# ±300°/s Single Chip Yaw Rate Gyro with Signal Conditioning

## ADXRS300

## FEATURES
**Complete rate gyroscope on a single chip**
**Z-axis (yaw rate) response**
**High vibration rejection over wide frequency**
**2000 *g* powered shock survivability**
**Self-test on digital command**
**Temperature sensor output**
**Precision voltage reference output**
**Absolute rate output for precision applications**
**5 V single-supply operation**
**Ultrasmall and light (< 0.15 cc, < 0.5 gram)**

## APPLICATIONS
**Vehicle chassis rollover sensing**
**Inertial measurement units**
**Platform stabilization**

## GENERAL DESCRIPTION

The ADXRS300 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 (see Figure 4). A single external resistor can be used to lower the scale factor. An external capacitor is used to set the bandwidth. Other external capacitors are required for operation (see Figure 5).

A precision reference and a temperature output are also provided for compensation techniques. Two digital self-test inputs electromechanically excite the sensor to test proper operation of both sensors and the signal conditioning circuits. The ADXRS300 is available in a 7 mm × 7 mm × 3 mm BGA chip-scale package.
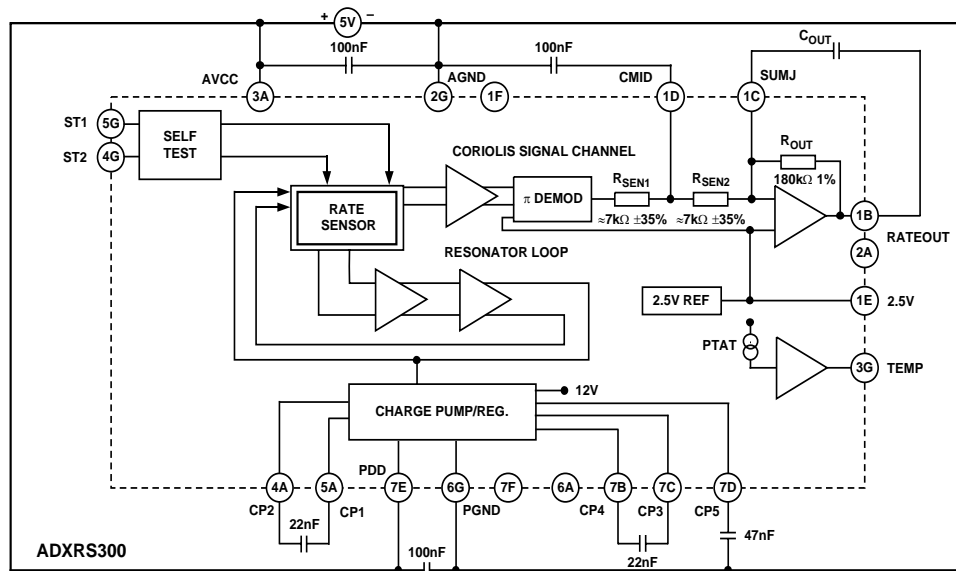
## FUNCTIONAL BLOCK DIAGRAM



*Figure 1.*

# ADXRS300

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## REVISION HISTORY

# SPECIFICATIONS

@$T_A$ = 25°C, $V_S$ = 5 V, Angular Rate = 0°/s, Bandwidth = 80 Hz ($C_{OUT}$ = 0.01 µF), ±1$g$, unless otherwise noted.

**Table 1.**

| Parameter | Conditions | ADXRS300ABG Min[1] | Typ | Max[1] | Unit |
|---|---|---|---|---|---|
| SENSITIVITY | Clockwise rotation is positive output | | | | |
| Dynamic Range[2] | Full-scale range over specifications range | ±300 | | | °/s |
| Initial | @25°C | 4.6 | 5 | 5.4 | mV/°/s |
| Over Temperature[3] | $V_S$ = 4.75 V to 5.25 V | 4.6 | 5 | 5.4 | mV/°/s |
| Nonlinearity | Best fit straight line | | 0.1 | | % of FS |
| NULL | | | | | |
| Initial Null | | 2.3 | 2.50 | 2.7 | V |
| Over Temperature[3] | $V_S$ = 4.75 V to 5.25 V | 2.3 | | 2.7 | V |
| Turn-On Time | Power on to ±½°/s of final | | 35 | | ms |
| Linear Acceleration Effect | Any axis | | 0.2 | | °/s/$g$ |
| Voltage Sensitivity | $V_{CC}$ = 4.75 V to 5.25 V | | 1 | | °/s/V |
| NOISE PERFORMANCE | | | | | |
| Rate Noise Density | @25°C | | 0.1 | | °/s/√Hz |
| FREQUENCY RESPONSE | | | | | |
| 3 dB Bandwidth (User Selectable)[4] | 22 nF as comp cap (see the Setting Bandwidth section) | | 40 | | Hz |
| Sensor Resonant Frequency | | | 14 | | kHz |
| SELF-TEST INPUTS | | | | | |
| ST1 RATEOUT Response[5] | ST1 pin from Logic 0 to 1 | −150 | −270 | −450 | mV |
| ST2 RATEOUT Response[5] | ST2 pin from Logic 0 to 1 | +150 | +270 | +450 | mV |
| Logic 1 Input Voltage | Standard high logic level definition | 3.3 | | | V |
| Logic 0 Input Voltage | Standard low logic level definition | | | 1.7 | V |
| Input Impedance | To common | | 50 | | kΩ |
| TEMPERATURE SENSOR | | | | | |
| $V_{OUT}$ at 298°K | | | 2.50 | | V |
| Max Current Load on Pin | Source to common | | | 50 | µA |
| Scale Factor | Proportional to absolute temperature | | 8.4 | | mV/°K |
| OUTPUT DRIVE CAPABILITY | | | | | |
| Output Voltage Swing | $I_{OUT}$ = ±100 µA | 0.25 | | $V_S$ − 0.25 | V |
| Capacitive Load Drive | | 1000 | | | pF |
| 2.5 V REFERENCE | | | | | |
| Voltage Value | | 2.45 | 2.5 | 2.55 | V |
| Load Drive to Ground | Source | | 200 | | µA |
| Load Regulation | 0 < $I_{OUT}$ < 200 µA | | 5.0 | | mV/mA |
| Power Supply Rejection | 4.75 $V_S$ to 5.25 $V_S$ | | 1.0 | | mV/V |
| Temperature Drift | Delta from 25°C | | 5.0 | | mV |
| POWER SUPPLY | | | | | |
| Operating Voltage Range | | 4.75 | 5.00 | 5.25 | V |
| Quiescent Supply Current | | | 6.0 | 8.0 | mA |
| TEMPERATURE RANGE | | | | | |
| Specified Performance Grade A | Temperature tested to max and min specifications | −40 | | +85 | °C |

[1] All minimum and maximum specifications are guaranteed. Typical specifications are not tested or guaranteed.
[2] Dynamic range is the maximum full-scale measurement range possible, including output swing range, initial offset, sensitivity, offset drift, and sensitivity drift at 5 V supplies.
[3] Specification refers to the maximum extent of this parameter as a worst-case value of $T_{MIN}$ or $T_{MAX}$.
[4] Frequency at which response is 3 dB down from dc response with specified compensation capacitor value. Internal pole forming resistor is 180 kΩ. See the Setting Bandwidth section.
[5] Self-test response varies with temperature. See the Self-Test Function section for details.

# 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$_S$ | −0.3 V to +6.0 V |
| 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.

Applications requiring more than 200 cycles to MIL-STD-883 Method 1010 Condition B (−55°C to +125°C) require underfill or other means to achieve this requirement.

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 that is 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.
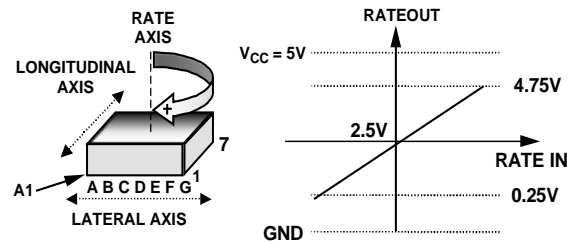


*Figure 2. RATEOUT Signal Increases with Clockwise Rotation*

## ESD CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although this product features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

# PIN CONFIGURATION AND FUNCTION DESCRIPTIONS
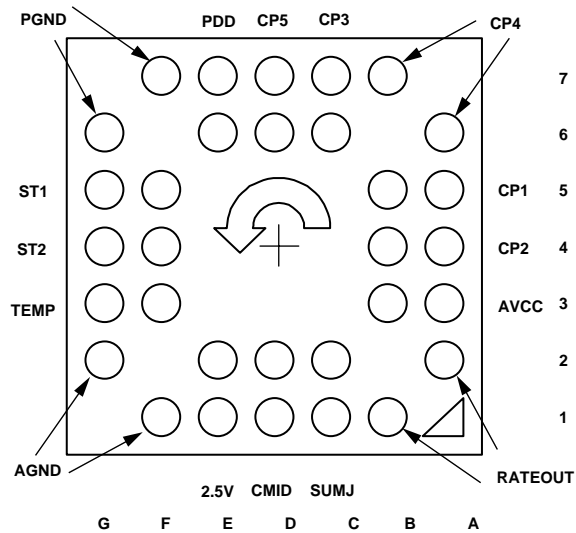


*Figure 3. 32-Lead BGA (Bottom View)*

**Table 3. Pin Function Descriptions**

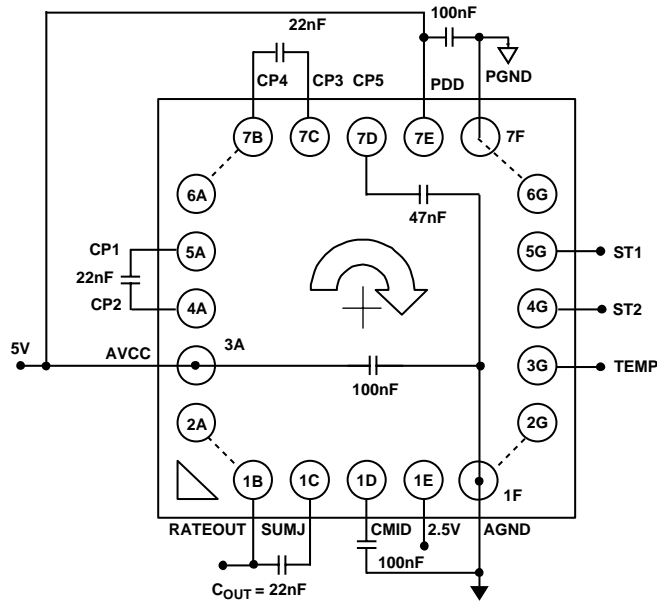| Pin No. | Mnemonic | Description |
| --- | --- | --- |
| 6D, 7D | CP5 | HV Filter Capacitor—47 nF |
| 6A, 7B | CP4 | Charge Pump Capacitor—22 nF |
| 6C, 7C | CP3 | Charge Pump Capacitor—22 nF |
| 5A, 5B | CP1 | Charge Pump Capacitor—22 nF |
| 4A, 4B | CP2 | Charge Pump Capacitor—22 nF |
| 3A, 3B | AVCC | + Analog Supply |
| 1B, 2A | RATEOUT | Rate Signal Output |
| 1C, 2C | SUMJ | Output Amp Summing Junction |
| 1D, 2D | CMID | HF Filter Capacitor—100 nF |
| 1E, 2E | 2.5V | 2.5 V Precision Reference |
| 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 | PDD | + Charge Pump Supply |

# THEORY OF OPERATION

The ADXRS300 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 14 V to 16 V for operation. Since only 5 V is typically available in most applications, a charge pump is included on-chip. If an external 14 V to 16 V supply is available, the two capacitors on CP1–CP4 can be omitted and this supply can be connected to CP5 (Pin 7D) with a 100 nF decoupling capacitor in place of the 47 nF.

After the demodulation stage, there is a single-pole low-pass filter consisting of an internal 7 kΩ resistor ($R_{SEN1}$) and an external user-supplied capacitor (CMID). A CMID capacitor of 100 nF sets a 400 Hz ±3 5% low-pass pole and is used to limit high frequency artifacts before final amplification. The band-width limit capacitor, $C_{OUT}$, sets the pass bandwidth (see Figure 5 and the Setting Bandwidth section).

## SUPPLY AND COMMON CONSIDERATIONS

Only power supplies used for supplying analog circuits are recommended for powering the ADXRS300. High frequency noise and transients associated with digital circuit supplies may have adverse effects on device operation.

Figure 4 shows the recommended connections for the ADXRS300 where both AVCC and PDD have a separate decoupling capacitor. These should be placed as close to the their respective pins as possible before routing to the system analog supply. This mini-mizes the noise injected by the charge pump that uses the PDD supply.

It is also recommended to place the charge pump capacitors connected to the CP1–CP4 pins as close to the part as possible. These capacitors are used to produce the on-chip high voltage supply switched at the dither frequency at approximately 14 kHz. Care should be taken to ensure that there is no more than 50 pF of stray capacitance between CP1–CP4 and ground. Surface-mount chip capacitors are suitable as long as they are rated for over 15 V.
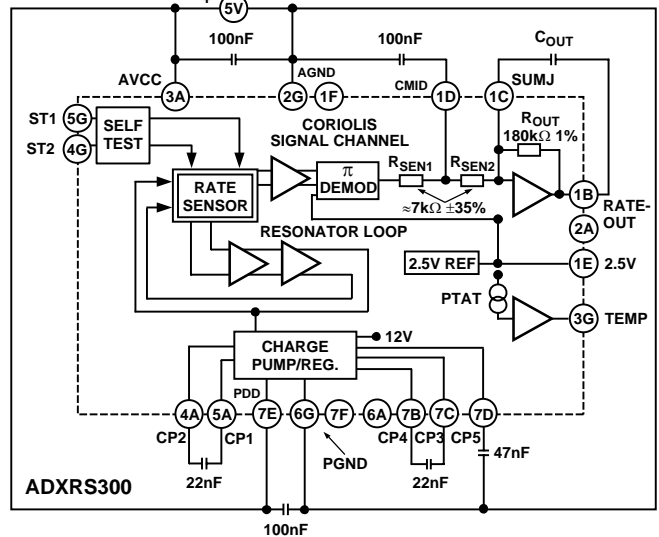


Figure 5. Block Diagram with External Components



NOTE THAT INNER ROWS/COLUMNS OF PINS HAVE BEEN OMITTED FOR CLARITY BUT SHOULD BE CONNECTED IN THE APPLICATION.

Figure 4. Example Application Circuit (Top View)

## SETTING BANDWIDTH

External capacitors CMID and C$_{OUT}$ are used in combination with on-chip resistors to create two low-pass filters to limit the bandwidth of the ADXRS300'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 results in

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

The –3 dB frequency is set by RSEN (the parallel combination of R$_{SEN1}$ and R$_{SEN2}$) at about 3.5 kΩ nominal; CMID is less well controlled since R$_{SEN1}$ and R$_{SEN2}$ have been used to trim the rate sensitivity during manufacturing and have a ±35% tolerance. Its primary purpose is to limit the high frequency demodulation artifacts from saturating the final amplifier stage. Thus, this pole of nominally 400 Hz @ 0.1 μF need not be precise. Lower frequency is preferable, but its variability usually requires it to be about 10 times greater (in order to preserve phase integrity) than the well-controlled output pole. In general, both –3 dB filter frequencies should be set as low as possible to reduce the amplitude of these high frequency artifacts and to reduce the overall system noise.

## INCREASING MEASUREMENT RANGE

The full-scale measurement range of the ADXRS300 can be increased by placing an external resistor between the RATEOUT (1B, 2A) and SUMJ (1C, 2C) pins, which would parallel the internal R$_{OUT}$ resistor that is factory-trimmed to 180 kΩ. For example, a 330 kΩ external resistor will give ~50% increase in the full-scale range. This is effective for up to a 4× increase in the full-scale range (minimum value of the parallel resistor allowed is 45 kΩ). Beyond this amount of external sensitivity reduction, the internal circuitry headroom requirements prevent further increase in the linear full-scale output range. The drawbacks of modifying the full-scale range are the additional output null drift (as much as 2°/sec over temperature) and the readjustment of the initial null bias (see the Null Adjust section).

## USING THE ADXRS300 WITH A SUPPLY-RATIOMETRIC ADC

The ADXRS300's RATEOUT signal is nonratiometric, i.e., neither the null voltage nor the rate sensitivity is proportional to the supply. Rather they are nominally constant for dc supply changes within the 4.75 V to 5.25 V operating range. If the ADXRS300 is used with a supply-ratiometric ADC, the ADXRS300's 2.5 V output can be converted and used to make corrections in software for the supply variations.

## NULL ADJUST

Null adjustment is possible by injecting a suitable current to SUMJ (1C, 2C). Adding a suitable resistor to either ground or to the positive supply is a simple way of achieving this. 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. Note that if a resistor is connected to the positive supply, then supply disturbances may reflect some null instabilities. Digital supply noise should be avoided, particularly in this case (see the Supply and Common Considerations section).

The resistor value to use is approximately

$$R_{NULL} = (2.5 \times 180,000)/(V_{NULL0} - V_{NULL1})$$

$V_{NULL0}$ is the unadjusted zero rate output, and $V_{NULL1}$ is the target null value. If the initial value is below the desired value, the resistor should terminate on common or ground. If it is above the desired value, the resistor should terminate on the 5 V supply. Values are typically in the 1 MΩ to 5 MΩ range.

If an external resistor is used across RATEOUT and SUMJ, then the parallel equivalent value is substituted into the preceding equation. Note that the resistor value is an estimate since it assumes V$_{CC}$ = 5.0 V and V$_{SUMJ}$ = 2.5 V.

## SELF-TEST FUNCTION

The ADXRS300 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 causes a voltage at RATEOUT equivalent to typically –270 mV, and ST2 causes an opposite +270 mV change. The self-test response follows the viscosity temperature dependence of the package atmosphere, approximately 0.25%/°C.

Activating both ST1 and ST2 simultaneously is not damaging. Since ST1 and ST2 are not necessarily closely matched, actuating both simultaneously may result in an apparent null bias shift.

## CONTINUOUS SELF-TEST

The one-chip integration of the ADXRS300 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. Application notes outlining continuous self-test techniques are also available on the Analog Devices website.
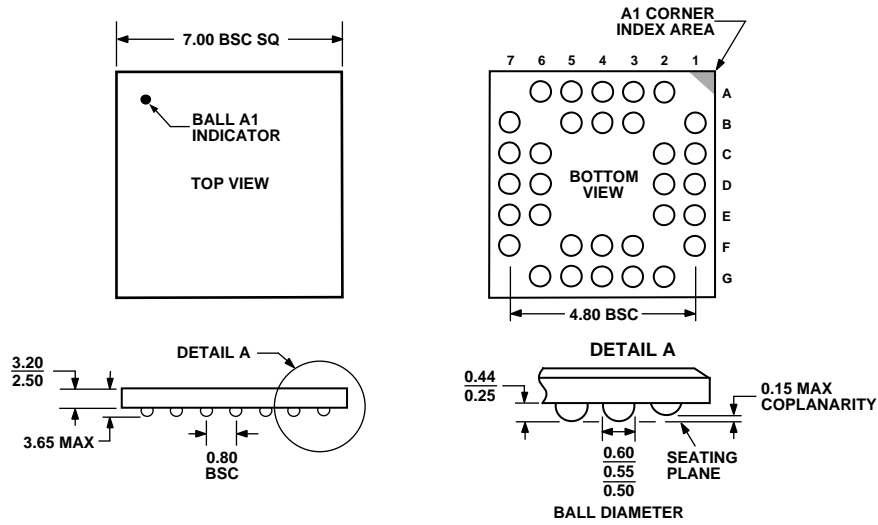
## OUTLINE DIMENSIONS



Figure 6. 32-Lead Chip Scale Ball Grid Array [CSPBGA]
(BC-32)
Dimensions shown in millimeters

## ORDERING GUIDE

| Model | Temperature Range | Package Description | Package Outline |
|---|---|---|---|
| ADXRS300ABG | −40°C to +85°C | 32-Lead BGA | BC-32 |
| ADXRS300ABG-Reel | −40°C to +85°C | 32-Lead BGA | BC-32 |
| ADXRS300EB | | Evaluation Board | |

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