Tactical Grade
Ten Degrees of Freedom Inertial Sensor

Data Sheet **KT-EX9-2**

FEATURES

Triaxial, digital gyroscope, ±450°/sec dynamic range
±0.05° orthogonal alignment error ,4.0°/hr in -run bias stability ,0.26°/√hr angular random walk, 0.01% nonlinearity
Triaxial, digital accelerometer, ±18 g
Triaxial, delta angle and delta velocity outputs
Triaxial, digital magnetometer, ±2.5 gauss
Digital pressure sensor, 300 mbar to 1100 mbar
Factory-calibrated sensitivity, bias, and axial alignment
Operating and calibration temperature range: −45℃ to +85 ℃
SPI-compatible serial interface
Programmable operation and control
4 FIR filter banks, 120 configurable taps
Digital input/output: data-ready alarm indicator, optional external sample clock up to 2.4 kHz
Alarms for condition monitoring
Single-supply operation: 3.0 V to 3.6 V
10000 g shock survivability

GENERAL DESCRIPTION

The KT-EX9-2 device is a complete inertial system that includes a triaxis gyroscope, a triaxis accelerometer, triaxis magnetometer, and pressure sensor. Each inertial sensor in the KT-EX9-2 combines industry-leading technology with signal conditioning that optimizes dynamic performance. The factory calibration characterizes each sensor for sensitivity, bias, alignment, and linear acceleration (gyroscope bias). As a result, each sensor has its own dynamic compensation formulas that provide accurate sensor measurements. The KT-EX9-2 adopts a technical solution of internal shock absorption design in a closed chamber, and the inertial sensors are packaged in a vacuum ceramic shell. These measures greatly improve the product's noise acoustic resistance.

The KT-EX9-2 provides a simple, cost-effective method for integrating accurate, multiaxis inertial sensing into industrial systems, especially when compared with the complexity and investment associated with discrete designs. All necessary motion testing and calibration are part of the production process at the factory, greatly reducing system integration time.

The KT-EX9-2 is packaged in a module that is approximately 47 mm × 44 mm × 14 mm and includes a standard connector interface.

APPLICATIONS

Platform stabilization and control
Navigation
Personnel tracking
Instrumentation
Robotics

FUNCTIONAL BLOCK DIAGRAM

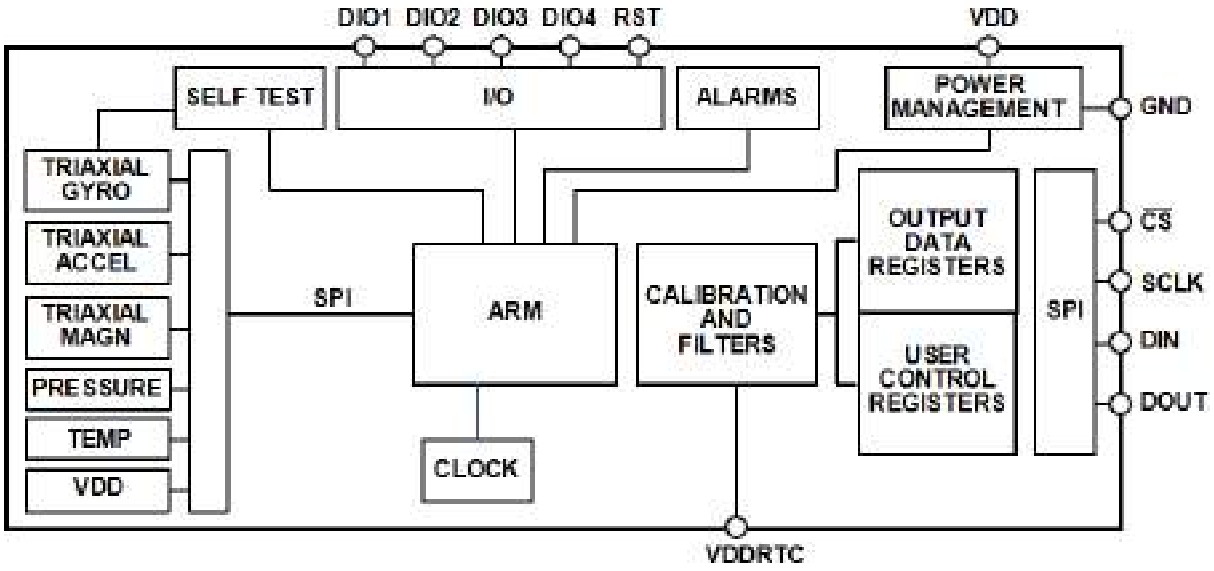

Figure 1.Functional Block Diagram

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REVISION HISTORY

12/2023—Revision A: Initial Version

SPECIFICATIONS

T_C = 25°C, VDD = 3.3 V, angular rate = 0°/sec, dynamic range = ±450°/sec, ±1 g, 300 mbar to 1100 mbar, unless otherwise noted.

Table 1. Specifications

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
GYROSCOPES					
Dynamic Range		±450		±510	°/sec
Sensitivity	x_GYRO_OUT and x_GYRO_LOW (32-bit)		3.052×10^{-7}		°/sec/LSB
Repeatability[1]	−45°C ≤ T_C ≤ +85°C			0.02	%
Sensitivity Temperature Coefficient	−45°C ≤ T_C ≤ +85°C, 1 σ		±10		ppm/°C
Misalignment	Axis to axis		±0.03		Degrees
	Axis to frame (package)		±0.03		Degrees
Nonlinearity	Best fit straight line, FS = 450°/sec		0.01		% of FS
Bias Repeatability[1, 2]	−45°C ≤ T_C ≤ +85°C, 1 σ		0.016		°/sec
In-Run Bias Stability	1 σ		4.0		°/hr
Angular Random Walk	1 σ		0.26		°/√hr
Bias Temperature Coefficient	−45°C ≤ T_C ≤ +85°C, 1 σ		±0.00025		°/sec/°C
Linear Acceleration Effect on Bias	Any axis, 1 σ (CONFIG[7] = 1)		0.003		°/sec/ *g*
Output Noise	No filtering		0.1		°/sec rms
Rate Noise Density	f = 10 Hz to 40 Hz, no filtering		0.0049		°/sec/√Hz rms
3 dB Bandwidth			330		Hz
Sensor Resonant Frequency			22		kHz
ACCELEROMETERS	Each axis				
Dynamic Range		±18		±20	g
Sensitivity	x_ACCL_OUT and x_ACCL_LOW (32-bit)		1.221×10^{-8}		*g*/LSB
Repeatability[1]	−45°C ≤ T_C ≤ +85°C			±0. 02	%
Sensitivity Temperature Coefficient	−45°C ≤ T_C ≤ +85°C, 1 σ		±5		ppm/°C
Misalignment	Axis to axis		±0.06		Degrees
	Axis to frame (package)		±0.06		Degrees
Nonlinearity	Best fit straight line, ±10 *g*		0.05		% of FS
	Best fit straight line, ±18 *g*		0.08		% of FS
Bias Repeatability[1, 2, 3]	−45°C ≤ T_C ≤ +85°C, 1 σ		5		m*g*
In-Run Bias Stability	1 σ		0.01		m*g*
Velocity Random Walk	1 σ		0.007		m/sec/√hr
Bias Temperature Coefficient	−45°C ≤ T_C ≤ +85°C		±0.025		m*g*/°C
Output Noise	No filtering		1		m*g* rms
Noise Density	f = 10 Hz to 40 Hz, no filtering		0.088		m*g*/√Hz rms
3 dB Bandwidth			330		Hz
Sensor Resonant Frequency			5.5		kHz
MAGNETOMETER					
Dynamic Range		±2.5			gauss
Sensitivity			0.1		mgauss/LSB

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
Initial Sensitivity Tolerance				±2	%
Sensitivity Temperature Coefficient	KT-EX9-2, −45℃ ≤ T_C ≤ +85℃, 1 σ		60		ppm/℃
Misalignment	Axis to axis		0.35		Degrees
	Axis to frame (package)		1.0		Degrees
Nonlinearity	Best fit straight line		0.5		% of FS
Initial Bias Error	0 gauss stimulus		±15		mgauss
Bias Temperature Coefficient	KT-EX9-2, −45℃ ≤ T_C ≤ +85℃, 1 σ		0.03		mgauss/℃
Output Noise	No filtering		0.22		mgauss rms
Noise Density	f = 2 Hz to 5 Hz, no filtering		0.042		mgauss/√Hz
3 dB Bandwidth			330		Hz
BAROMETER					
Pressure Range		300		1100	mbar
	Extended	10		1200	mbar
Sensitivity	BAROM_OUT and BAROM_LOW (32-bit)		6.1×10^{-7}		mbar/LSB
Total Error			4.5		mbar
Relative Error[4]	−45℃ ≤ T_C ≤ +85℃		2.5		mbar
Nonlinearity[5]	Best fit straight line, FS = 1100 mbar		0.1		% of FS
	−45℃ ≤ T_C ≤ +85℃		0.2		% of FS
Linear-*g* Sensitivity	±1 *g*, 1 σ		0.005		mbar/g
TEMPERATURE SENSOR					
Scale Factor	Output = 0x0000 at 25℃ (±5℃)		0.00565		℃/LSB
LOGIC INPUTS[6]					
Input High Voltage, V_{IH}		2.0			V
Input Low Voltage, V_{IL}				0.8	V
Logic 1 Input Current, I_{IH}	V_{IH} = 3.3 V			10	µA
Logic 0 Input Current, I_{IL}	V_{IL} = 0 V				
All Pins Except RST and CS				10	µA
RST and CS Pins[7]			0.33		mA
Input Capacitance, C_{IN}			10		pF
DIGITAL OUTPUTS					
Output High Voltage, V_{OH}	I_{SOURCE} = 0.5 mA	2.4			V
Output Low Voltage, V_{OL}	I_{SINK} = 2.0 mA			0.4	V
FLASH MEMORY	Endurance[8]	100,000			Cycles
Data Retention[9]	T_J = 85℃	20			Years
FUNCTIONAL TIMES[10]	Time until data is available				
Power-On Start-Up Time			1000		ms
Reset Recovery Time[11]			500		ms
Flash Memory					
Update Time			375		ms
Test Time			50		ms
CONVERSION RATE			2.46		kSPS
Initial Clock Accuracy			0.01		%

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
Temperature Coefficient			20		ppm/℃
Sync Input Clock		0.7[12]		2.4	kHz
POWER SUPPLY, VDD	Operating voltage range	3.0		3.6	V
Power Supply Current[13]	Normal mode, VDD = 3.3 V, μ ± σ		60		mA
POWER SUPPLY, VDDRTC	Operating voltage range	3.0		3.6	V
Real-Time Clock Supply Current	Normal mode, VDDRTC = 3.3 V		13		μA

[1] The repeatability specifications represent analytical projections based on the following drift contributions and conditions: temperature hysteresis (−45℃ to +85℃), electronics drift (high temperature operating life test: +110℃, 500 hours), drift from temperature cycling, rate random walk and broadband noise.

[2] Bias repeatability describes a long-term behavior over a variety of conditions. Short-term repeatability relates to the in-run bias stability and noise density specifications.

[3] X-ray exposure can degrade this performance metric.

[4] The relative error assumes that the initial error, at 25℃, is corrected in the end application.

[5] Specification assumes a full scale (FS) of 1000 mbar.

[6] The digital input/output signals use a 3.3 V system.

[7] RST and CS pins are connected to the VDD pin through 10 kΩ pull-up resistors.

[8] Measured at −45℃, +25℃, +85℃.

[9] Data retention lifetime decreases with TJ.

[10] These times do not include thermal settling and internal filter response times, which may affect overall accuracy.

[11] The RST line must be in a low state for at least 10 μs to assure a proper reset initiation and recovery.

[12] Device functions at clock rates below 0.7 kHz, but at reduced performance levels.

[13] Supply current transients can reach 800 mA(200us) during initial start up or reset recovery.

TIMING SPECIFICATIONS

TC = 25℃, VDD = 3.3 V, unless otherwise noted.

Table 2. Timing Specifications

Parameter	Description	Normal Mode			Unit
		Min[1]	Typ	Max[1]	
f_{SCLK}	Serial clock	4		16	MHz
t_{STALL}[2]	Stall period between data	2			µs
t_{CLS}	Serial clock low period	31			ns
t_{CHS}	Serial clock high period	31			ns
t_{CS}	Chip select to clock edge	32			ns
t_{DAV}	DOUT valid after SCLK edge			10	ns
t_{DSU}	DIN setup time before SCLK rising edge	2			ns
t_{DHD}	DIN hold time after SCLK rising edge	2			ns
t_{DR}, t_{DF}	DOUT rise/fall times, ≤100 pF loading		3	8	ns
t_{DSOE}	CS assertion to data out active	0		11	ns
t_{HD}	SCLK edge to data out invalid	0			ns
t_{SFS}	Last SCLK edge to CS deassertion	32			ns
t_{DSHI}	CS deassertion to data out high impedance	0		9	ns
t_1	Input sync pulse width	5			µs
t_2	Input sync to data invalid		490		µs
t_3	Input sync period	417			µs

[1] Guaranteed by design and characterization, but not tested in production.

[2] See Table 3 for exceptions to the stall time rating.

Table 3. Register Specific Stall Times

Register	Function	Minimum Stall Time (ms)
FNCTIO_CTRL	Configure DIOx functions	500
FLTR_BNK0	Enable/select FIR filter banks	500
FLTR_BNK1	Enable/select FIR filter banks	500
DEC_RATA	Configure the number of frequency divisions	500
ALM_CFG_x	Enable/select Alarm Line	500
xG_ALM_MAGN	Sets the gyro threshold for an axis	500
xA_ALM_MAGN	Sets the acce threshold for an axis	500

TIMING DIAGRAMS

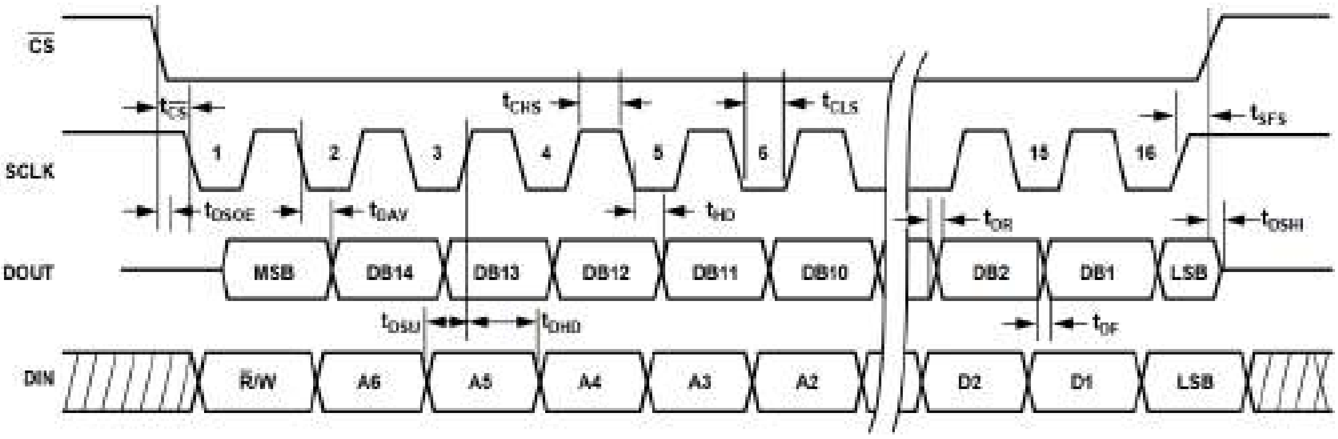


Figure 2. SPI Timing and Sequence

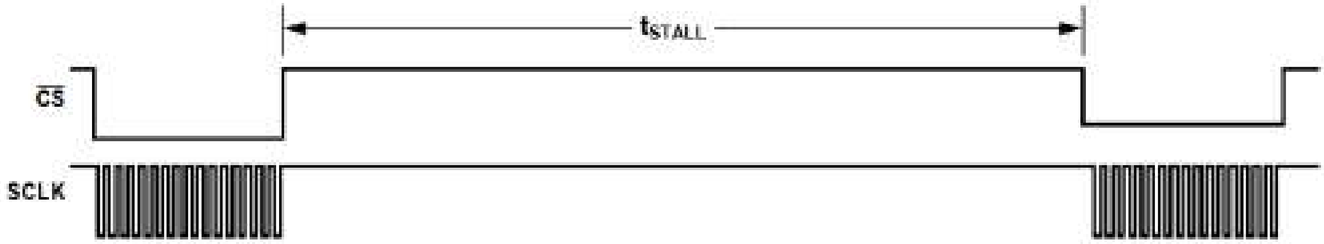


Figure 3. Stall Time and Data Rate

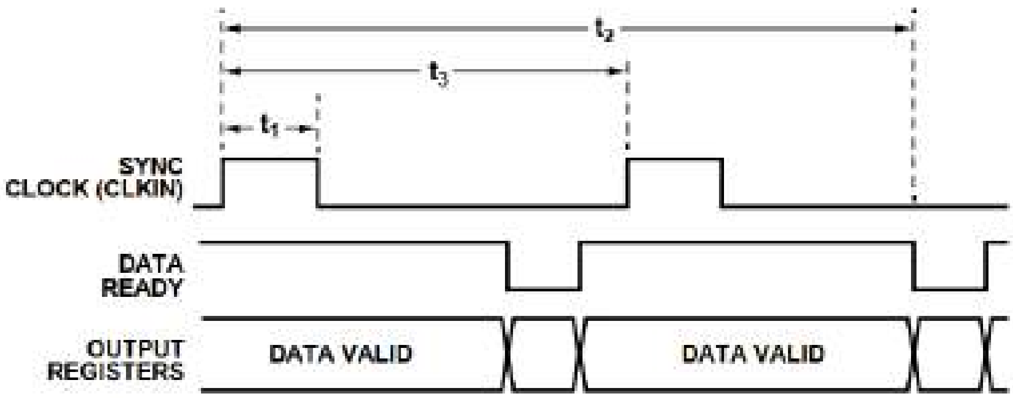


Figure 4.Input Clock Timing Diagram

ABSOLUTE MAXIMUM RATINGS

Table 4. Absolute Maximum Ratings

Parameter	Rating
Acceleration	
Any Axis, Unpowered	10000 *g*
Any Axis, Powered	10000 *g*
VDD to GND	−0.3 V to +3.6 V
Digital Input Voltage to GND	−0.3 V to VDD + 0.2 V
Digital Output Voltage to GND	−0.3 V to VDD + 0.2 V
Operating Temperature Range	
KT-EX9-2	−45℃ to +85℃
Storage Temperature Range[1]	−55℃ to +105℃
Barometric Pressure	2 bar

Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

THERMAL RESISTANCE

Table 5. Package Characteristics

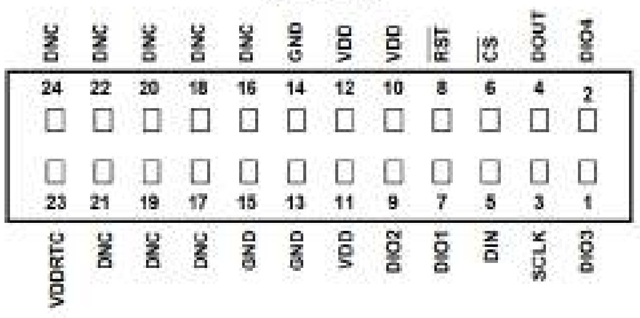
Package Type	θ_{JA}	θ_{JC}	Device Weight
24-Lead Module	22.8℃/W	10.1℃/W	48 g

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

KT-EX9-2



Note

[1]THIS REPRESENTATION DISPLAYS THE TOP VIEW PINOUT FOR THE MATING SOCKET CONNECTOR.

[2] THE ACTUAL CONNECTOR PINS ARE NOT VISIBLE FROM THE TOP VIEW.

[3]MATING CONNECTOR: SAMTEC CLM-112-02 OR EQUIVALENT.

[4]DNC = DO NOT CONNECT TO THESE PINS.

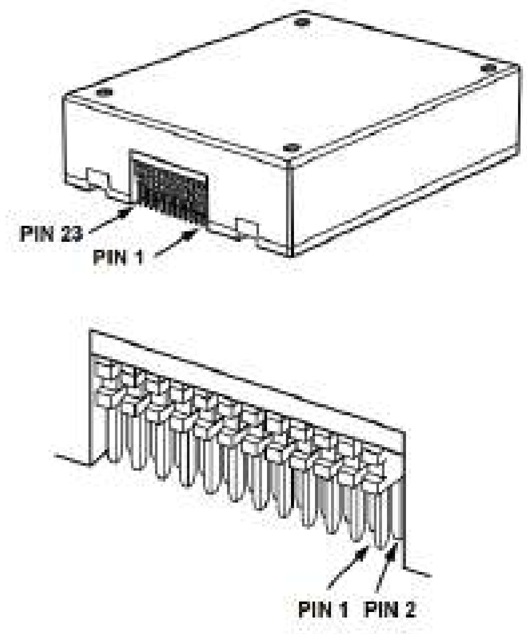


Figure 5. Mating Connector Pin Assignments

Figure 6. Axial Orientation (Topside Facing Up)

Table 6. Pin Function Descriptions

Pin No.	Mnemonic	Type	Description
1	DIO3	Input/output	Configurable Digital Input/Output.
2	DIO4	Input/output	Configurable Digital Input/Output.
3	SCLK	Input	SPI Serial Clock.
4	DOUT	Output	SPI Data Output. Clocks output on SCLK falling edge.
5	DIN	Input	SPI Data Input. Clocks input on SCLK rising edge.
6	CS	Input	SPI Chip Select.
7	DIO1	Input/output	Configurable Digital Input/Output.
8	RST	Input	Reset. Float if not used.
9	DIO2	Input/output	Configurable Digital Input/Output.
10, 11, 12	VDD	Supply	Power Supply.
13, 14, 15	GND	Supply	Power Ground.
16 to 22, 24	DNC	Not applicable	Do Not Connect. Do not connect to these pins.
23	VDDRTC	Supply	Real-Time Clock Power Supply.

TYPICAL PERFORMANCE CHARACTERISTICS

BIAS VARIATION OVER TEMPERATURE

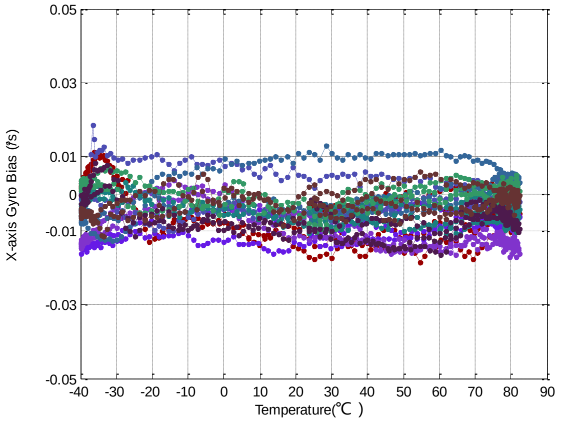


Figure 7. X-axis gyroscope bias variation over Temperature

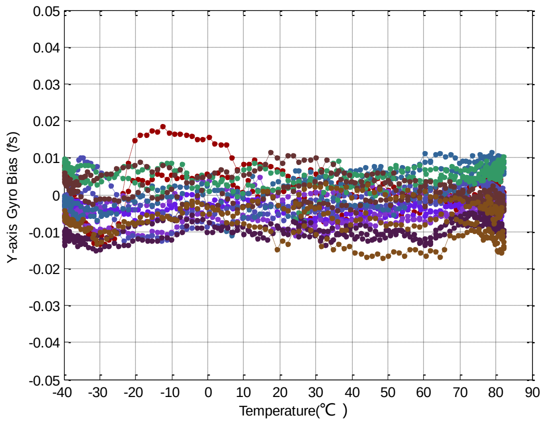


Figure 8. Y-axis gyroscope bias variation over Temperature

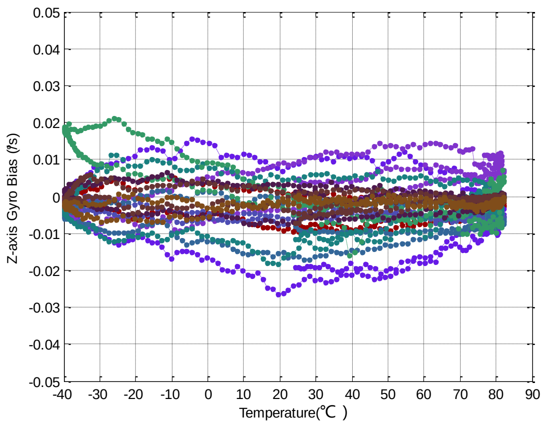


Figure 9. Z-axis gyroscope bias variation over Temperature

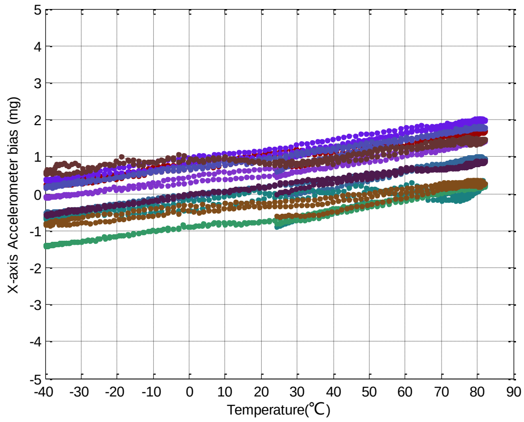


Figure 10. X-axis accelerometer bias variation over Temperature

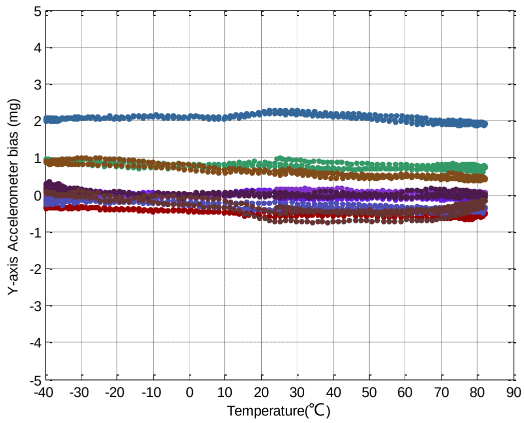


Figure 11. Y-axis accelerometer bias variation over Temperature

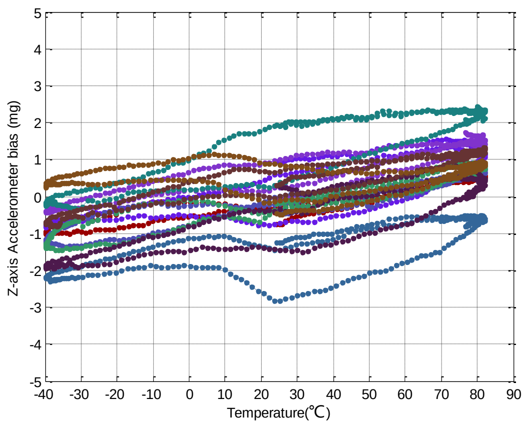


Figure 12. Z-axis accelerometer bias variation over Temperature

BIAS VARIATION OVER LONGTIME

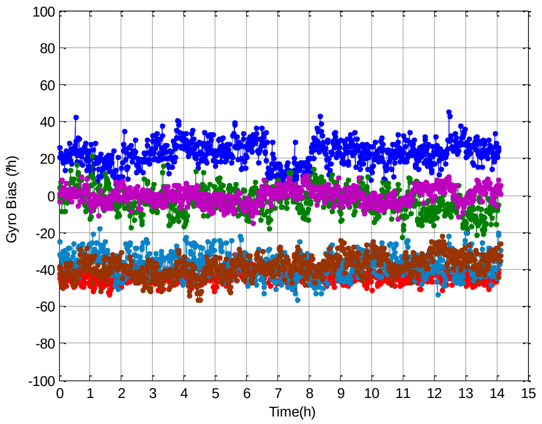


Figure 13. 3-axis Gyroscope bias variation over long time

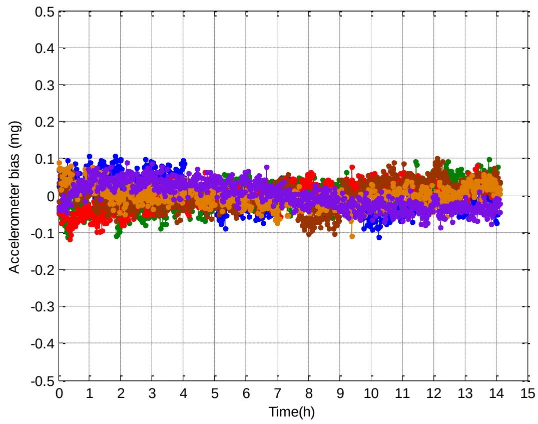


Figure 14. 3-axis Accelerometer bias variation over long time

ALLAN VARIANCE

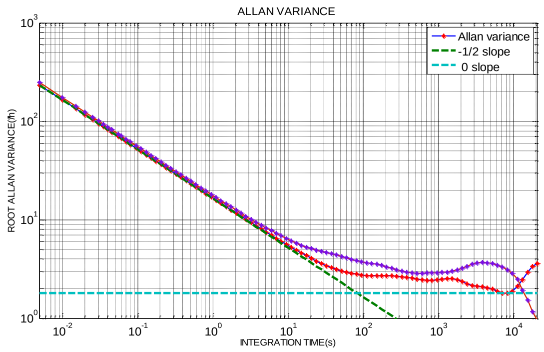


Figure 15. X-axis Gyroscope Allan Variance

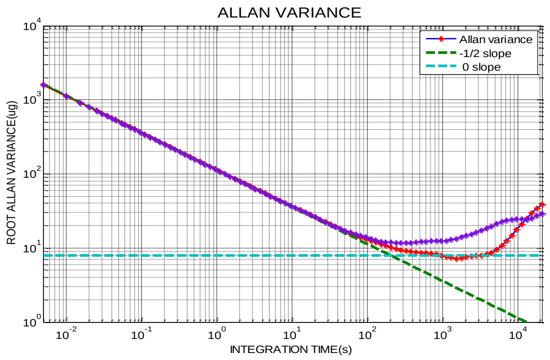


Figure 18. X-axis Accelerometer Allan Variance

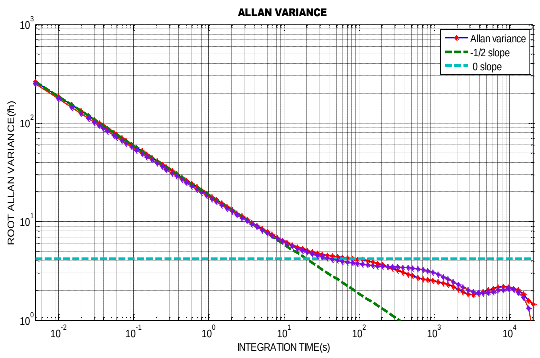


Figure 16. Y-axis Gyroscope Allan Variance

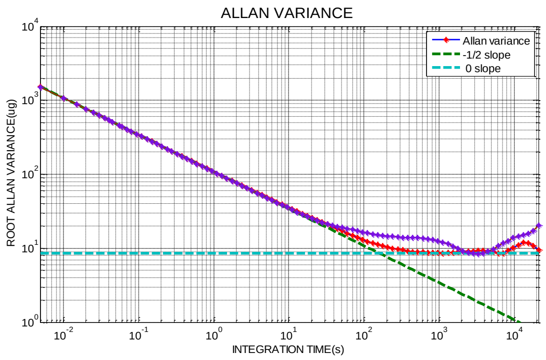


Figure 19. Y-axis Accelerometer Allan Variance

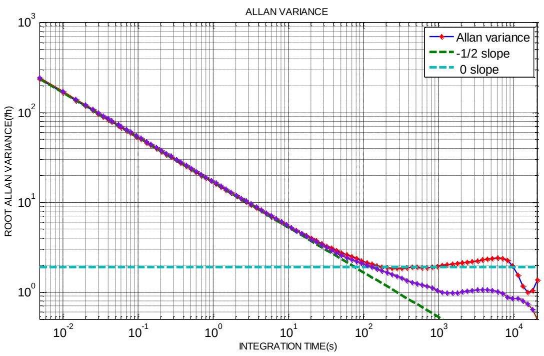


Figure 17. Z-axis Gyroscope Allan Variance

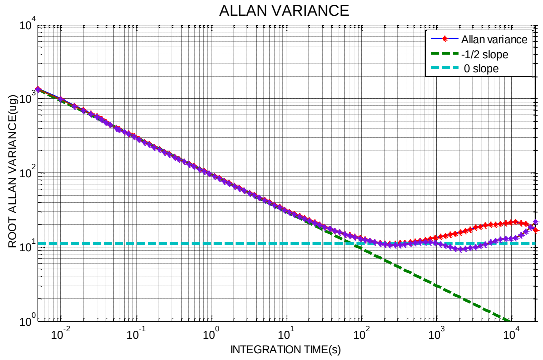


Figure 20.Z-axis Accelerometer Allan Variance

SCALE ERROR OVER TEMPERATURE

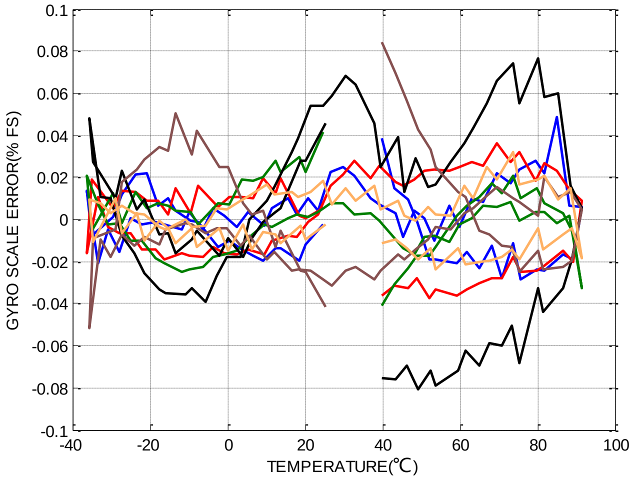


Figure 21. 3-axis Gyroscope Scale Error Over Temperature

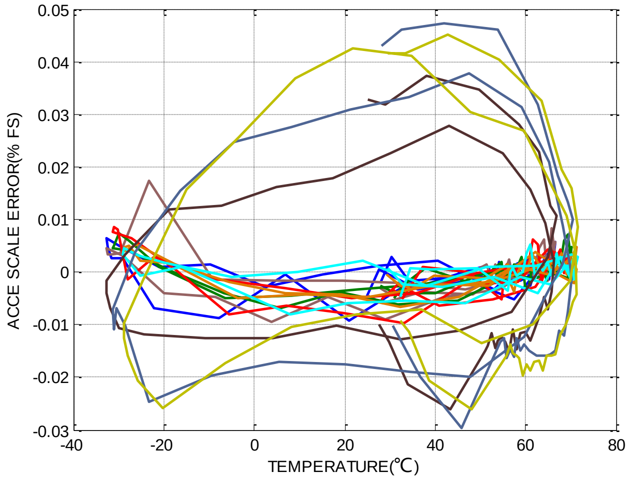


Figure 22. 3-axis Accelerometer Scale Error Over Temperature