			X		Section 4.4.22 - Analytical Verification
Section 3.8.3 - System Safety		X			X		Section 4.4.22 - Analytical Verification

5. Preparation for Delivery

5.1. Preservation, Packaging, and Packing

Packaging for delivery shall be in accordance with ASTM D3951 “Standard Practice for Commercial Packaging”.

Note: For long term storage it is recommended that the RS be stored under controlled lab like conditions with temperature maintained between 5° to 30°C and humidity maintained between 40% to 70%RH. [RS_SRS_12870]

6. Notes

6.1. Changes

Engineering changes shall be classified as Class I changes or Class II changes. Class I changes are defined as any design change which affects the form, fit or function of the RS or any changes which causes the RS not to conform to any of the requirement in design, material or processes specified herein. All other changes are classified as Class II changes. [RS_SRS_13765]

6.2. Definition of Performance Parameters

The following paragraphs define the performance parameters as they apply to this specification. These definitions are used when measuring and reporting performance of the Rate Sensor.

6.2.1. Gyro Performance Parameters

Gyro performance definitions in this section apply to the body angular rate (ω_b) and incremental angle ($\Delta\Theta$) outputs of the Rate Sensor. Note that the $\Delta\Theta$ outputs are equivalent to an angular rate output when divided by the corresponding output sampling interval Δt. The $\Delta\Theta$ and ω_b are computed from the same basic sensor measurements, but the ω_b outputs may be digitally filtered in the Rate Sensor to shape the frequency response and reduce noise. In addition, the ω_b output will not incorporate coning corrections.

6.2.1.1. Gyro Bias Error

The deterministic component of gyro output measured at specified operating conditions that has no correlation with input rotation or acceleration. Bias is typically expressed in °/hr.

6.2.1.1.1. Gyro Bias Stability (In Run Stability)

In-run gyro bias stability is a measure of random variation in bias as computed over a specified sample time and averaging time interval. This non-stationary (evolutionary) process is characterized by 1/f power spectral density. It is typically expressed in °/hr.

6.2.1.1.2. Gyro Bias Repeatability

Gyro bias repeatability is defined as the residual output bias error after calibration and internal compensation, including the effects of turn-off and turn-on, time, radiation, and temperature variations. This measure represents the statistical expected value for output bias error at any given time and thermal condition.

6.2.1.2. Gyro Output Scale Factor

Gyro output scale factor is a measure of the change in the slope of the straight line that can be fitted by the method of least squares of the angular rate input-output data. It is defined as ppm error of the output.

6.2.1.2.1. Gyro Scale Factor Repeatability

Gyro SF repeatability is defined as the residual output SF error, as defined in Section 6.2.1.2 - Gyro Output Scale Factor, after calibration and internal compensation, including the effects of turn-off and turn-on, time, radiation, and temperature variations. The repeatability error is expressed in ppm of the output angular rate.

6.2.1.2.2. Gyro Scale Factor Linearity

Gyro SF linearity is a measure of the one sigma deviation of the output from the least squares linear fit of the input-output data expressed in ppm of the output.

6.2.1.2.3. Gyro Scale Factor In-Run Stability

In-run gyro scale factor stability is a measure of random variation in the sensitivity of the gyro. It is typically assessed at a constant temperature and constant angular rate. The instability is found at the minimum of the Allan Deviation. It is expressed in ppm.

6.2.1.3. Gyro Noise (Angle Random Walk)

Gyro noise can consist of multiple types that are typically differentiated from each other by their spectral content. The most significant type is often the angular random walk (ARW), which is characterized as the relatively wide band (i.e. “white”) noise on angular rate output. ARW is the angular error buildup with time due to white noise in angular rate expressed in $°/\sqrt{hr}$.

6.2.1.4. Gyro Frequency Response

The gyro frequency response is defined as the total Rate Sensor transfer function, from angular rate input to digital rate data (rate or $\Delta\Theta$) output. This includes the isolator, the actual rate sensor, the Rate Sensor processing delay, any incorporated filters, the sampling effect of the output message rate, and the transport lag for the serial transmission.

6.2.1.5. Gyro Operating Rate Range

Gyro operating rate range is the maximum angular rate input in both directions to which the Rate Sensor rate output (rate or $\Delta\Theta$) performance parameters apply.

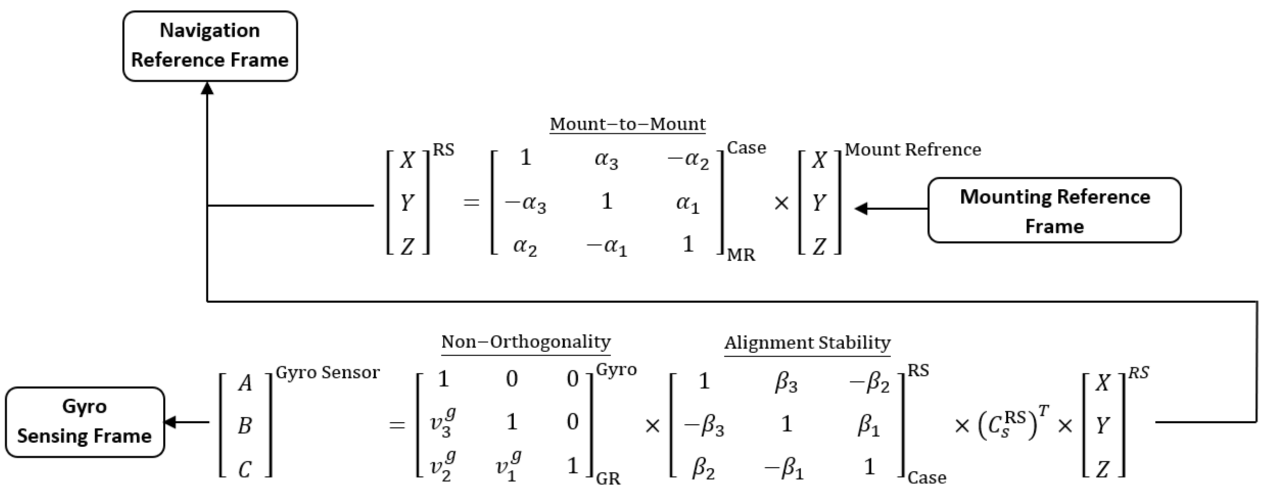
6.2.1.6. Rate Sensor Alignment

The mathematical Rate Sensor alignment error model is shown in Figure 14 - Rate Sensor Alignment Error Model. It consists of Mount-to-Mount, Axes Alignment Stability to Case, and Axes Non-Orthogonality error components.

Mount-to-Mount is a largely temperature-independent alignment error due to Rate Sensor mounting pin-hole diameter and positional tolerance and Rate Sensor housing flatness and angularity.

Axes Alignment Stability to Case is a largely temperature-dependent gyro reference frame alignment error due to the rigid motion of the Rate Sensor on its isolation system.

Axes Non-Orthogonality is largely a temperature-dependent alignment error with respect to the orthogonal gyro reference frame due to residual (uncompensated) motion of the individual gyro mounting surfaces with respect to each other.



$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}^{RS} = \underbrace{\begin{bmatrix} 1 & \alpha_3 & -\alpha_2 \\ -\alpha_3 & 1 & \alpha_1 \\ \alpha_2 & -\alpha_1 & 1 \end{bmatrix}_{MR}^{Case}}_{\text{Mount-to-Mount}} \times \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}^{\text{Mount Refrence}}$$

$$\begin{bmatrix} A \\ B \\ C \end{bmatrix}^{\text{Gyro Sensor}} = \underbrace{\begin{bmatrix} 1 & 0 & 0 \\ v_3^g & 1 & 0 \\ v_2^g & v_1^g & 1 \end{bmatrix}_{GR}^{Gyro}}_{\text{Non-Orthogonality}} \times \underbrace{\begin{bmatrix} 1 & \beta_3 & -\beta_2 \\ -\beta_3 & 1 & \beta_1 \\ \beta_2 & -\beta_1 & 1 \end{bmatrix}_{Case}^{RS}}_{\text{Alignment Stability}} \times \left(C_s^{RS}\right)^T \times \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}^{RS}$$

C_s^{RS}= Nominal Gyro Sensor-to-Rate Sensor Body Transformation

GR = Gyro Reference Frame (Orthogonal)

*Error matrices are small-angle approximations

Figure 14 - Rate Sensor Alignment Error Model

6.3. Definitions of Abbreviations, Acronyms, and Symbols Used

Table 24 - Definitions of Abbreviations, Acronyms, and Symbols Used

Abbreviation / Acronym / Symbol	Definition
% of FS	percent of full scale
amp	Ampere
ARW	angular random walk
ASIC	Application Specific Integrated Circuit

Abbreviation / Acronym / Symbol	Definition
ATP	Acceptance Test Procedure
BIT	Built-In Test
CBIT	Continuous BIT
CG	Center of Gravity
CMOS	Complementary Metal Oxide Semiconductor
CON	Center of Navigation
CRC	Cyclic Redundancy Check
CVCM	Collected Volatile Condensable Mass
°C	degree Celsius
dB	decibel
DD	Displacement Damage
DS	Design Specification
EEE	Electrical, Electronic, and Electromechanical
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FDC	Fault Detection and Correction
FMECA	Failure Mode, Effect and Criticality Analysis
g	gravity units
GCR	Galactic Cosmic Ray
HAQM	Honeywell Aerospace Quality Manual
Hz	Hertz
ISO	International Organization for Standardization
lbs	pounds
LEO	Low Earth Orbit
LET	Linear Energy Transfer
LS	Least Significant
LSB	Least Significant Bit
LVCMOS	Low Voltage Complementary Metal Oxide Semiconductor
mA	milliAmpere
max	maximum
mg	milli-g's
min	minimum
mrad	milliradians

Abbreviation / Acronym / Symbol	Definition
ms	millisecond
MTBU	Mean Time Between Upset
MTTF	Mean Time To Failure
mV	millivolt
N/A	Not Applicable
PBIT	Power up BIT
p-p	peak to peak value
Ps	Probability of Success
PSD	Power Spectral Density
PWB	Printed Wiring Board
RAM	Random-Access Memory
RDM	Radiation Design Margin
RLAT	Radiation Lot Acceptance Testing
RMTTF	Radiation Mean Time To Failure
ROM	Read-Only Memory
RS	Rate Sensor
SAR	Safety Assessment Report
SEE	Single Event Effect
SF	Scale Factor
SEFI	Single Event Functional Interrupt
SEL	Single Event Latchup
SEU	Single Event Upset
SRS	Shock Response Spectrum
TID	Total Ionizing Dose
TVAC	Thermal Vacuum
UART	Universal Asynchronous Receiver-Transmitter
μrad	microradian
μs	microsecond
V	Volt
VDC	Volt Direct Current
WDT	Watch Dog Timer