R02AN0009EJ0110
Rev.1.10
Sep. 30, 2013

Smart Analog IC 500

Amplifier Selection - Example Implementation: Connection of Non-Inverting Amplifier (Configuration 1) and Gyro Sensor

Introduction

This application note provides an example implementation for connecting Smart Analog IC 500 to a gyro sensor.

Operation Verified Devices

Smart Analog IC 500 (RAA730500)

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1. Overview

1.1 General

This application note provides an example implementation showing how to connect a non-inverting amplifier, which is one of the amplifier configurations (configuration 1) introduced in the application note *Smart Analog Selecting Amplifiers Based on Sensor Type* (R02AN0008E), to a gyro sensor. In this example, the Smart Analog IC 500 evaluation board (on which Smart Analog IC 500 and RL78/G1A are mounted) is used as the hardware, and Smart Analog Easy Starter ("Easy Starter") is used as the software.

At first, the mechanism and characteristics of the sensor (gyro sensor in this document) are checked, and the ideal configuration of the configurable amplifier is selected based on characteristics of the sensor. And next, the connection between the sensor pins and the Smart Analog IC 500 pins is determined. After that, the analog circuit parameters, such as the configuration of the configurable amplifier, gain, and reference voltage from D/A converter, are specified. Finally, the waveforms are checked to verify the operation of the circuits.

The analog circuit parameters can be specified and the circuit operation verified by using Easy Starter. For information on the selection of the configurable amplifier and the use of Easy Starter, refer to the application notes listed in *1.3 Related Application Notes*.

1.2 Conditions for Verifying Operation

The operation of the hardware and software described in this application note has been verified under the conditions shown below.

Table 1-1 Conditions for Verifying Operation

Item	Description
Devices used	Smart Analog IC 500 (model number: RAA730500) RL78/G1A (model number: R5F10ELE)
Evaluation board used	R0K027801D000BR (MCU Firmware - 21 Mar 2012)
External devices used	ENC-03RC-R made by Murata Manufacturing Co., Ltd.
Software	Smart Analog Easy Starter Ver 1.3

1.3 Related Application Notes

Related application notes are shown below. Also refer to these documents when using this application note.

- Smart Analog Evaluating Sensors By Using Smart Analog Easy Starter (R02AN0007E)
- Smart Analog Selecting Amplifiers Based on Sensor Type (R02AN0008E)

2. Sensor

In this section, the sensing mechanism of regular gyro sensors is described and the characteristics and specifications of the ENC-03RC-R gyro sensor made by Murata Manufacturing Co., Ltd. are also shown below.

2.1 Sensing Mechanism

A gyro sensor senses angular velocity. Gyro sensors come in various types. One common type of gyro sensor is the vibrating gyro sensor, which senses angular velocity from the Coriolis force applied to its vibrating element. The Coriolis force is the force that is generated in an orthogonal direction toward the axis of vibration when a rotational force is applied to a vibrating element. A vibrating element in the sensor is distorted by this Coriolis force, and this distortion produces a potential difference (voltage) which is applied to sense the angular velocity.

2.2 Characteristics and Specifications

In this application note, the vibrating gyroscope ENC-03RC-R made by Murata Manufacturing Co., Ltd. is used for an example implementation. The sensor characteristics which are required to select the best amplifier configuration have been excerpted from the ENC-03RC-R datasheet and are shown in Table 2-1 below. When evaluating the sensor, be sure to download the latest datasheet from the Murata Manufacturing website.

Table 2-1 Gyroscope ENC-03RC-R Extracted Electrical Characteristics

Parameter	Rating	Unit
Oscillation frequency	30.8	kHz
Supply voltage	2.7 to 5.25	V
Detection range	±300	deg/sec
Output (at angular velocity = 0)	1.35	Vdc
Sensitivity	0.67	mV/deg/sec

3. Amplifier Configuration

Use the amplifier configuration selection flowchart in Figure 3-1 to decide which amplifier configuration in Smart Analog IC 500 to use based on the sensing mechanism and characteristics of the sensor. In this application note, the vibrating gyroscope ENC-03RC-R made by Murata Manufacturing Co., Ltd. is connected to a non-inverting amplifier (configuration 1).

The reason of selecting this non-inverting amplifier (Configuration 1) is explained below.

- Seeing the mechanism described in *2.1 Sensing Mechanism*, a gyro sensor outputs voltage according to the angular velocity. "Voltage output" was therefore selected in the amplifier selection flowchart.
- As the system requirements, the measurement range of the angular velocity is defined as –300 to 300 deg/sec in this application note. In this case, from the table 2-1, output voltage (at angular velocity = 0) is 1.35 V, and the sensitivity is 0.67 mV/deg/sec, so that the output voltage range of the sensor will be 1.15 to 1.55 V (0.4Vp-p). The amplifier gain should be lower than 21 dB when Smart Analog IC 500 is connected to the A/D converter whose input voltage range is 0 to 3.3 V, therefore, a non-inverting amplifier (configuration 1) was selected in the amplifier selection flowchart.

The route by which the non-inverting amplifier (configuration 1) was selected in this application note is highlighted in Figure 3-1. For a detailed description of the amplifier configuration selection flowchart, refer to the relevant application note in *1.3 Related Application Notes*.

It is needed, however, to change the value of branch condition depending on the requirement for the systems. Note that this flowchart is one of the examples to select the amplifier configuration.

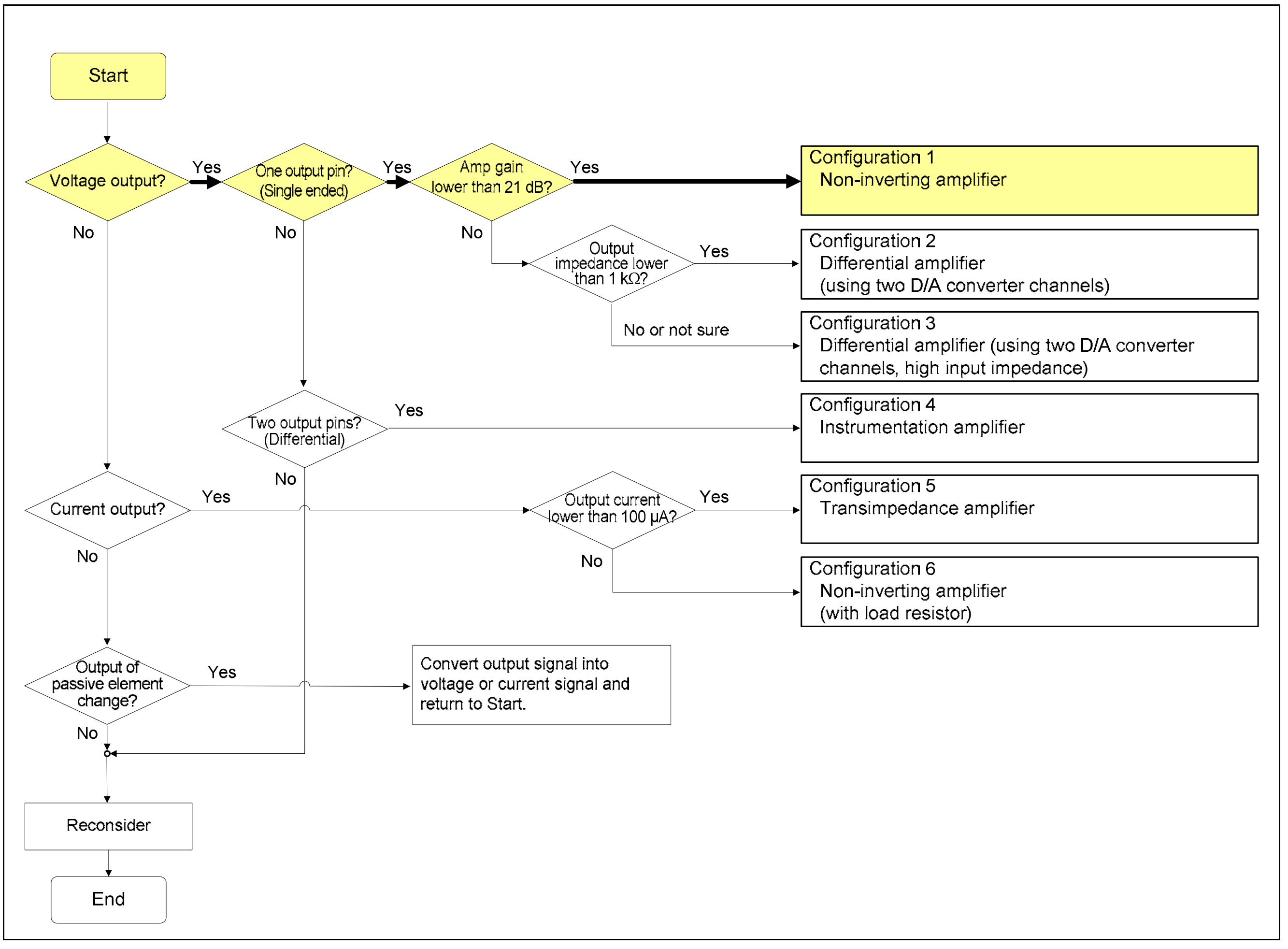

Figure 3-1 Amplifier Configuration Selection Flowchart

4. Connecting Smart Analog IC 500 to the Sensor

Figure 4-1 shows an example of connecting Smart Analog IC 500 to the gyro sensor. The output of the gyro sensor is connected to the non-inverted input pin of a configurable amplifier in Smart Analog IC 500. In this application note, output voltage of D/A converter is used as the reference voltage for the configurable amplifier without using the reference voltage (Vref) from the gyro sensor, and configurable amplifier Ch1 is used, so the MPXIN20 pin is used as the non-inverted input pin.

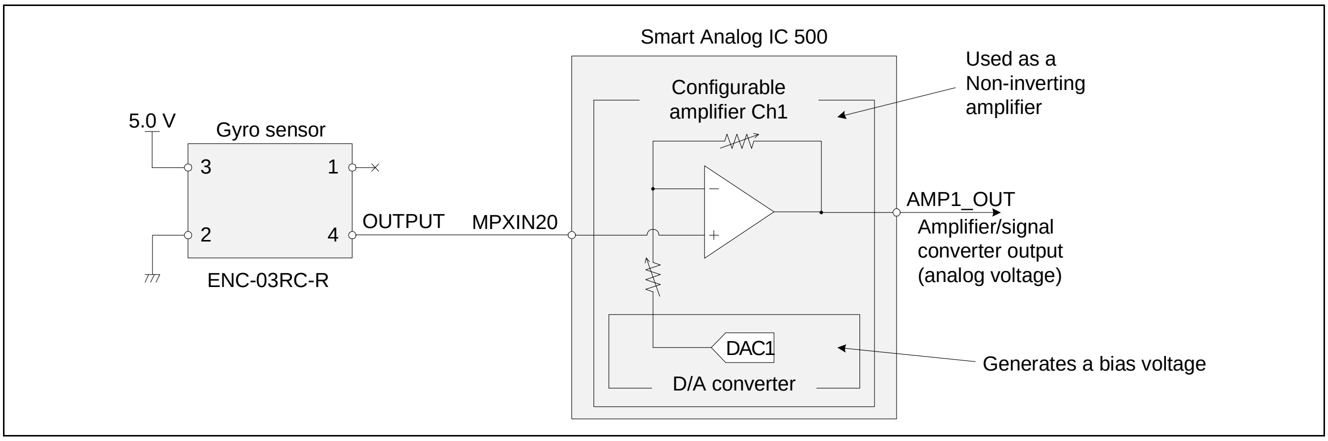

Figure 4-1 Example of Connecting Smart Analog IC 500 to the Gyro Sensor

5. Setting Procedure

Once the amplifier configuration and pins to be used for connection have been determined, the analog circuit parameters must be specified. In this application note, an example of the settings specified when connecting the non-inverting amplifier (configuration 1) to the gyro sensor is provided below. The settings of the analog circuit parameters are specified in the **Chip Config** window of Easy Starter. For how to use Easy Starter to evaluate the sensor, refer to the relevant application note in *1.3 Related Application Notes*, which describes the setting procedure in detail.

5.1 Analog Circuit Parameters to Set

The analog parameters which should be specified in the **Chip Config** window are summarized below in the implementation example of this application note.

- Amplifier configuration: Non-inverting amplifier
  This is the configuration selected by using the amplifier selection flowchart.

- Amplifier gain: 14 dB
  When the measured angular velocity is –300 to 300 deg/sec, which is the requirement of the system, the output voltage range of the gyro sensor is to be 1.15 to 1.55 V. On the evaluation board used in this application note, the reference voltage for A/D converter is 3.3 V, which is supplied by a variable output voltage regulator of Smart Analog IC500. It is necessary to specify a gain that does not cause the input voltage to the A/D converter to exceed the reference voltage for A/D converter. The gain is therefore set to 14 dB.

- D/A converter output voltage: 1.31 V
  The reference voltage for the configurable amplifier should be adjusted by D/A converter so that the output voltage range of the amplifier is within the input voltage range of A/D converter, which is 0 to 3.3 V. In this example, the output voltage of the D/A converter is set to 1.31 V.

- Amplifier input pin: MPXIN20 pin
  The amplifier input pin is the pin to which the sensor output pin is connected.

- Variable output voltage regulator: 3.3 V
  This is used as the reference voltage for A/D converter.

5.2 Settings in **Chip Config** Window

The parameters of the analog circuits in Smart Analog IC 500 are specified in the **Chip Config** window.

An example of the setting procedure used in this application note is shown below.

- Specify "non-inverting amplifier" as the configuration of configurable amplifier Ch1.
- Set the gain of configurable amplifier Ch1 to "14 dB".
- Set the output voltage of D/A converter Ch1 to "67" (1.31 V).
- Specify the MPXIN20 pin as the pin connecting the sensor to the Smart Analog IC.
- Set configurable amplifier Ch1 to "ON".
- Set the output voltage of the variable output voltage regulator to "3.3 V".
- Set the variable output voltage regulator to "ON".

This completes setting the analog circuit parameters.

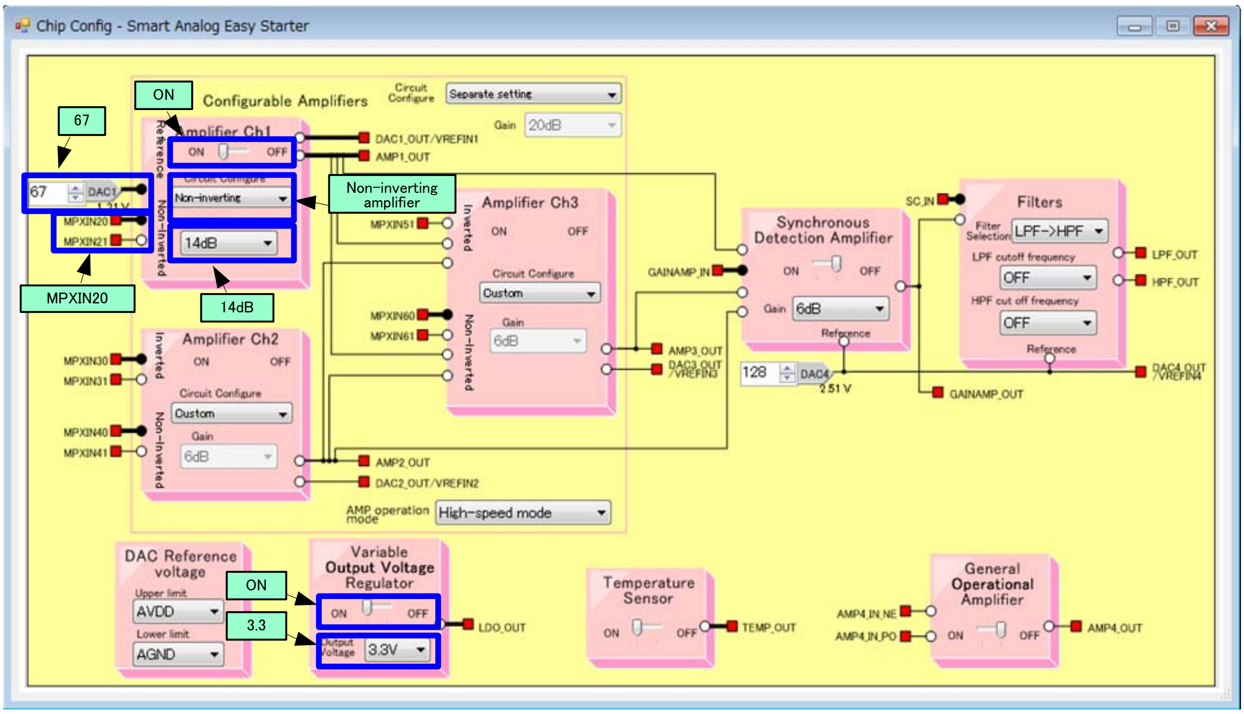

Figure 5-1 Settings in **Chip Config** Window

5.3 Checking the Circuit Configuration in Smart Analog IC 500

After the analog circuit parameters have been specified, the internal circuit configuration can be reviewed. The internal circuit configuration of Smart Analog IC 500 as specified in this application note is described below.

- Amplifier configuration: Non-inverting amplifier
  Configurable amplifier Ch1 is used as a non-inverting amplifier.
  - SW11 and SW13 are set to "0" (open) and SW12 is set to "1" (short) in the CONFIG1 register.
  - MPX11 is set to "1" and MPX10 is set to "0" in the MPX1 register.
  - SW01 is set to "1" (short) in the CONFIG2 register.
  - AMP1OF is set to "1" (operation enabled) in the PC1 register.

- Amplifier gain: 14 dB
  The amplifier gain is specified as follows:
  - The GC1 register is set to "03H".

- D/A converter output voltage: 67 (1.31 V)
  The D/A converter setting is specified as follows:
  - VRT1, VRT0, VRB1, and VRB0 are set to "0" in the DACRC register.
  - The DAC1C register is set to "43H".
  - DAC1OF is set to "1" (operation enabled) in the PC1 register.

- Amplifier input pin: MPXIN20 pin
  The amplifier input pin setting is specified as follows:
  - MPX21 and MPX20 are set to "0" in the MPX1 register.

- Variable output voltage regulator: 3.3 V
  The variable output voltage regulator setting is specified as follows:
  - LDO3, LDO2, and LDO0 are set to "1" and LDO1 is set to "0" in the LDOC register.
  - LDOOF is set to "1" (operation enabled) in the PC2 register.

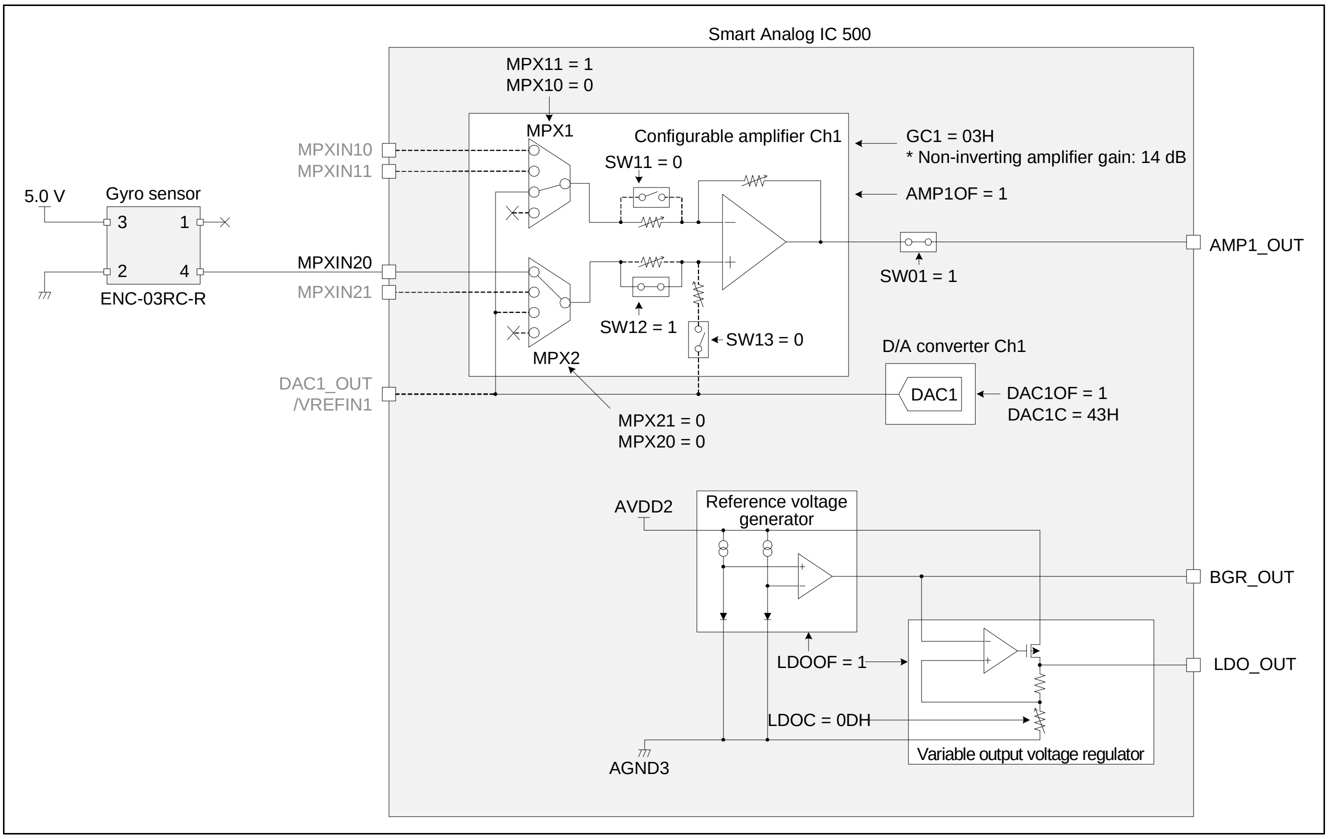

Figure 5-2 Circuit Configuration of Smart Analog IC 500

5.4 List of Register Settings

Figure 5-3 shows the values of the SPI control registers in Smart Analog IC 500. For details of each register, see the *RAA730500 Monolithic Programmable Analog IC Datasheet (R02DS0008E).*

Register List - Smart Analog Easy Starter

Font Size 9 RegisterReload C source output

Address	Register	R/W	D7	D6	D5	D4	D3	D2	D1	D0	HEX
00h	Configuration register 1	R/W	–	SW11	SW12	SW13	–	SW21	SW22	SW23	20h
	(CONFIG1)		0	0	1	0	0	0	0	0	
01h	Configuration register 2	R/W	–	SW31	SW32	SW33	–	SW02	SW01	SW00	02h
	(CONFIG2)		0	0	0	0	0	0	1	0	
03h	MPX setting register 1	R/W	MPX1[1:0]		MPX2[1:0]		MPX3[1:0]		MPX4[1:0]		80h
	(MPX1)		1	0	0	0	0	0	0	0	
04h	MPX setting register 2	R/W	–	MPX5[2:0]			–	MPX6[2:0]			00h
	(MPX2)		0	0	0	0	0	0	0	0	
05h	MPX setting register 3	R/W	0	0	SCF[2:1]		SCF0	MPX7[2:0]			00h
	(MPX3)		0	0	0	0	0	0	0	0	
06h	Gain control register 1	R/W	0	0	0	AMPG1[4:0]					03h
	(GC1)		0	0	0	0	0	0	1	1	
07h	Gain control register 2	R/W	0	0	0	AMPG2[4:0]					00h
	(GC2)		0	0	0	0	0	0	0	0	
08h	Gain control register 3	R/W	0	0	0	AMPG3[4:0]					00h
	(GC3)		0	0	0	0	0	0	0	0	
09h	AMP operation mode control register	R/W	0	0	–	–	–	–	CC[1:0]		00h
	(AOMC)		0	0	0	0	0	0	0	0	
0Ah	Gain control register 4	R/W	0	0	0	AMP4[4:0]					00h
	(GC4)		0	0	0	0	0	0	0	0	
0Bh	LDO control register	R/W	0	0	0	0	LDO[3:0]				0Dh
	(LDOC)		0	0	0	0	1	1	0	1	
0Ch	DAC reference voltage control register	R/W	0	0	0	0	VRT[1:0]		VRB[1:0]		00h
	(DACRC)		0	0	0	0	0	0	0	0	
0Dh	DAC control register 1	R/W	DAC1[7:0]								43h
	(DAC1C)		0	1	0	0	0	0	1	1	
0Eh	DAC control register 2	R/W	DAC2[7:0]								80h
	(DAC2C)		1	0	0	0	0	0	0	0	
0Fh	DAC control register 3	R/W	DAC3[7:0]								80h
	(DAC3C)		1	0	0	0	0	0	0	0	
10h	DAC control register 4	R/W	DAC4[7:0]								80h
	(DAC4C)		1	0	0	0	0	0	0	0	
11h	Power control register 1	R/W	DAC4OF	DAC3OF	DAC2OF	DAC1OF	AMP4OF	AMP3OF	AMP2OF	AMP1OF	11h
	(PC1)		0	0	0	1	0	0	0	1	
12h	Power control register 2	R/W	–	–	–	GAINOF	LPFOF	HPFOF	LDOOF	TEMPOF	03h
	(PC2)		0	0	0	0	0	0	1	1	
13h	Reset control register	R/W	0	0	0	0	0	0	0	RESET	00h
	(RC)		0	0	0	0	0	0	0	0	

Figure 5-3 List of Registers

6. Operation Verification Results

Finally, the operation of the circuit of Smart Analog IC500 with the sensor connected is verified. To verify that the circuits are operating correctly, check the waveforms in the **ADC Graph** window. For instructions on the use of Easy Starter, refer to the application notes listed in *1.3 Related Application Notes*.

The procedure for verifying operation used in this application note is described below.

It was verified that the output voltage changed according to the angular velocity of the sensor when the evaluation board was rotated in the direction of the sensing axis. The A/D conversion interval was set to 100 ms.

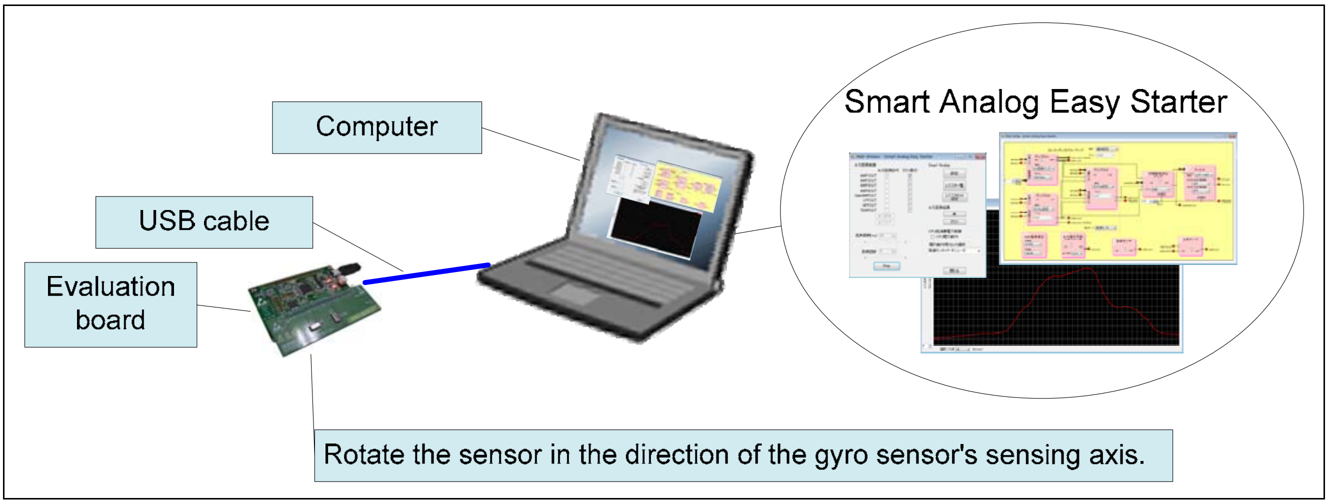

Figure 6-1 Operation Verification Environment

The measurement waveforms obtained from the **ADC Graph** window are shown in Figure 6-2.

The waveforms when angular acceleration was and was not applied to the sensor are shown below. When angular acceleration was not applied, the voltage waveform was steady. On the other hand, when angular acceleration was applied, the polarity of the voltage output from the sensor changed according to the sensor's rotational direction. When the sensor was rotating in direction A, the output voltage was higher than when angular acceleration was not applied; when the sensor was rotating in direction B, the voltage was lower. Note that the voltage level depends on the rate of rotation.

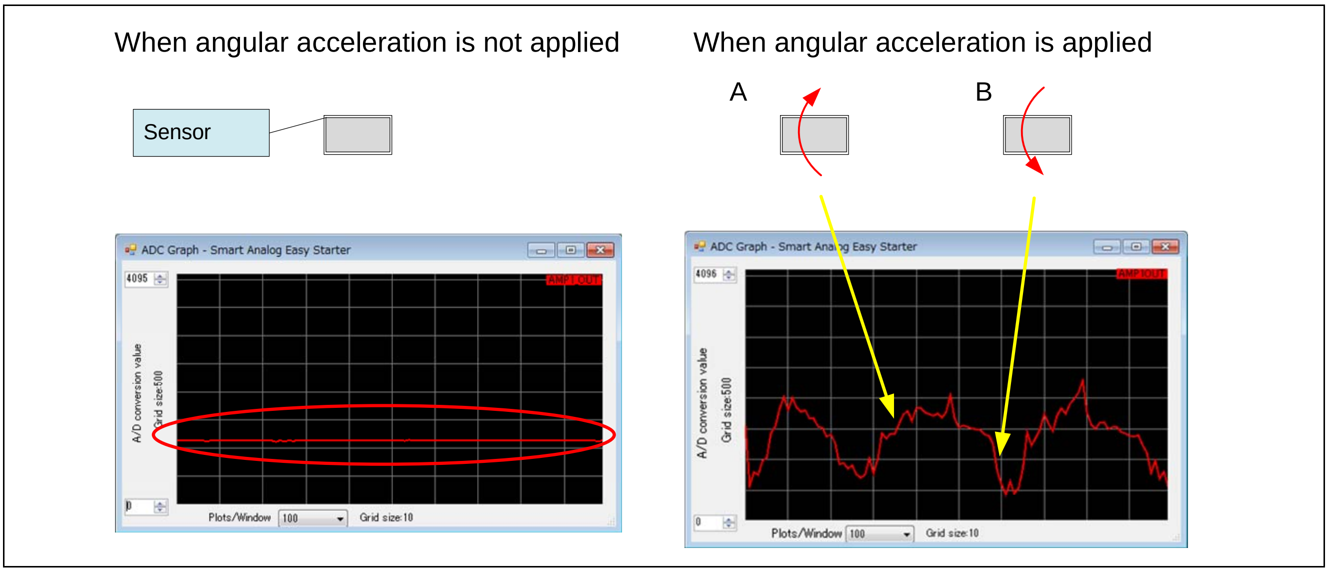

Figure 6-2 Operation Verification Waveforms

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Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Oct. 30, 2012	—	First edition issued.
1.10	Sep. 30, 2013	—	The wrong words are removed to the correct words. Some explanations are added for more details. Some descriptions are changed to more appropriate one.

General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU products from Renesas. For detailed usage notes on the products covered by this manual, refer to the relevant sections of the manual. If the descriptions under General Precautions in the Handling of MPU/MCU Products and in the body of the manual differ from each other, the description in the body of the manual takes precedence.

1. Handling of Unused Pins
   Handle unused pins in accord with the directions given under Handling of Unused Pins in the manual.
   — The input pins of CMOS products are generally in the high-impedance state. In operation with unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.
2. Processing at Power-on
   The state of the product is undefined at the moment when power is supplied.
   — The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the moment when power is supplied.
   In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the moment when power is supplied until the reset process is completed.
   In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the moment when power is supplied until the power reaches the level at which resetting has been specified.
3. Prohibition of Access to Reserved Addresses
   Access to reserved addresses is prohibited.
   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.
4. Clock Signals
   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has stabilized.
   — When the clock signal is generated with an external resonator (or from an external oscillator) during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Moreover, when switching to a clock signal produced with an external resonator (or by an external oscillator) while program execution is in progress, wait until the target clock signal is stable.
5. Differences between Products
   Before changing from one product to another, i.e. to one with a different part number, confirm that the change will not lead to problems.
   — The characteristics of MPU/MCU in the same group but having different part numbers may differ because of the differences in internal memory capacity and layout pattern. When changing to products of different part numbers, implement a system-evaluation test for each of the products.

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