Smart Analog IC 500

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Amplifier Selection - Example Implementation: Connection of Instrumentation Amplifier (Configuration 4) and Hall Element

Introduction

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

Operation Verified Devices

Smart Analog IC 500 (RAA730500)

Contents

1. Overview

1.1 General

This application note provides an example implementation showing how to connect an instrumentation amplifier, which is one of the amplifier configurations (configuration 4) introduced in the application note *Smart Analog Selecting Amplifiers Based on Sensor Type (R02AN0008E)*, to a Hall element. In this example, the Smart Analog IC 500 evaluation board (on which Smart Analog IC 500 and the 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 (Hall element 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	HW-300B made by Asahi Kasei Microdevices Corp.
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 Hall elements is described and the characteristics and specifications of the HW-300B made by Asahi Kasei Microdevices Corp. are also shown below.

2.1 Sensing Mechanism

A Hall element is a magnetic sensor that uses the Hall effect. The Hall effect is a phenomenon in which, when a magnetic field is applied to an electrical conductor, an electric field (electromotive force) is produced along the vertical direction to both current and magnetic field. A Hall element uses this phenomenon to convert a magnetic field into a voltage to output.

A Hall element is made of a semiconductor such as indium antimonide (InSb) and gallium arsenide (GaAs), and has a pair of input pins (current input or voltage input) and a pair of voltage output pins. The change of the voltage from output pins is very small, so that the difference in voltage between the output pins is usually used for detection.

2.2 Characteristics and Specifications

In this application note, the InSb Hall element HW-300B made by Asahi Kasei Microdevices Corp. is used for an example implementation. The sensor characteristics which are required to select the best amplifier configuration have been excerpted from the HW-300B datasheet and are shown in Table 2-1 below. When evaluating the sensor, be sure to download the latest datasheet from the Asahi Kasei Microdevices website.

Table 2-1 Hall Element HW-300B Extracted Electrical Characteristics

(Ta = 25°C, Vcc = 5 V)

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Output hall voltage	V_H	Const. voltage drive B = 50 mT, V_c = 1 V	168	–	320	mV
Input resistance	R_{in}	B = 0 mT, I_c = 0.1 mA	240	–	550	Ω
Output resistance	R_{out}	B = 0 mT, I_c = 0.1 mA	240	–	550	Ω
Offset voltage	V_{os}(Vu)	B = 0 mT, V_c = 1 V	-7	–	7	mV

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 InSb Hall element HW-300B made by Asahi Kasei Microdevices Corp. is connected to an instrumentation amplifier (configuration 4).

The reason of selecting this instrumentation amplifier (configuration 4) is explained below.

- Based on the mechanism described in *2.1 Sensing Mechanism*, a Hall element outputs a differential voltage which is converted from a magnetic field. "Voltage output" and "two output pins" were therefore selected in the amplifier selection flowchart.

The route by which the instrumentation amplifier (configuration 4) 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.

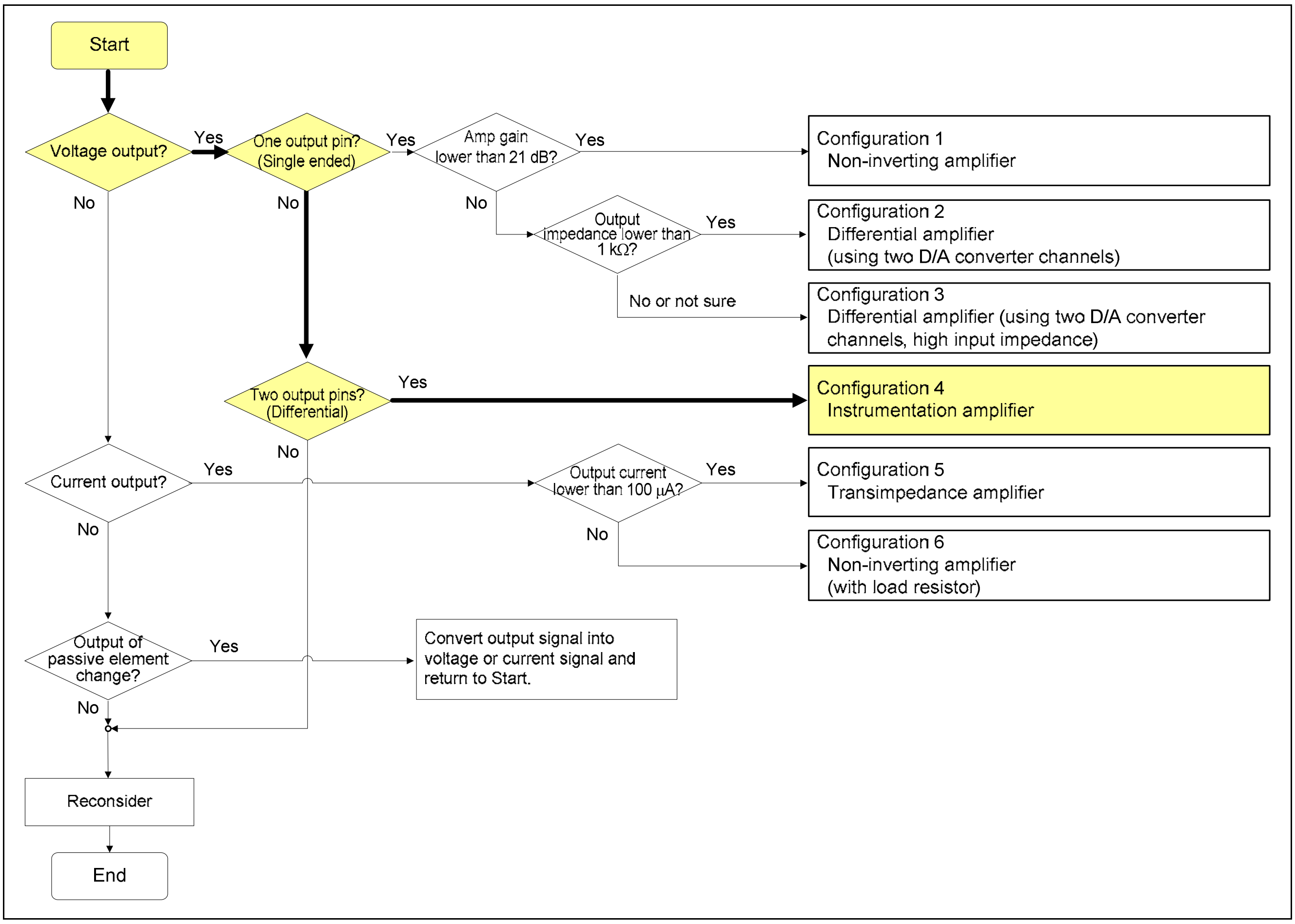

Figure 3-1 Amplifier Configuration Selection Flowchart

4. Connecting Smart Analog IC 500 to the Sensor

Figure 4-1 shows an example of connecting Smart Analog IC 500 to the Hall element. The Hall element is connected to an instrumentation amplifier that is configured by using configurable amplifier Ch1 to Ch3. Input pins of the instrumentation amplifier are the non-inverted input pins of a configurable amplifier Ch1 and Ch2. In this application note, the MPXIN20 pin is used as the non-inverted input pin for configurable amplifier Ch1, and the MPXIN40 pin is used as the non-inverted input pin for configurable amplifier Ch2.

And, the output voltage of variable output voltage regulator is set to 3.3 V to be used as a reference voltage for A/D converter, however it is also used as a power supply to drive HW-300B whose driving voltage must not exceed 2.0 V. Therefore, a diode is connected between LDO_OUT pin and HW-300B to step down the sensor driving voltage to 1.0 V.

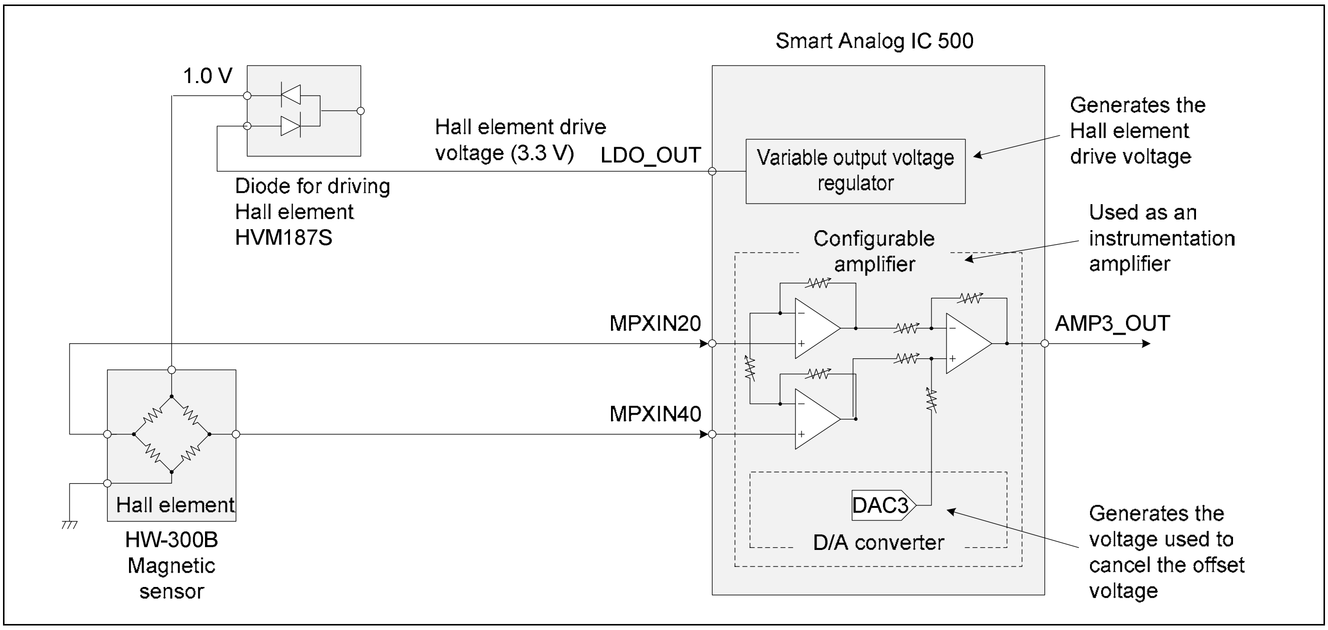

Figure 4-1 Example of Connecting Smart Analog IC 500 to the Hall Element

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 instrumentation amplifier (configuration 4) to the Hall element 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: Instrumentation amplifier
  This is the configuration selected by using the amplifier selection flowchart.

- Amplifier gain: 20 dB
  As an example of the system requirements, the measurement range of the magnetic flux density is defined as 0 to 25 mT in this application note. In this case, the maximum output voltage is ±150 mV. The input voltage to the A/D converter is needed to set not to exceed the reference voltage for A/D converter of 3.3 V, which is supplied by a variable output voltage regulator of Smart Analog IC500. Therefore, it is necessary to specify a gain that does not cause the input voltage to the A/D converter over 3.3 V. The gain is therefore set to 20 dB.

- D/A converter Ch3 output voltage: 1.65 V
  Because the directions of magnetic force of north and south poles of a magnet are opposite with each other, the output voltage polarity is also opposite with each other when bringing a magnet closer to the sensor. To enable the detection of both north and south poles, therefore, the output voltage of the sensor when no magnetic field is applied to the sensor must be set at the middle of the A/D converter's input voltage range. The input voltage range of the A/D converter is 0 to 3.3 V, so the output voltage of the sensor when no magnetic field applied is set to 1.65 V, which is the middle point in this range from 0 to 3.3 V.

- Amplifier input pins: MPXIN20 and MPXIN40 pins
  The amplifier input pins are the pins to which the sensor output pins are connected.

- Variable output voltage regulator: 3.3 V
  This is used as the reference voltage for A/D converter and the supply source of the sensor drive voltage.

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 "instrumentation amplifier" as the configuration of the configurable amplifier.
- Set the gain of the configurable amplifier to "20 dB".
- Set the output voltage of D/A converter Ch3 to "84" (1.65 V).
- Specify the MPXIN20 and MPXIN40 pins as the pins connecting the sensor to the Smart Analog IC.
- 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.

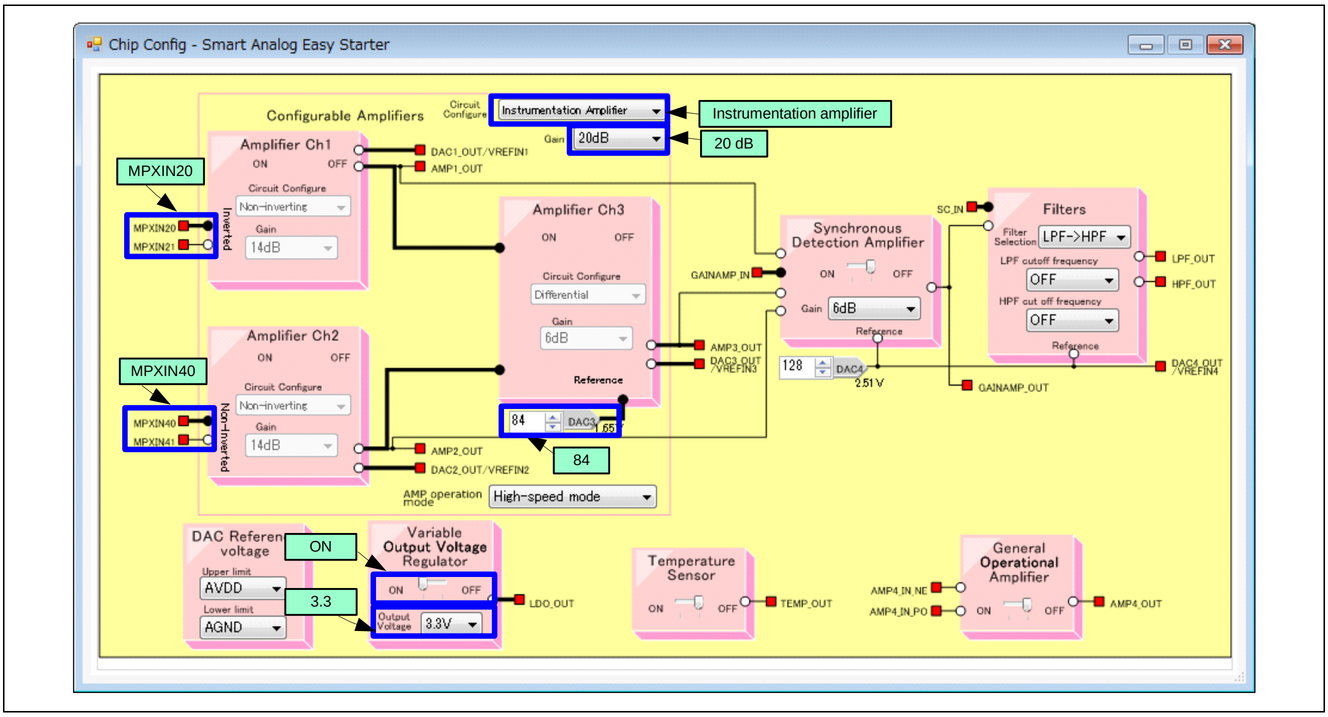

Figure 5-1 Settings in **Chip Config** Window

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: Instrumentation amplifier
  Configurable amplifier channels Ch1 to Ch3 are used as instrumentation amplifiers.
  - SW11, SW13, SW21 and SW23 are set to "0" (open) and SW12 and SW22 are set to "1" (short) in the CONFIG1 register.
  - SW31, SW32, SW02, and SW01 are set to "0" (open) and SW33 and SW00 are set to "1" (short) in the CONFIG2 register.
  - MPX11, MPX10, MPX31, and MPX30 are set to "1" in the MPX1 register.
  - MPX52, MPX50, and MPX62 are set to "0" and MPX51, MPX61, and MPX60 are set to "0" in the MPX2 register.
  - AMP1OF, AMP2OF, and AMP3OF are set to "1" (operation enabled) in the PC1 register.

- Amplifier gain: 20 dB
  The amplifier gain is specified as follows:
  - The GC1 register is set to "03H".
  - The GC2 register is set to "03H".
  - The GC3 register is set to "00H".

- D/A converter Ch3 output voltage: 84 (1.65 V)
  The D/A converter Ch3 setting is specified as follows:
  - VRT1, VRT0, VRB1, and VRB0 are set to "0" in the DACRC register.
  - The DAC3C register is set to "54H".
  - DAC3OF is set to "1" (operation enabled) in the PC1 register.

- Amplifier input pins: MPXIN20 and MPXIN40 pins
  The amplifier input pin setting is specified as follows:
  - MPX21 and MPX20 are set to "0" in the MPX1 register.
  - MPX41 and MPX40 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.

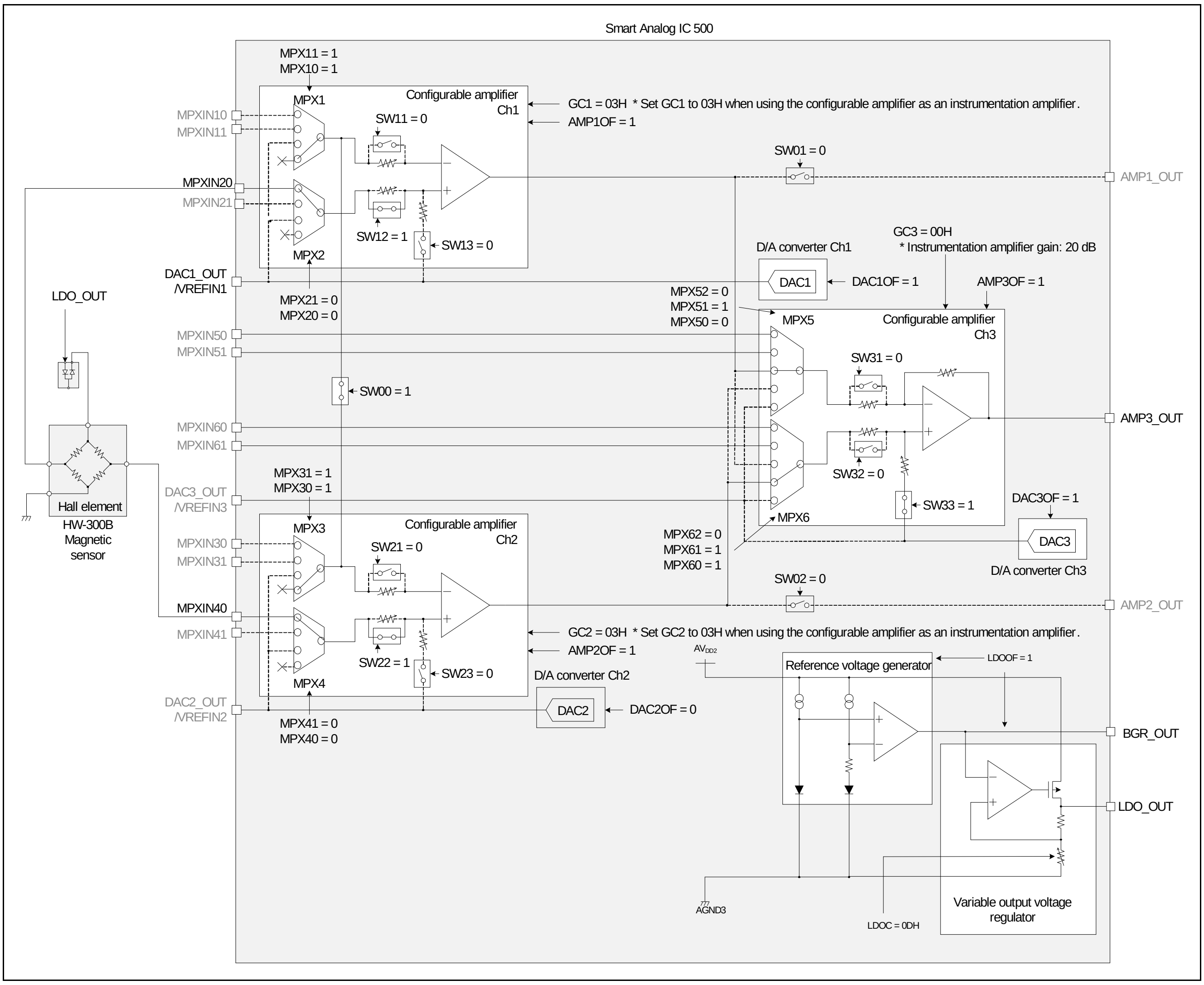

Figure 5-2 Circuit Configuration of Smart Analog IC 500

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	Data								HEX
			D7	D6	D5	D4	D3	D2	D1	D0	
00h	Configuration register 1	R/W	–	SW11	SW12	SW13	–	SW21	SW22	SW23	22h
	(CONFIG1)		0	0	1	0	0	0	1	0	
01h	Configuration register 2	R/W	–	SW31	SW32	SW33	–	SW02	SW01	SW00	11h
	(CONFIG2)		0	0	0	1	0	0	0	1	
03h	MPX setting register 1	R/W	MPX1[1:0]		MPX2[1:0]		MPX3[1:0]		MPX4[1:0]		CCh
	(MPX1)		1	1	0	0	1	1	0	0	
04h	MPX setting register 2	R/W	–	MPX5[2:0]			–	MPX6[2:0]			23h
	(MPX2)		0	0	1	0	0	0	1	1	
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]					03h
	(GC2)		0	0	0	0	0	0	1	1	
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]								80h
	(DAC1C)		1	0	0	0	0	0	0	0	
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]								54h
	(DAC3C)		0	1	0	1	0	1	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	77h
	(PC1)		0	1	1	1	0	1	1	1	
12h	Power control register 2	R/W	–	–	–	GAINOF	LPFOF	HPFOF	LDOOF	TEMPOF	02h
	(PC2)		0	0	0	0	0	0	1	0	
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 when a magnet was brought closer to the sensor from the south pole and from the north pole. The A/D conversion interval was set to 100 ms.

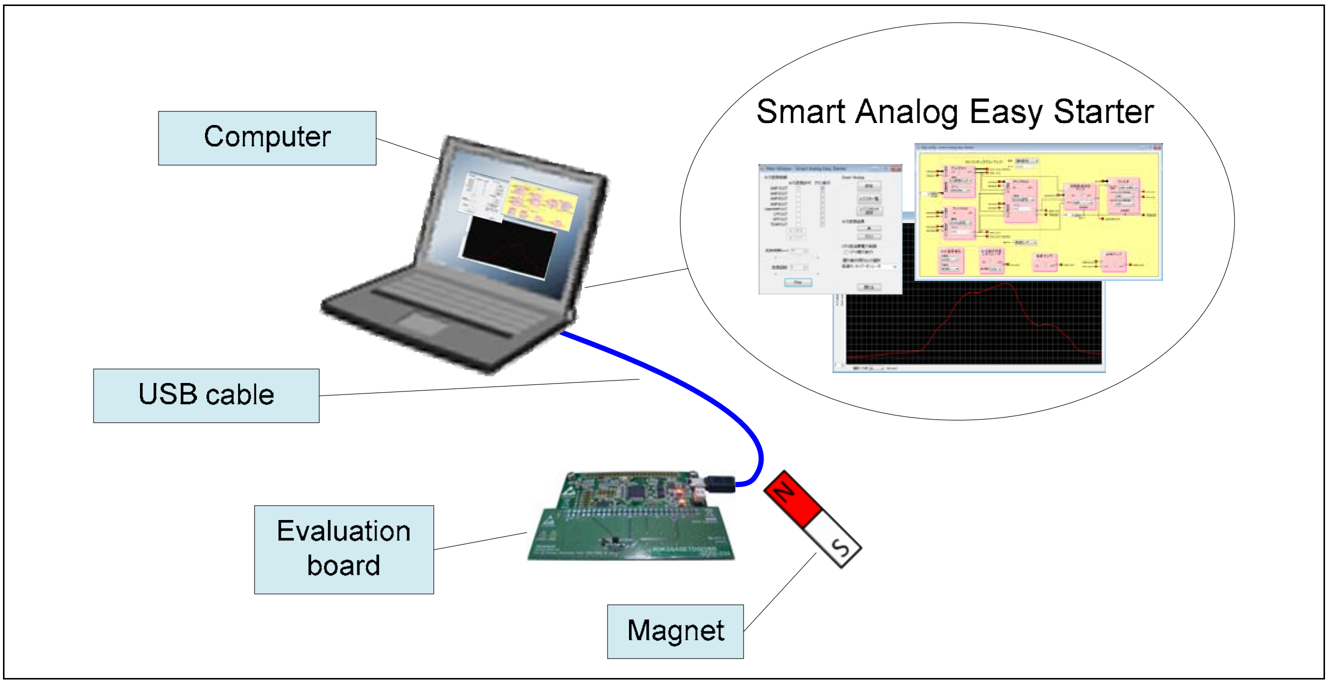

Figure 6-1 Operation Verification Environment

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

Measurement started with no magnetic field applied to the sensor. As a magnet was brought closer to the sensor from the south pole, it was observed that the output voltage rose above the initial state of no magnetic field applied. As a magnet was brought closer to the sensor from the north pole, it was observed that the output voltage fell below the initial state of no magnetic field applied.

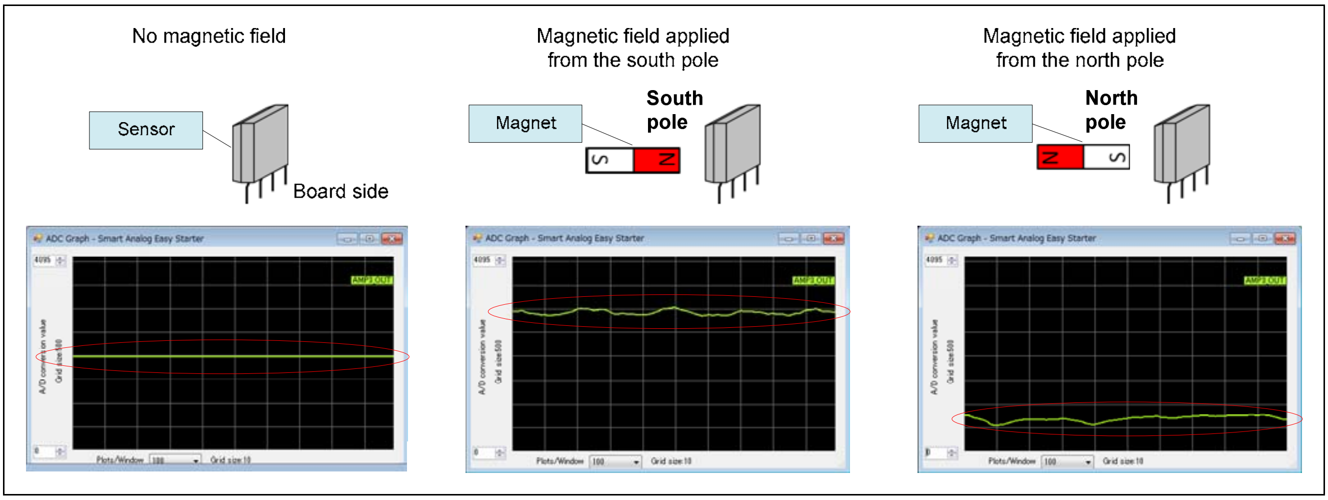

Figure 6-2 Operation Verification Waveforms

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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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