ANALOG DEVICES

AN-942
APPLICATION NOTE

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Optimizing MEMS Gyroscope Performance with Digital Control
by Mark Looney

INTRODUCTION

The ADIS16060 is a 14-bit digital MEMS gyroscope that uses a serial peripheral interface (SPI) to facilitate data communication and channel selection. This gyroscope provides ±50°/sec of measurement range and 1 kHz of bandwidth. With a few external components, the ADIS16060 provides digital control over its measurement range and bandwidth. Providing this function involves the integration of two features, which are normally independent of one another: external measurement range and bandwidth control and digital channel selection.

EXTERNAL RANGE AND BANDWIDTH CONTROL

The RATE and FILT pins provide access to an important amplifier stage in the gyroscope's analog signal chain. Using external components across these pins enables range extension and bandwidth modification. Lowering the effective resistance (see Equation 1 and Equation 2) on this node lowers the amplifier's gain and increases the measurement range available from the MEMS sensor core. This configuration supports increases of up to 4× the original measurement range of ±50°/sec. Users can use an external capacitor (see Equation 3) on this node to optimize the bandwidth/noise trade-off for their needs.

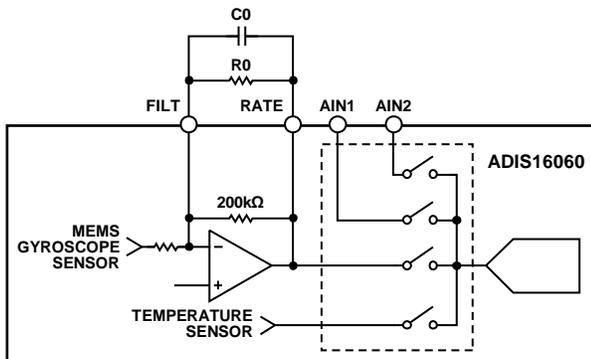Figure 1. External Range and Bandwidth Control for the ADIS16060

$$\phi_{MR} = desired\ range\left(\pm°/\sec\right) \tag{1}$$

$$R0 = \frac{200\ \text{k}\Omega}{\left[\dfrac{\phi_{MR}}{\pm 50°/\sec} - 1\right]} \tag{2}$$

$$C0 = \frac{1}{2\pi \times R_{FR} \times f_{3\ \text{dB}}} \tag{3}$$

$$R_{FR} = R0 \parallel 200\ \text{k}\Omega \tag{4}$$

DIGITAL CHANNEL SELECTION

The ADC input switch provides access to four separate analog channels: angular rate (gyroscope), sensor temperature, and two auxiliary analog input channels (AIN1, AIN2). Each analog channel has its own unique switch that is not dependent on the others. In other words, the ADIS16060 can selectively tie its RATE, AIN1, and AIN2 pins together. Figure 2 shows three separate impedances (Z0, Z1, Z2) in generic terms to identify that four custom measurement ranges and bandwidths can be made available via digital control.
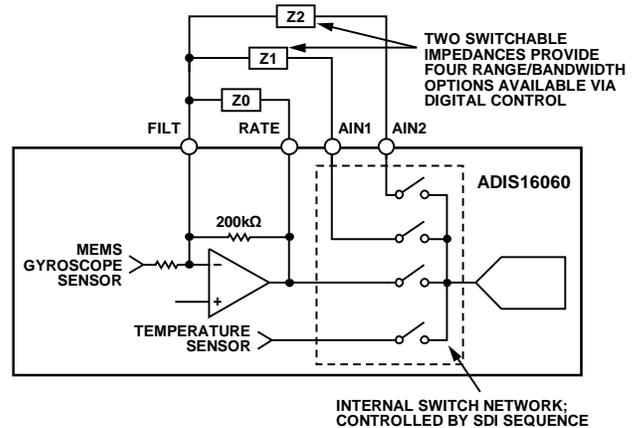

Figure 2. Digital Range and Bandwidth Selection Circuit

In the ADIS16060, use the last eight bits on the SDI line (prior to the chip select line rising) to configure the ADC input switch. Table 1 offers the configuration sequence for each potential configuration in Figure 2.

Table 1. Mode Definition and Configuration

Mode	Channels On	SPI Configuration Code
1	RATE	00100000
2	RATE, AIN1	01100000
3	RATE, AIN2	10100000
4	RATE, AIN1, AIN2	11100000

EXAMPLE 1

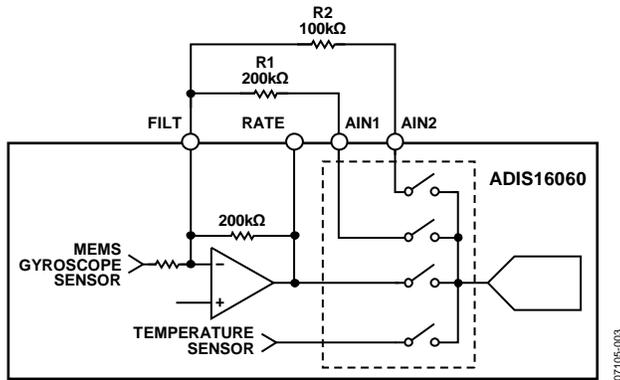In this example, two external resistors provide three custom measurement ranges, in addition to the standard ±50°/sec.

Figure 3. Gain Ranging Schematic, Example 1

Table 2. ADIS16060 Measurement Range Example

Mode	Channels On	Measurement Range
1	RATE	±50°/sec
2	RATE, AIN1	±100°/sec
3	RATE, AIN2	±150°/sec
4	RATE, AIN1, AIN2	±200°/sec

EXAMPLE 2

In this example, three internal capacitors provide three custom bandwidths, in addition to the standard 79.6 Hz.

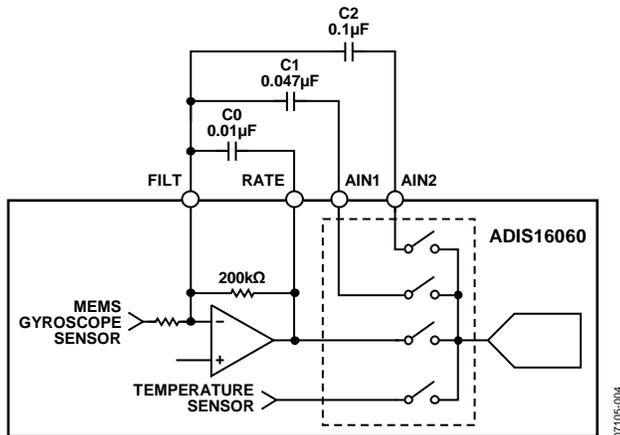*Figure 4. Bandwidth Ranging Schematic, Example 2*

Table 3. ADIS16060 Bandwidth Setting Example

Mode	Channels On	Bandwidth
1	RATE	79.6 Hz
2	RATE, AIN1	14.0 Hz
3	RATE, AIN2	7.2 Hz
4	RATE, AIN1, AIN2	4.8 Hz

EXAMPLE 3

This example offers four different measurement ranges, while maintaining the overall bandwidth to within 10% of its original value (36.2 Hz) and using two extra capacitors (C1, C2).
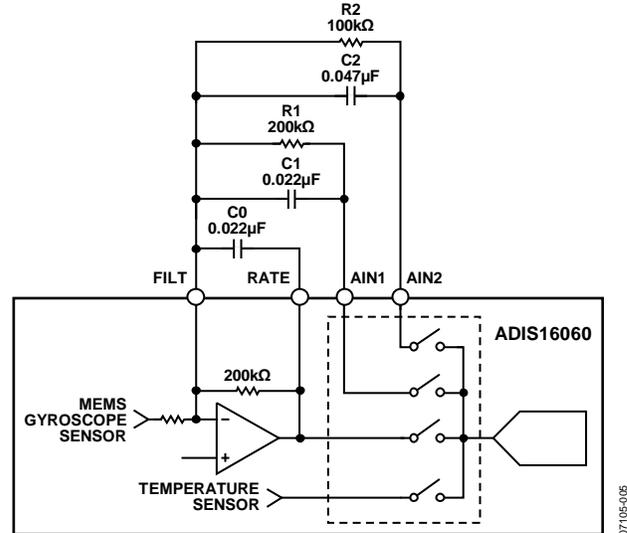

Figure 5. Gain Ranging with Bandwidth Limits, Example 3

Table 4. Range/Bandwidth Setting Example

Mode	Channels On	Measurement Range, Bandwidth
1	RATE	±50°/sec, 36.2 Hz
2	RATE, AIN1	±100°/sec, 36.2 Hz
3	RATE, AIN2	±150°/sec, 34.3 Hz
4	RATE, AIN1, AIN2	±200°/sec, 35.0 Hz

CONCLUSION

Digital performance control in the ADIS16060 offers design flexibility and can reduce system complexity. Here are a few final tips to consider when developing this type of system:

- When calibrating systems that use this feature, device tolerances are likely to require separate calibration for each setting.
- In layout, employ the best practices for minimizing potential EMI sources because these components provide access to the gyroscope's internal analog signal chain.
- When using the temperature sensor, the RATE, AIN1, and AIN2 pins need to be open. This introduces a bandwidth change for the gyroscope signal chain, for the time of the temperature read. When switching back to reading the gyroscope, allow the appropriate time (dictated by bandwidth setting) for the gyroscope signal chain to settle.

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