PRELIMINARY TECHNICAL DATA

ANALOG DEVICES

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

## Preliminary Technical Data ADXRS300*

### FEATURES

**Complete Rate Gyroscope on a Single Chip**
**Z Axis or Yaw rate response**
**High Vibration rejection over wide frequency**
**2000g Powered Shock Operation**
**Self-Test on Digital Command**
**Temperature Sensor Output**
**Precision Voltage Reference Output**
**Absolute Rate Output for Precision Applications**
**+5V Single Supply Operation**
**Ultra small and light (<150mm$^2$, <1 gram)**

### APPLICATIONS

- Vehicle Chassis Rollover Sensing
- Inertial measurement units
- Platform stabilization

### GENERAL DESCRIPTION

The ADXRS300 is a complete angular rate sensor, (gyroscope) which uses Analog Devices surface-micro-machining process to make a functionally complete and low cost angular rate sensor integrated with all of the required electronics.

The ADXRS300 operates on the principle of a resonator or “tuning fork” 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 which sense 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 output signal, RATEOUT(1B,2A), is a voltage proportional to angular rate about the axis normal to the top surface of the package. 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 4*). A precision reference and a temperature output are also provided for compensation techniques. Two digital self-test inputs electro-mechanically excite the sensor to test proper operation of both sensors and the signal conditioning circuits.

The manufacturing technique for this device is the same high-volume BIMOS process used to for high reliability automotive airbag accelerometers.

The ADXRS300 is available in a 7mm x 7mm x 3mm BGA surface-mount package from –40 °C to +85 °C.



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## ADXRS300-SPECIFICATIONS

@TA =+25°C, Vs=+5V; Angular Rate = 0 °/s, unless otherwise noted.

| | | ADXRS300AQC | | | |
|---|---|---|---|---|---|
| Parameter | Conditions | Min | Typ | Max | Units |
| SENSITIVITY | Clockwise rotation is positive output | | | | |
| Dynamic Range[1] | Full scale range over spec. range | | +/- 300 | | °/s |
| Initial | @25 °C | 4.7 | 5 | 5.3 | mV/°/s |
| vs. Temp[2] | | 4.7 | | 5.3 | mV/°/s |
| Nonlinearity | Best fit straight line | | 0.1 | | % of FS |
| Voltage Sensitivity | Vcc=4.75 to 5.25V | | 0.7 | | %/V |
| NULL | | | | | |
| Initial Null | See apps. note for null compensation | 2.3 | 2.50 | 2.7 | V |
| vs. Temp | | 2.3 | | 2.7 | V |
| Temperature Hysteresis of Null[3] | Return after temp excursion | | 0.1 | | °/sec |
| Turn On Time | Power on to ± ½ °/sec of final | | 35 | | ms |
| Stability (after turn on time) | 0. 5 sec to 3 minutes from power-on | | 0.03 | | °/sec |
| Linear acceleration effect | Any axis | | 0.2 | | °/sec/g |
| Voltage Sensitivity | Vcc=4.75 to 5.25V | | 0.6 | | °/sec/V |
| NOISE PERFORMANCE | | | | | |
| Rate Noise Density | @25°C | | 0.2 | | °/s/ √Hz |
| FREQUENCY RESPONSE | | | | | |
| 3 dB Bandwidth **(user selectable)**[4] | 22 nF as comp cap (see apps. section) | | 40 | | Hz |
| Sensor Resonant Frequency | | | 14 | | kHz |
| SELF TEST INPUTS | | | | | |
| ST1 RATEOUT Response | ST1 pin from Logic '0' to '1' | | -50 | | °/s |
| ST2 RATEOUT Response | ST2 pin from Logic '0' to '1' | | +50 | | °/s |
| Logic '1' Voltage | Standard high logic level definition | 3.3 | | | V |
| Logic '0' Voltage | Standard low logic level definition | | | 1.7 | V |
| Input Impedance | To Common | | 50 | | kΩ |
| TEMPERATURE SENSOR | For die temperature monitoring | | | | |
| V out at 298 °K | | | 2.50 | | V |
| Max current load on pin | Sink to common | | | 50 | uA |
| Scale factor | Proportional to absolute temperature | | 8.4 | | mV/°K |
| OUTPUT DRIVE CAPABILITY | | | | | |
| Output Voltage Swing | Iout = 100 µA | 0.25 | | Vs-0.25 | V |
| Capacitive Load Drive | | 1000 | | | pF |
| 2.5 VOLT REFERENCE | | | | | |
| Voltage value | | 2.470 | 2.5 | 2.530 | Volts |
| Load Drive to ground | Source | | 300 | | uA |
| Load Regulation | 0 < Iout < 200uA | | 5.0 | | mV/mA |
| Power Supply Rejection | 4.75 to 5.25 Vs | | 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 | | | 5.0 | 8.0 | mA |
| TEMPERATURE RANGE | | | | | |
| Specified Performance A grade[5] | Temp. tested to Max and Min specs. | –40 | | 85 | °C |

Notes:
1. Dynamic range is the maximum full scale measurement range possible including output swing range, initial offset, sensitivity, offset drift, and sensitivity drift at 5V supplies.
2. Specification refers to the maximum extent of this parameter as a worst case value at $T_{min}$ or $T_{max}$.
3. Repeatability of the null offset reading with returning to the same temperature after worst case operating temperature swing. Please see apps. note on temperature calibration.
4. Frequency at which response is 3dB down from DC response with specified compensation capacitor value. Internal pole forming resistor is 180k Ohms. See data sheet apps.
5. Part functions to below –40C. Above 85 C operation is not recommended.
All min and max specifications are guaranteed. Typical specifications are not tested or guaranteed

**ABSOLUTE MAXIMUM RATING:**

Acceleration (any axis, unpowered, 0.5ms)……………..2000*g*
Acceleration (any axis, powered for 0.5ms)…………….1000*g*
+Vs……………………………….…………….-0.3V to +6.0V
Output Short Circuit Duration (any pin to Common)..Indefinite
Operating Temperature……………..……..…-55°C to +125°C
Storage Temperature…………………….……..-65°C to +150°C

Stresses above those listed under 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 sections 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 yaw-rate sensing. 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.

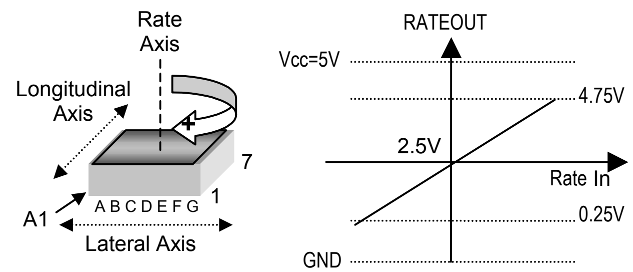
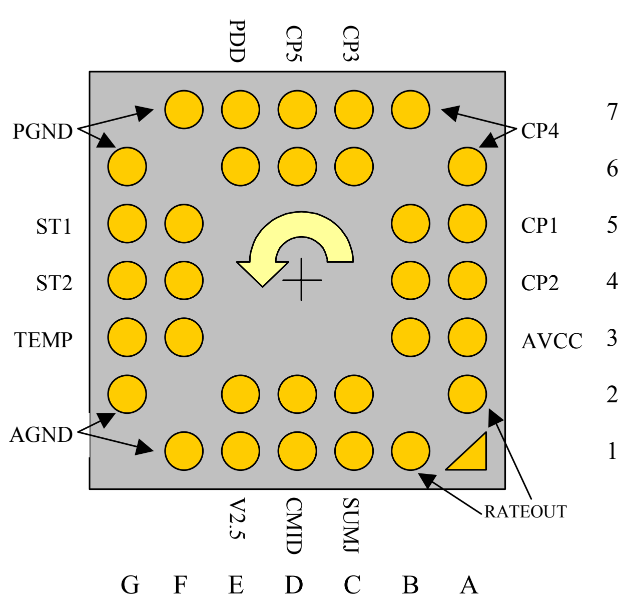



*Figure 2:RATEOUT signal increases with clockwise rotation.*

| ORDERING GUIDE | | | |
|---|---|---|---|
| **Model** | **Temperature Range** | **Package Description** | **Package Option** |
| ADXRS300ABG | -40° to +85°C | 32 pad BGA | BGA-32 |

Figure 1: Bottom View




| Pin # | Name | Description |
|---|---|---|
| 6D, 7D | CP5 | HV Filter Capacitor – 47nF |
| 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 | CMID | HF Filter Capacitor – 100nf |
| 1E, 2E | V2.5 | 2.5 Volt 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 |

***Figure 3: XRS300 Pin Descriptions***

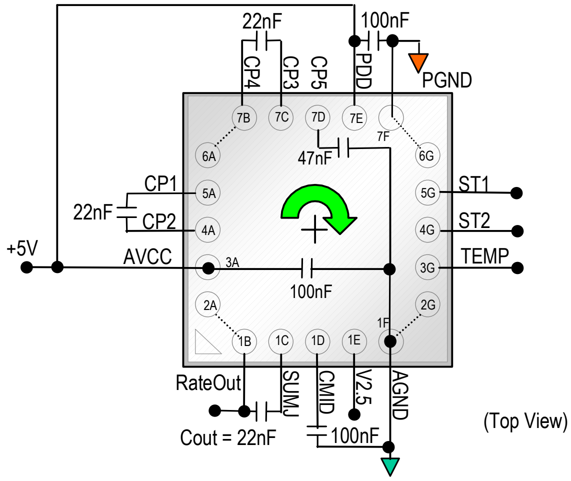



**Figure 4**: Example Application Circuit. A CMID capacitor of 100 nF sets a 400 Hz low pass pole ±35% and is used to limit high frequency artifacts before final amplification. Bandwidth limit capacitor Cout at 22 nF sets the pass bandwidth to 40 Hz. (See figure 3 below and Setting Bandwidth section following)

## 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 affects 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 will minimize the noise injected by the charge pump that uses the PDD supply.

Also recommended is to place the three charge pump capacitors connected to the CP1-CP5 pins as close to the part as possible. These capacitors used to produce the on chip high-voltage supply switched at the dither frequency at approximately 15kHz. Surface-mount chip capacitors are suitable.

If an external 14V to 16V supply is available, the two capacitors on CP1-CP4 can be omitted and this supply connected to CP5 (pin 7D) with a 100nF decoupling capacitor in place of the 47nF.

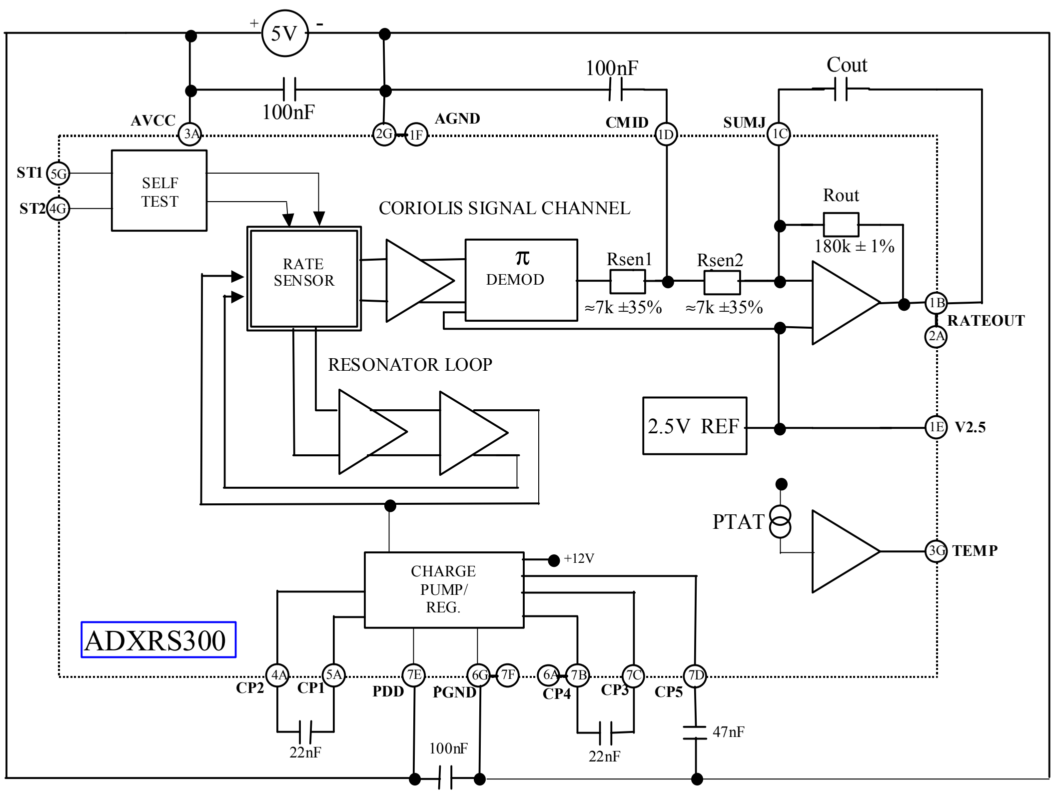



***Figure 5 –** ADXRS300 Block Diagram with External Components*

**SETTING BANDWIDTH**

Refer to figure3. External capacitors $C_{mid}$ 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 –3dB frequency set by $R_{out}$ and $C_{out}$ is:

$$f_{out}=1 / (2 * \pi * R_{out} * C_{out})$$

and can be well controlled since $R_{out}$ has been trimmed during manufacture to be 180kΩ +/-1%. Any external resistor applied between RATEOUT(1B, 2A) and SUMJ(1C) pins, will result in

$$R_{out}=180K\Omega // R_{ext}$$

The –3dB frequency set by $R_{sen}$ (the parallel combination of $R_{sen1}$ and $R_{sen2}$) at about 3.5KΩ nominal and $C_{mid}$ is less well controlled since $R_{sen1}$ and $R_{sen2}$have been used to trim the rate sensitivity during manufacture 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 uF, need not be precise. Lower frequency is preferable but its variability usually requires it to be at least higher than the well-controlled output pole. In general both –3dB filter frequencies should be set as low as possible to reduce the amplitude of these high frequency artifacts as well as to reduce 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) pins which would parallel the internal Rout resistor that is factory-trimmed to 180KΩ. For example, a 330KΩ external resistor will give ~ 50% increase in the full-scale range. This is effective for up to a 4X increase in the full-scale range (minimum value of the parallel resistor allowed is 45KΩ). Beyond this amount of external sensitivity reduction, the internal circuitry headroom requirements prevent further increase in 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 re-adjustment of the initial null bias (See section on Null Adjust).

**USING THE ADXRS300 WITH A SUPPLY-RATOMETRIC ADC**

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

**NULL ADJUST**

Null adjustment is made possible by injecting a suitable current to SUMJ(1C). Adding a suitable resistor to either ground or the positive supply is a simple way of achieving this. The nominal 2.5 V null is for symmetrical swing range at RATEOUT(1B, 2A). However, a non-symmetric 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 is to be particularly avoided in this case. (See Supply and Common Considerations).

The value of the resistor to use is approximately:

$$R_{null} = (2.5 * 180{,}000) / (V_{null0} - V_{null1})$$

$Vnull_0$ is the un-adjusted zero rate output; $Vnull_1$ 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 5V supply. Values typically are in the 1-5 MΩ range

If an external resistor is used across RATEOUT and SUMJ then the parallel equivalent value is substituted into the above equation. Note that the resistor value is an estimate as it assumes $V_{cc}$=5.0 volts and $V_{SUMJ}$= 2.5 Volts.

**SELF TEST FUNCTION**

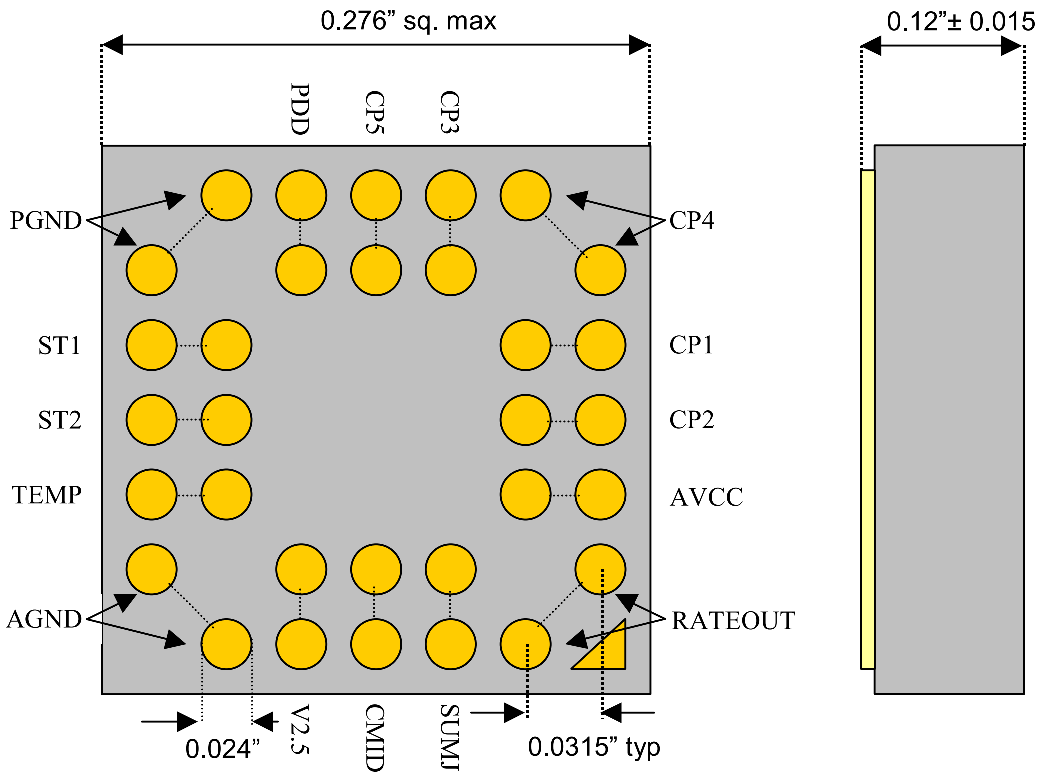
The ADXRS300 includes a self-test feature that actuates each of the sensing structures and associated electronics in the same manner as if subjected to angular rate. It is activated by standard logic high levels applied to inputs ST1(5F, 5G) or ST2(4F, 4G), or both. ST1 will cause a voltage change at RATEOUT equivalent to typically –280mV and ST2 will cause an opposite +280mV 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. As 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 which 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 available.

**SURFACE-MOUNT BGA** (BOTTOM VIEW)




NOTE: Metal lid is internally connected to AGND.

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