±250°/s Yaw Rate Gyro

ADW22307

FEATURES

Complete rate gyroscope on a single chip
Z-axis (yaw rate) response
High vibration rejection over wide frequency
2000 *g* powered shock survivability
Ratiometric to referenced supply
5 V single-supply operation
105°C operation
Self-test on digital command
Ultrasmall and light (< 0.15 cc, < 0.5 gram)
Temperature sensor output
RoHS Compliant

APPLICATIONS

Vehicle chassis rollover sensing
Vehicle yaw/roll stability control
Inertial measurement units
Platform stabilization

GENERAL DESCRIPTION

The ADW22307 is a complete angular rate sensor (gyroscope) that uses Analog Devices' surface-micromachining process to make a functionally complete and low cost angular rate sensor integrated with all of the required electronics on one chip. The manufacturing technique for this device is the same high volume BIMOS process used for high reliability automotive airbag accelerometers.

The output signal, RATEOUT (1B, 2A), is a voltage proportional to angular rate about the axis normal to the top surface of the package. The output is ratiometric with respect to a provided reference supply. An external capacitor is used to set the bandwidth. Other external capacitors are required for operation.

A temperature output is provided for compensation techniques. Two digital self-test inputs electromechanically excite the sensor to test proper operation of both the sensor and the signal conditioning circuits. The ADW22307 is available in a 7 mm × 7 mm × 3 mm BGA chip-scale package.

FUNCTIONAL BLOCK DIAGRAM

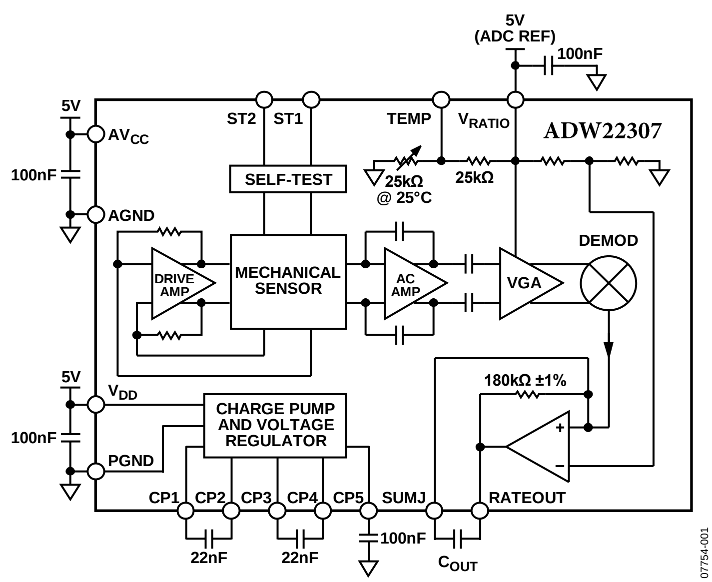

Figure 1. ADW22307 Block Diagram

Rev. G

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REVISION HISTORY

7/2008 - Revision A: Initial Version

9/2008 – Revision B:

Updated Self Test Limits (Table 1)
Updated Calibration Coefficient Ranges (Table 3)

10/2008 – Rev C:

Updated figures with finalized graphics
Changes ratiometricity table to reflect new data
Updated 10g vibration response image

10/2008 – Rev D:

Changed Naming to ADW22307
Modified General Description

2/2009 – Rev E:

Updated Package type/drawing. Physical dimensions unchanged from previous version

9/2009 – Revision F:

Updated Ordering guide

11/2009 – Revision G:

Updated Ordering guide

SPECIFICATIONS

All minimum and maximum specifications are guaranteed. Typical specifications are not guaranteed.

@T_A = -40°C to +105°C, V_S=AV_{CC}=V_{DD}=5V, V_{RATIO}= AV_{CC}, Angular Rate = 0°/s, Bandwidth = 80 Hz (C_{OUT} = 0.01 μF), I_{OUT}=100μA, ±1*g*, unless otherwise noted.

Table 1.

Parameter	Conditions	ADW22307 Min	Typ	Max	Unit
SENSITIVITY[7]	Clockwise rotation is positive output				
Measurement Range[1]	Full-scale range over specifications range	±250			°/s
Initial and Over Temperature		6.2	7	7.8	mV/°/s
Temperature Drift[2]			±2		%
Calibrated Sensitivity Error[3]				±2	%
Cross Axis Sensitivity			±1	±3	%
Nonlinearity	Best fit straight line		0.1		% of FS
NULL[7]					
Null	-40°C to +105°C	2.175	2.5	2.825	V
Calibrated Null[3]				±3	°/s
Linear Acceleration Effect	Any axis		0.1		°/s/*g*
NOISE PERFORMANCE					
Rate Noise Density	T_A ≤ 25°C		0.03		°/s/√Hz
Rate Noise Density	T_A ≤ 85°C			0.06	°/s/√Hz
FREQUENCY RESPONSE					
Bandwidth[4]		0.01		2500	Hz
Sensor Resonant Frequency		12	14.5	17	kHz
SELF-TEST					
ST1 RATEOUT Response[7]	ST1 pin from Logic 0 to 1	-700	-500	-300	mV
ST2 RATEOUT Response[7]	ST2 pin from Logic 0 to 1	300	500	700	mV
Calibrated ST1 Error[3]		-25		25	mV
Calibrated ST2 Error[3]		-25		25	mV
ST1 – ST2 Mismatch[6]		-5	±1	5	%
Logic 1 Input Voltage[7]		3.3			V
Logic 0 Input Voltage[7]				1.7	V
Input Impedance	To common	40	50	100	kΩ
TEMPERATURE SENSOR[7]					
V_{OUT} at 25°C	Load > 100M	2.35	2.5	2.65	V
Scale Factor[5]	@25°C, V_{RATIO}=5V		9		mV/°C
Calibrated Temperature Error		-6		+6	°C
Load to V_S			25		kΩ
Load to Common			25		kΩ

(Table Continued on Next Page)

Turn-On					
Turn-On Time	Power on to ±½°/s of final			50	ms
OUTPUT DRIVE CAPABILITY					
Current Drive	For rated specifications			200	uA
Capacitive Load Drive				1000	pF
POWER SUPPLY					
Operating Voltage (V_S)		4.85	5.00	5.15	V
Quiescent Supply Current			3.5	4.5	mA
TEMPERATURE RANGE					
Specified Performance		–40		+105	°C

[1] Measurement range is the maximum range possible, including output swing range, initial offset, sensitivity, offset drift, and sensitivity drift at 5 V supplies.
[2] From 25°C to -40°C or 25°C to 105°C
[3] Calibrated performance (using supplied calibration data) is based on characterization and not production tested.
[4] Adjusted by external capacitor C_{OUT}. Reducing bandwidth below 0.01Hz will not result in further noise improvement.
[5] Scale factor for a change in temperature from 25°C to 26°C. V_{TEMP} is ratiometric to V_{RATIO}. See the Temperature Sensor section for more details.
[6] Self test mismatch is described as (ST2+ST1) / ((ST2-ST1) / 2).
[7] Parameter is linearly ratiometric with V_{RATIO}.

ABSOLUTE MAXIMUM RATINGS

Table 2.

Parameter	Rating
Acceleration (Any Axis, Unpowered, 0.5 ms)	2000*g*
Acceleration (Any Axis, Powered, 0.5 ms)	2000*g*
$+V_{DD}$, $+AV_{CC}$	−0.3V to +6.0V
V_{RATIO}	AV_{CC}
ST1, ST2	AV_{CC}
Output Short-Circuit Duration (Any Pin to Common)	Indefininte
Operating Temperature Range	−55°C to +125°C
Storage Temperature	−65°C to +150°C

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

Drops onto hard surfaces can cause shocks of greater than 2000 *g* and exceed the absolute maximum rating of the device. Care should be exercised in handling to avoid damage.

RATE SENSITIVE AXIS

This is a Z-axis rate-sensing device (also called a yaw rate sensing device). It produces a positive going output voltage for clockwise rotation about the axis normal to the package top, i.e., clockwise when looking down at the package lid.

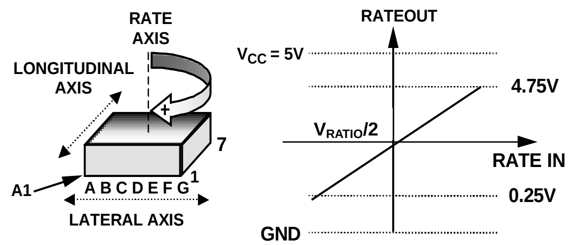
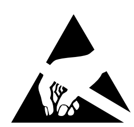


Figure 2. RATEOUT Signal Increases with Clockwise Rotation

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.

CALIBRATION DATA

ADI provides calibration information for each uniquely serialized part. Calibration information is provided for the following key parameters:

- Null
- Self-Test 1
- Self-Test 2
- Sensitivity

For each of the above parameters, at least the following information is provided:

- Initial Value at Temperature T_0
- *A* Coefficient (Linear Term)
- *B* Coefficient (Quadratic Term)

In addition, the temperature sensor output voltage at T_0 is also provided so that calibration can be performed according to:

$$V_{CAL}=V_{T0} + A(V_{TEMP@T1} - V_{TEMP@T0})+B(V_{TEMP@T1} - V_{TEMP@T0})^2$$

Minimum and maximum values for all *A* and *B* coefficients are shown in Table 3.

Additionally, ADI also provides calibration data used to establish temperature, in degrees C, from the sensor V_{TEMP} voltage output by:

$$\text{Temperature} = \text{Temp\_a}(V_{TEMP@T})^2 + \text{Temp\_b}(V_{TEMP@T}) + \text{Temp\_c}$$

Table 3 also includes minimum and maximum values for these calibration coefficients.

Complete details on calibration are provided in a separate application note.

Table 3. Minimim/Maximum Coefficient Values

Parameter	Units	Minimum	Maximum
Null *A*	Volts / Volt	-0.35	0.35
Null *B*	Volts / Volt^2	-0.15	0.15
ST1 *A*	Volts / Volt	-0.3	-0.04
ST1 *B*	Volts / Volt^2	-0.04	0.07
ST2 *A*	Volts / Volt	0.04	0.3
ST2 *B*	Volts / Volt^2	-0.07	0.04
Sensitivity *A*	milliVolts / ° / s / Volt	-1.5	1.5
Sensitivity *B*	milliVolts / ° / s / Volt^2	-0.7	0.7
Temp_a	°C / Volts^2	-6.0	100.0
Temp_b	°C / Volts	-55.0	140.0
Temp_c	°C	-1000.0	0.0

TYPICAL PERFORMANCE CHARACTERISTICS

N > 1000 for all typical performance plots, unless otherwise noted

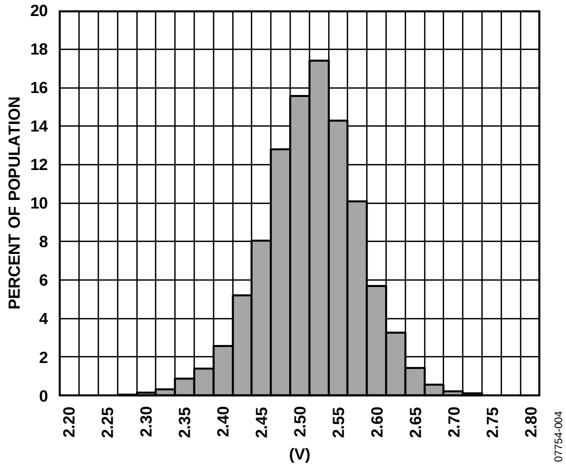


Figure 3. Null Output at 25°C – V_{RATIO}=5V

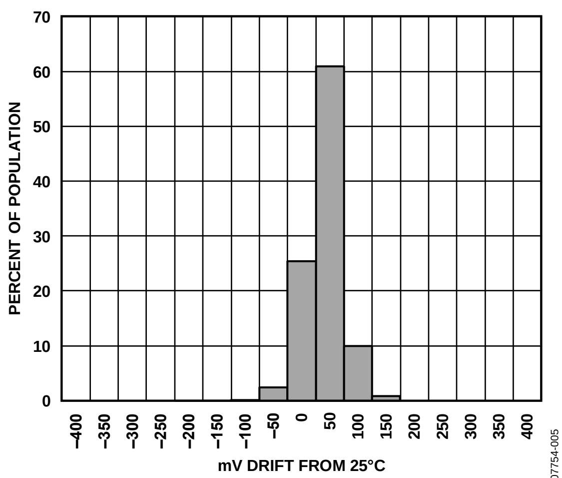


Figure 4. Null Drift Over Temperature (V_{RATIO}=5V)

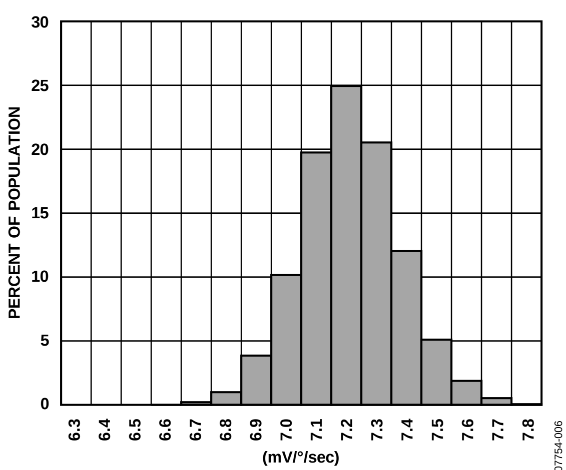


Figure 5. Sensitivity at 25°C (V_{RATIO}=5V)

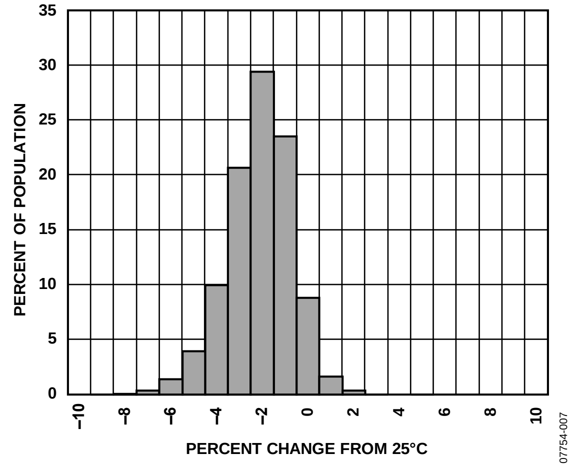


Figure 6. Sensitivity Drift Over Temperature

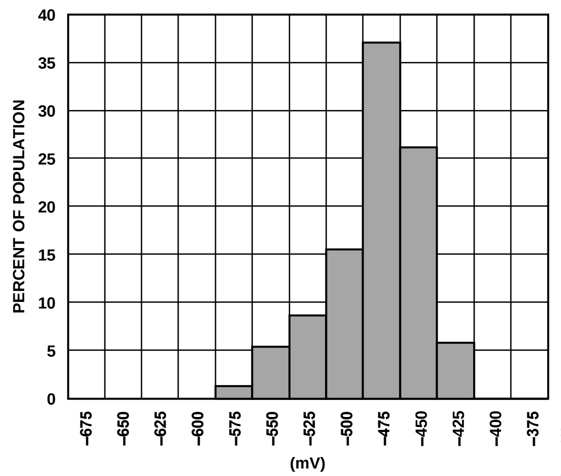


Figure 7. ST1 Output change at 25°C (V_{RATIO}=5V)

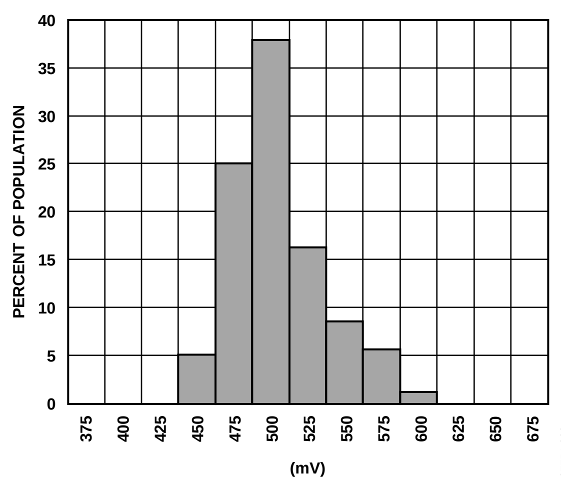


Figure 8. ST2 Output change at 25°C (V_{RATIO}=5V)

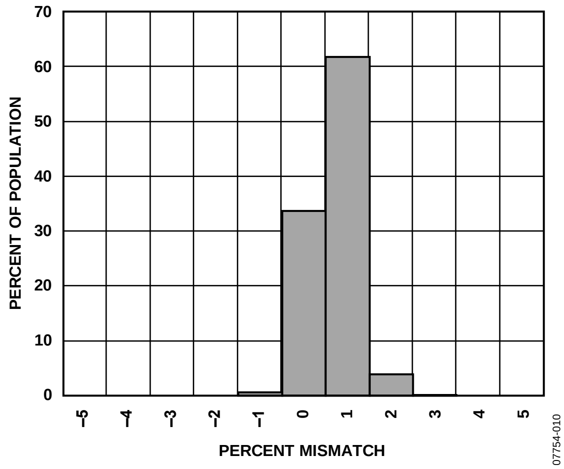


Figure 9. Self Test Mismatch at 25°C (V_{RATIO}=5V)

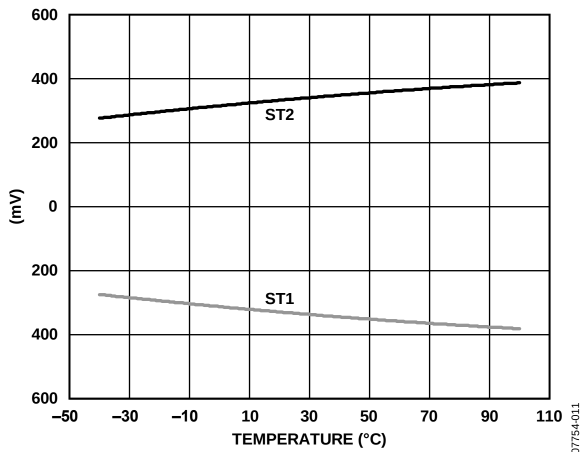


Figure 10. Typical Self Test Change Over Temperature

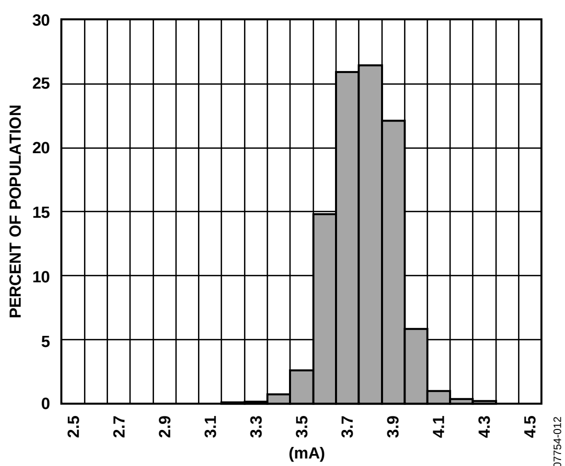


Figure 11. Current Consumption at 25°C (V_{RATIO}=5V)

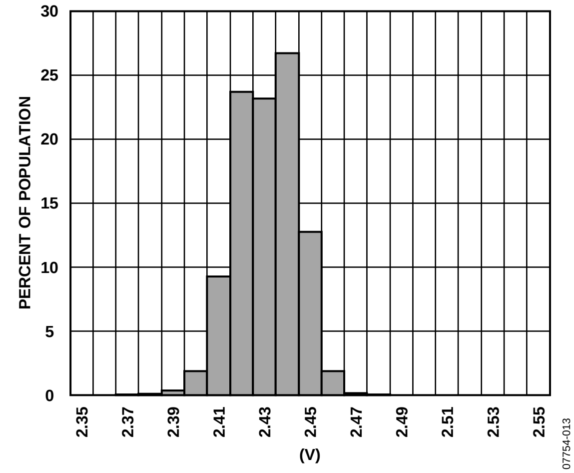


Figure 12. V_{TEMP} Output at 25°C (V_{RATIO}=5V)

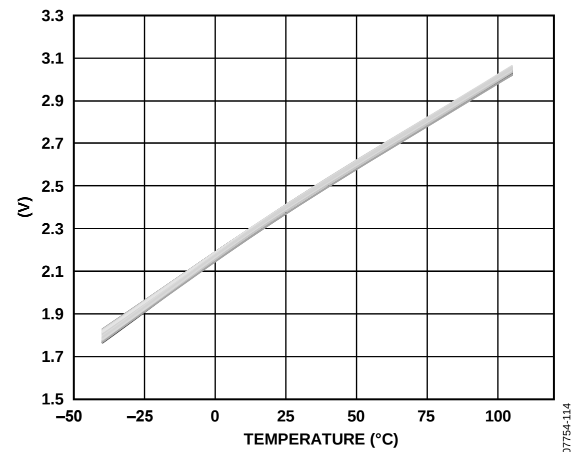


Figure 13. V_{TEMP} Output Over Temperature- 250 Parts (V_{RATIO}=5V)

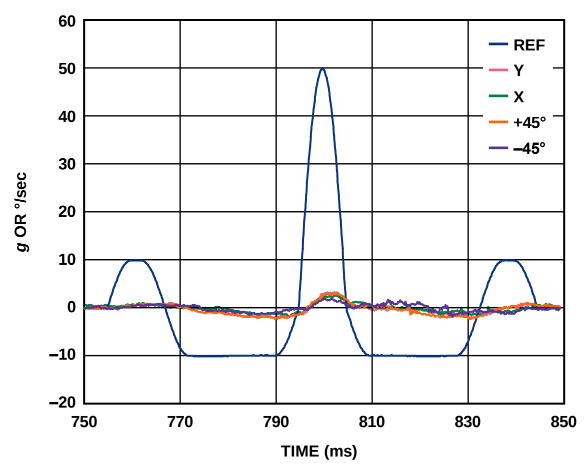


Figure 14. g and g x g Sensitivity for a 50g, 10ms Pulse

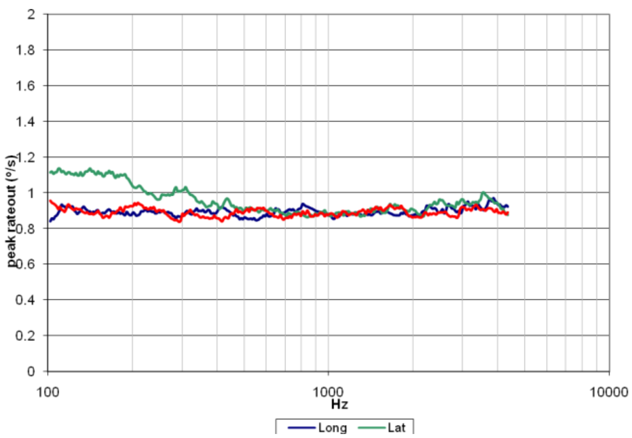


Figure 15. Typical Response to 10g Sinusoidal Vibration (Sensor Bandwidth = 40Hz)

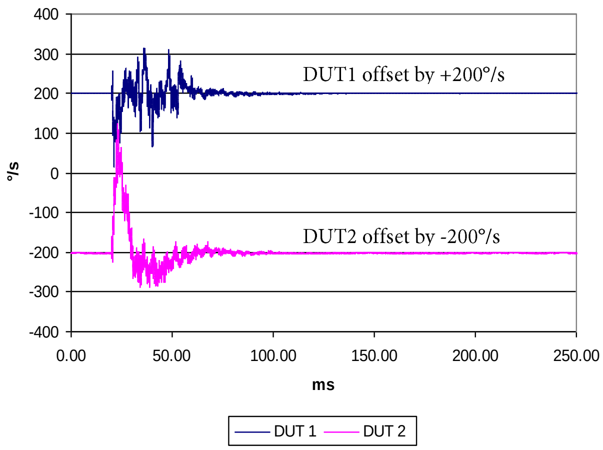


Figure 16. Typical High g (2500g) Shock Response (Sensor Bandwidth = 40Hz)

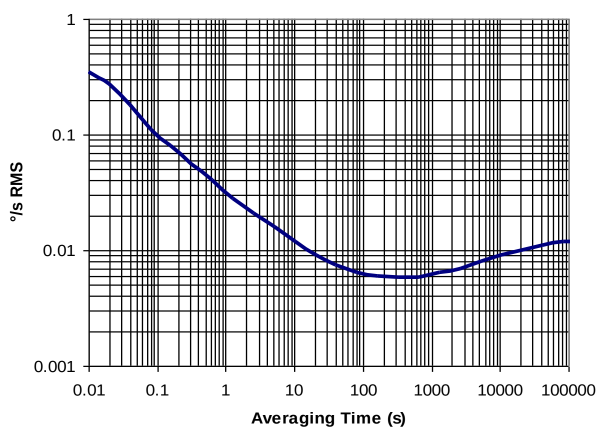


Figure 17. Typical Root Allan Variance at 25°C vs. Averaging Time

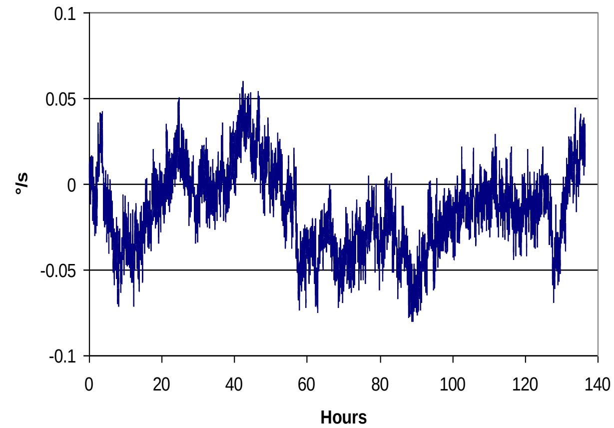


Figure 18. Typical Shift in 90 s Null Averages Accumulated Over 140 hours

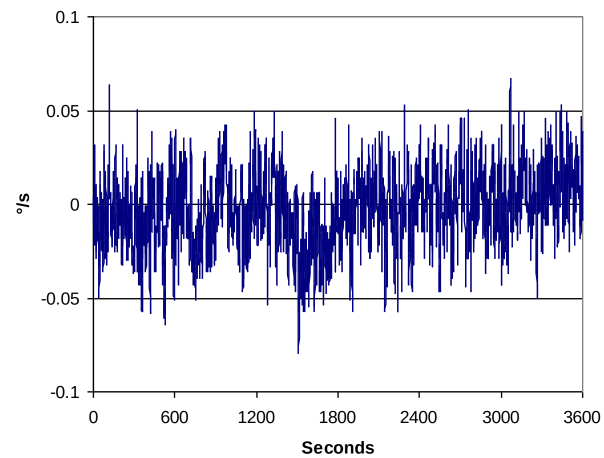


Figure 19. Typical Shift in Short Term Null (Bandwidth = 1 Hz)

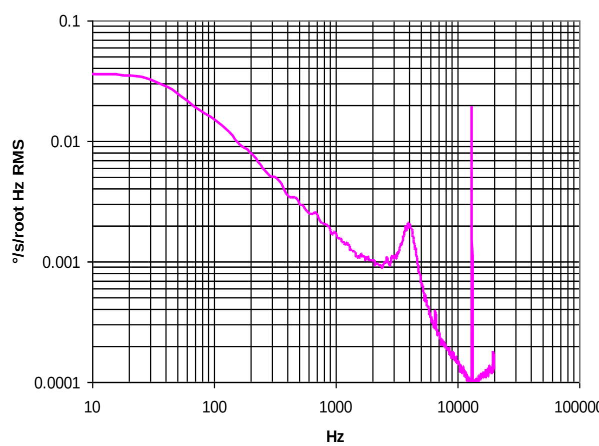


Figure 20. Typical Noise Spectral Density (Bandwidth = 40Hz)

THEORY OF OPERATION

The ADW22307 operates on the principle of a resonator gyro. Two polysilicon sensing structures each contain a dither frame, which is electrostatically driven to resonance. This produces the necessary velocity element to produce a Coriolis force during angular rate. At two of the outer extremes of each frame, orthogonal to the dither motion, are movable fingers that are placed between fixed pickoff fingers to form a capacitive pickoff structure that senses Coriolis motion. The resulting signal is fed to a series of gain and demodulation stages that produce the electrical rate signal output. The dual-sensor design rejects external g-forces and vibration. Fabricating the sensor with the signal conditioning electronics preserves signal integrity in noisy environments.

The electrostatic resonator requires 18 V to 20 V for operation. Since only 5 V is typically available in most applications, a charge pump is included on-chip. If an external 18 V to 20 V supply is available, the two capacitors on CP1–CP4 can be omitted and this supply can be connected to CP5 (Pin 7D). CP5 should not be grounded when power is applied to the ADW22307. No damage will occur, but under certain conditions the charge pump may fail to start up after the ground is removed without first removing power from the ADW22307.

SETTING BANDWIDTH

External capacitor C_{OUT} is used in combination with the on-chip R_{OUT} resistor to create a low-pass filter to limit the bandwidth of the ADW22307's rate response. The –3 dB frequency set by R_{OUT} and C_{OUT} is:

$$f_{OUT} = 1/(2 \times \pi \times R_{OUT} \times C_{OUT})$$

and can be well controlled since R_{OUT} has been trimmed during manufacturing to be 180 kΩ ±1%. Any external resistor applied between the RATEOUT (1B, 2A) and SUMJ (1C, 2C) pins will result in:

$$R_{OUT} = (180\ k\Omega \times R_{EXT})/(180\ k\Omega + R_{EXT})$$

In general, an additional filter (either in hardware or software) is added to attenuate high frequency noise arising from demodulation spikes at the gyro's 14kHz resonant frequency (the noise spikes at 14kHz can be clearly seen in the power spectral density curve shown in Figure 20). Normally this additional filter's corner frequency is set to greater than 5 times the required bandwidth so as to preserve good phase response.

Figure 21 shows the effect of adding a 250Hz filter to the output of an ADW22307 set to 40Hz bandwidth (as shown in Figure 20). High frequency demodulation artifacts are attenuated by approximately 18db.

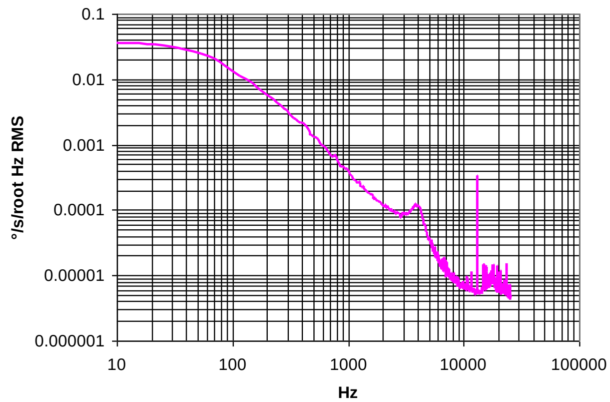


Figure 21. Noise Spectral Density with Additional 250Hz Filter

TEMPERATURE OUTPUT AND CALIBRATION

It is common practice to temperature-calibrate gyros to improve their overall accuracy. The ADW22307 has a temperature proportional voltage output that provides input to such a calibration method. The temperature sensor structure is shown in Figure 22. The temperature output is characteristically non-linear, and any load resistance connected to the TEMP output will result in decreasing the TEMP output and it's temperature coefficient. Therefore buffering the output is recommended.

The voltage at TEMP (3F, 3G) is nominally 2.5 V at 25°C and V_{RATIO}=5V. The temperature coefficient is ~9 mV/°C at 25°C. While the TEMP output is highly repeatable, it has only modest absolute accuracy. Even using the supplied calibration information for correction of the temperature sensor will result in best case absolute accuracy of no better than ±6°C.

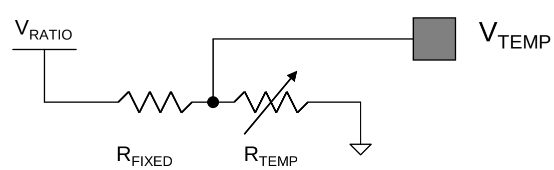


Figure 22. ADW22307 Temperature Sensor Structure

CALIBRATED PERFORMANCE

Using a 3-point calibration technique, it is possible to calibrate the ADW22307's null and sensitivity drift to an overall accuracy of nearly 200°/hour. An overall accuracy of 40°/hour or better is possible using more points. Limiting the bandwidth of the device reduces the flat-band noise during the calibration process, improving the measurement accuracy at each calibration point.

ADW22307 AND SUPPLY RATIOMETRICITY

The ADW22307's RATEOUT, ST1, ST2, and TEMP signals are ratiometric to the V_{RATIO} voltage, i.e., the null voltage, rate sensitivity, and temperature outputs are proportional to V_{RATIO}. So the ADW22307 is most easily used with a supply-ratiometric ADC which results in self cancellation of errors due to minor supply variations. There is some small error due to non-ratiometric behavior. Typical ratiomericity error for null, sensitivity, self-test, and temperature output are outlined in Table 4.

Note that V_{RATIO} must never be greater than AV_{CC}

Table 4. Ratiometricity Error for Various Parameters

Parameter	$V_S = V_{RATIO} = 4.85V$	$V_S = V_{RATIO} = 5.15V$
ST1	Mean = 0.3%	Mean = 0.09%
	Sigma = 0.21%	Sigma = 0.19%
ST2	Mean = -0.15%	Mean = -0.2%
	Sigma = 0.22%	Sigma = 0.2%
Null	Mean = -0.3%	Mean = -0.05%
	Sigma = 0.2%	Sigma = 0.08%
Sensitivity	Mean = 0.003%	Mean = -0.25%
	Sigma = 0.06%	Sigma = 0.06%
V_{TEMP}	Mean = -0.2%	Mean = -0.04%
	Sigma = 0.05%	Sigma = 0.06%

NULL ADJUSTMENT

The nominal 2.5 V null is for a symmetrical swing range at RATEOUT (1B, 2A). However, a nonsymmetric output swing may be suitable in some applications. Null adjustment is possible by injecting a suitable current to SUMJ (1C, 2C). Note that supply disturbances may reflect some null instability. Digital supply noise should be avoided particularly in this case.

SELF-TEST FUNCTION

The ADW22307 includes a self-test feature that actuates each of the sensing structures and associated electronics in the same manner as if subjected to angular rate. It is activated by standard logic high levels applied to inputs ST1 (5F, 5G), ST2 (4F, 4G), or both. ST1 will cause the voltage at RATEOUT to change about
−0.5 V and ST2 will cause an opposite change of +0.5 V. The self-test response follows the viscosity temperature dependence of the package atmosphere, approximately 0.25%/°C, as shown in Figure 10.

Activating both ST1 and ST2 simultaneously is not damaging. ST1 and ST2 are fairly closely matched (±1% typically), but actuating both simultaneously may result in a small apparent null bias shift proportional to the degree of self test mismatch.

ST1 and ST2 are activated by applying a voltage equal to V_{RATIO} to the ST1 and ST2 pins. The voltage applied to ST1 and ST2 must never be greater than AV_{CC}.

CONTINUOUS SELF-TEST

The one-chip integration of the ADW22307 gives it higher reliability than is obtainable with any other high volume manufacturing method. Also, it is manufactured under a mature BIMOS process that has field-proven reliability. As an additional failure detection measure, power-on self-test can be performed. However, some applications may warrant continuous self-test while sensing rate. Details outlining continuous self-test techniques are also available in a separate Application Note.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

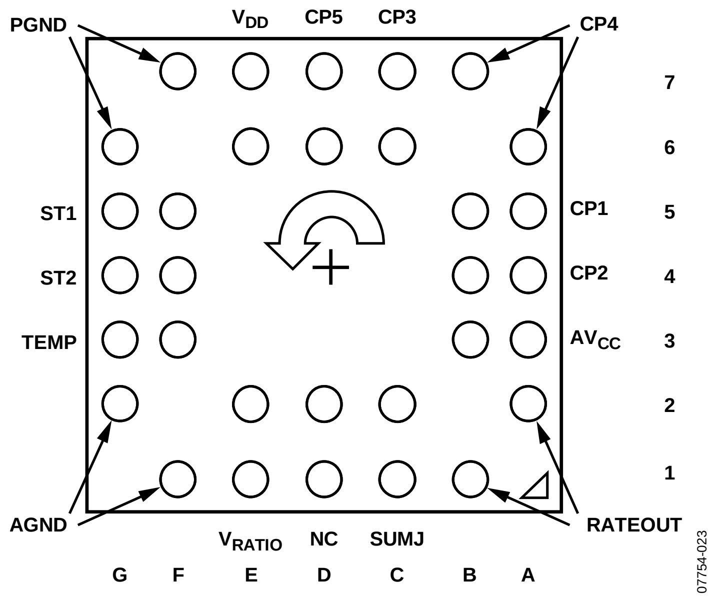


Figure 23. 32-Lead BGA (Bottom View)

Table 5. Pin Function Descriptions

Pin No.	Mnemonic	Description
6D, 7D	CP5	HV Filter Capacitor – 0.1 μF
6A, 7B	CP4	Charge Pump Capacitor – 22nF
6C, 7C	CP3	
5A, 5B	CP1	Charge Pump Capacitor – 22nF
4A, 4B	CP2	
3A, 3B	AVCC	+ Analog Supply
1B, 2A	RATEOUT	Rate Signal Output
1C, 2C	SUMJ	Output Amp Summing Junction
1D, 2D	NC	
1E, 2E	VRATIO	Reference Supply for Ratiometric Output
1F, 2G	AGND	Analog Supply Return
3F, 3G	TEMP	Temperature Voltage Output
4F, 4G	ST2	Self-Test for Sensor 2
5F, 5G	ST1	Self-Test for Sensor 1
6G, 7F	PGND	Charge Pump Supply Return
6E, 7E	VDD	+ Charge Pump Supply

OUTLINE DIMENSIONS

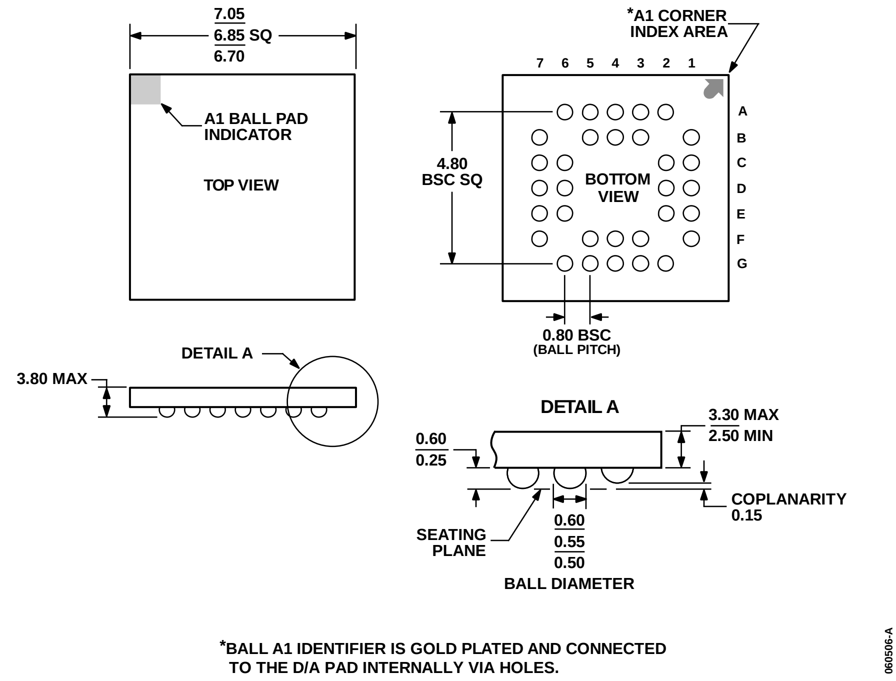


Figure 24. 32-Lead Ceramic Ball Grid Array [CBGA]
(BG-32-3)
Dimensions shown in millimeters

ORDERING GUIDE

Model	Temperature Range	Package Description	Package Outline
ADW22307ZA[1]	−40°C to +105°C	32-Lead Ceramic Ball Grid Array [CBGA]	BG-32-3
ADW22307ZA-RL[1]	−40°C to +105°C	32-Lead Ceramic Ball Grid Array [CBGA]	BG-32-3
ADW22307Z3-RL[1]	−40°C to +105°C	32-Lead Ceramic Ball Grid Array [CBGA], Pedigree 3	BG-32-3

[1] Z = RoHS Compliant Part.

C03227–0–3/04(B)