

# Smart Analog IC 500

## Amplifier Selection - Example Implementation: Connection of Differential Amplifier (Configuration 3) and MR Sensor

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### Introduction

This application note provides an example implementation for connecting Smart Analog IC 500 to a Magneto-Resistive (MR) sensor.

### Operation Verified Devices

Smart Analog IC 500 (RAA730500)

### Contents

1. Overview .....	2
2. Sensor .....	3
3. Amplifier Configuration .....	4
4. Connecting Smart Analog IC 500 to the Sensor .....	5
5. Setting Procedure.....	6
6. Operation Verification Results.....	12

## 1. Overview

### 1.1 General

This application note provides an example implementation showing how to connect a differential amplifier, which is one of the amplifier configurations (configuration 3) introduced in the application note *Smart Analog Selecting Amplifiers Based on Sensor Type* (R02AN0008E), to an MR sensor. 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 (MR 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	KG0823 made by KOHDEN 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 MR sensors is described and the characteristics and specifications of the KG0823 MR sensor made by KOHDEN Co., Ltd. are also shown below.

### 2.1 Sensing Mechanism

MR (magneto resistance) sensors are a type of magnetic sensor used to measure the size and direction of a magnetic field. These sensors are mainly configured by using elements made of a magnetic material whose electrical resistance changes according to the magnetic field intensity. (This is known as the magnetoresistance effect.) This change in resistance is used to detect a magnetic field.

### 2.2 Characteristics and Specifications

In this application note, the mold type high-resistance MR sensor KG0823 made by KOHDEN 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 KG0823 datasheet and are shown in Table 2-1 below. When evaluating the sensor, be sure to download the latest datasheet from the KOHDEN website.

Table 2-1 MR Sensor KG0823 Extracted Electrical Characteristics

(Ta = 25°C, Vcc = 5 V)

Parameter	Conditions	Min.	Typ.	Max.	Unit
Input resistance	Between Vcc and GND	450	550	650	KΩ
Median potential	0 T	2470	2500	2530	mV
Output voltage	16 kA/m	25	35	45	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 mold type high-resistance MR sensor KG0823 made by KOHDEN Co., Ltd. is connected to a differential amplifier (configuration 3).

The reason of selecting this differential amplifier (configuration 3) is explained below.

- Based on the mechanism described in 2.1 *Sensing Mechanism*, the resistance of the MR sensor changes according to the magnetic field intensity. By supplying power to the sensor, this change in resistance is output as a change in voltage. "Voltage output" was therefore selected in the amplifier selection flowchart.
- As an example of the system requirements, the measurement range of the magnetic field intensity is defined as  $\pm 16$  kA/m vertically and horizontally in this application note. This means that the output voltage range of the sensor is  $\pm 45$  mV max., requiring the signal to be amplified by approximately 30 dB to fall within the input voltage range to the A/D converter. Also, because the output impedance is 325 k $\Omega$  max., a differential amplifier that uses two D/A converter channels and has high impedance was selected in the amplifier selection flowchart.

The route by which the differential amplifier (configuration 3) 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.

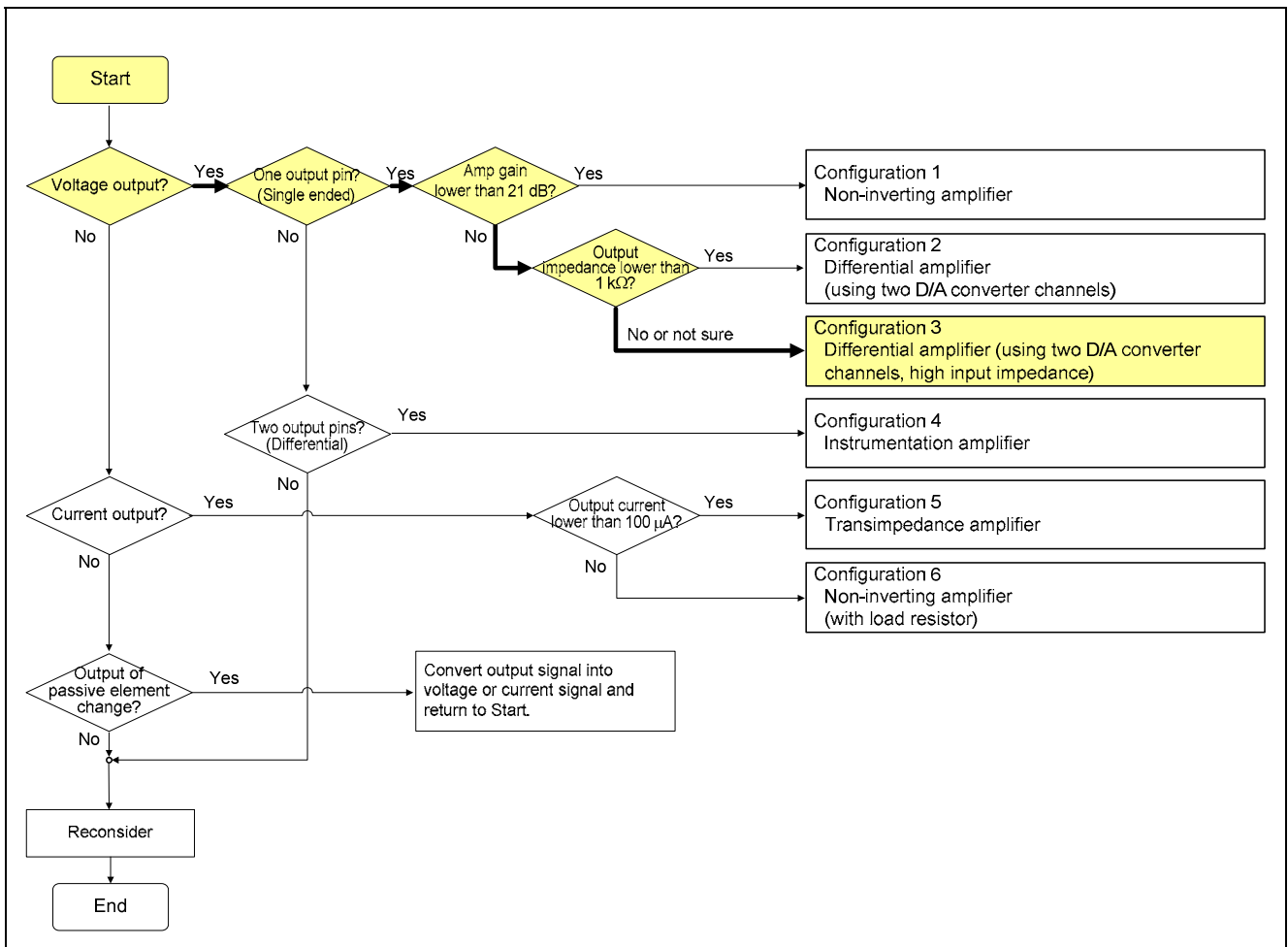


Figure 3-1 Amplifier Configuration Selection Flowchart

4. Connecting Smart Analog IC 500 to the Sensor

Figure 4-1 shows an example of connecting Smart Analog IC 500 to the MR sensor. The output pin of the MR sensor is connected to the non-inverted input pin of a configurable amplifier in Smart Analog IC 500. In this application note, configurable amplifier Ch2 is used, so the MPXIN40 pin is used as the non-inverted input pin.

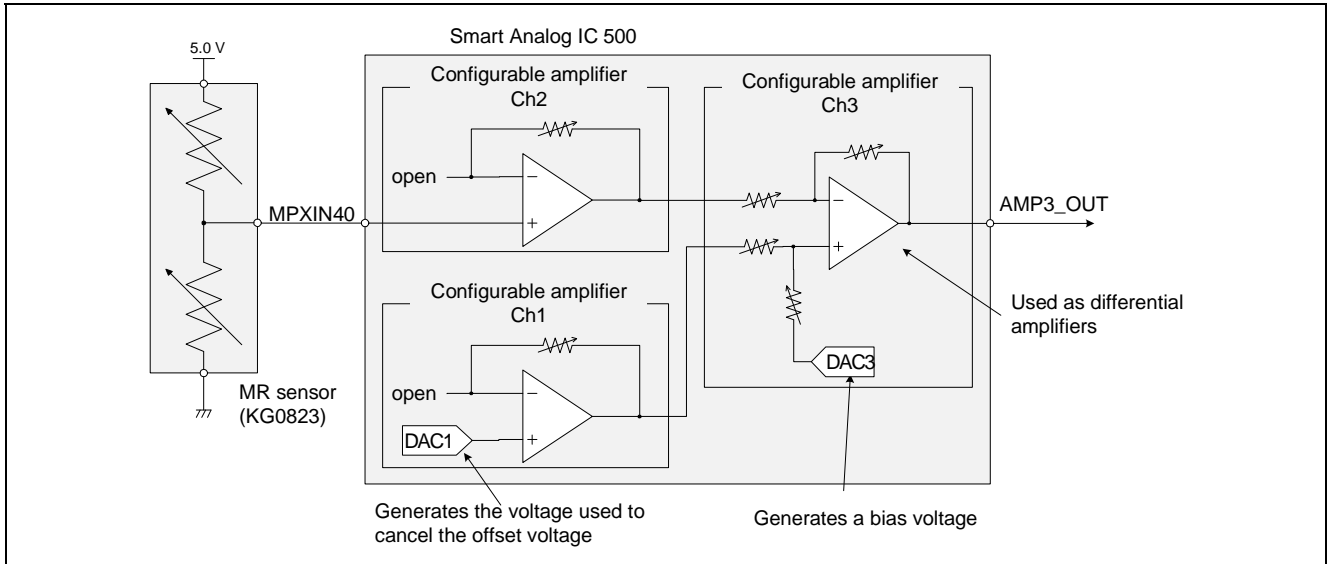


Figure 4-1 Example of Connecting Smart Analog IC 500 to the MR Sensor

## 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 differential amplifier (configuration 3) to the MR 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: Differential amplifier (using two D/A converter channels and with high impedance)**  
This is the configuration selected by using the amplifier selection flowchart.
- **Amplifier gain: 30 dB**  
When the measured magnetic field intensity is  $\pm 16$  kA/m, which is the requirement of the system, the maximum output voltage is  $\pm 45$  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 30 dB.
- **D/A converter Ch1 output voltage: 2.50 V**  
The sensor's output voltage when the sensor is not in a magnetic field is 2.5 V typ. To cancel this voltage, 2.5 V is applied to one of the inputs of the differential amplifier.
- **D/A converter Ch3 output voltage: 1.65 V**  
An output voltage from the sensor that fluctuates up and down around the middle of output voltage according to the direction of the magnetic field. The input voltage range of the A/D converter is 0 to 3.3 V, so the middle of output voltage of the sensor is set to 1.65 V, which is the middle point in this range from 0 to 3.3 V.
- **Amplifier input pin: MPXIN40 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.

Open the **AMP1 Config** window to specify detailed settings for configurable amplifier Ch1.

- Set SW12 and SW13 to "short".
- Set MPX1 to "3" (open) and MPX2 to "2" (DAC1).
- Set D/A converter Ch1 to "128" (2.51 V).
- Set D/A converter Ch1 to "ON".
- Set configurable amplifier Ch1 to "ON".

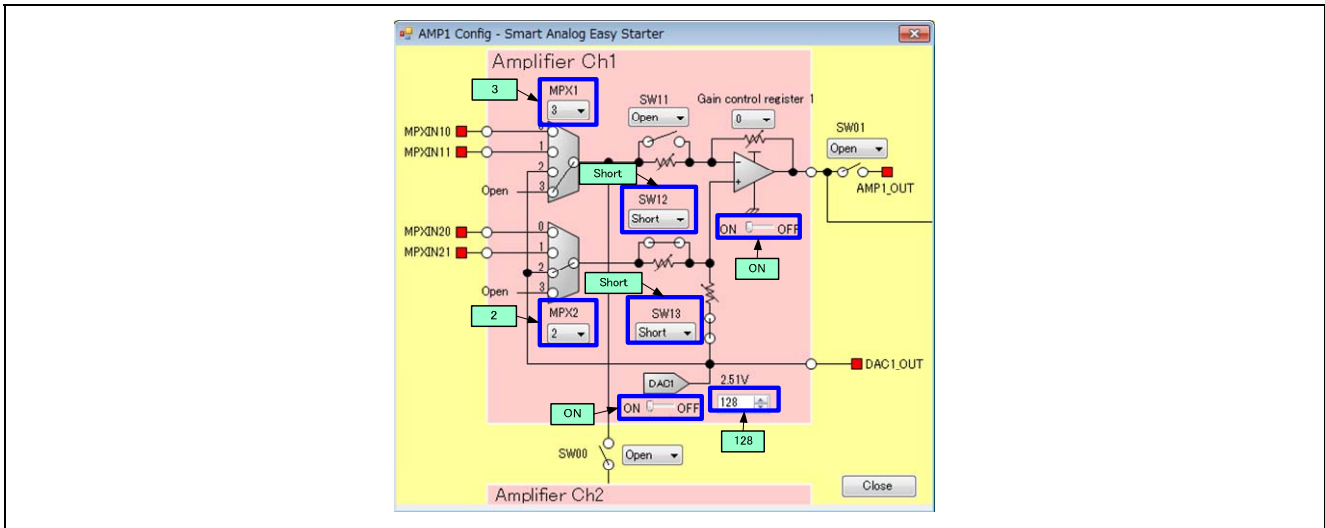


Figure 5-1 Settings in **AMP1 Config** Window

Open the **AMP2 Config** window to specify detailed settings for configurable amplifier Ch2.

- Set SW22 to "short" and SW23 to "open".
- Set MPX3 to "3" (open) and MPX4 to "0" (MPXIN40).
- Set configurable amplifier Ch2 to "ON".

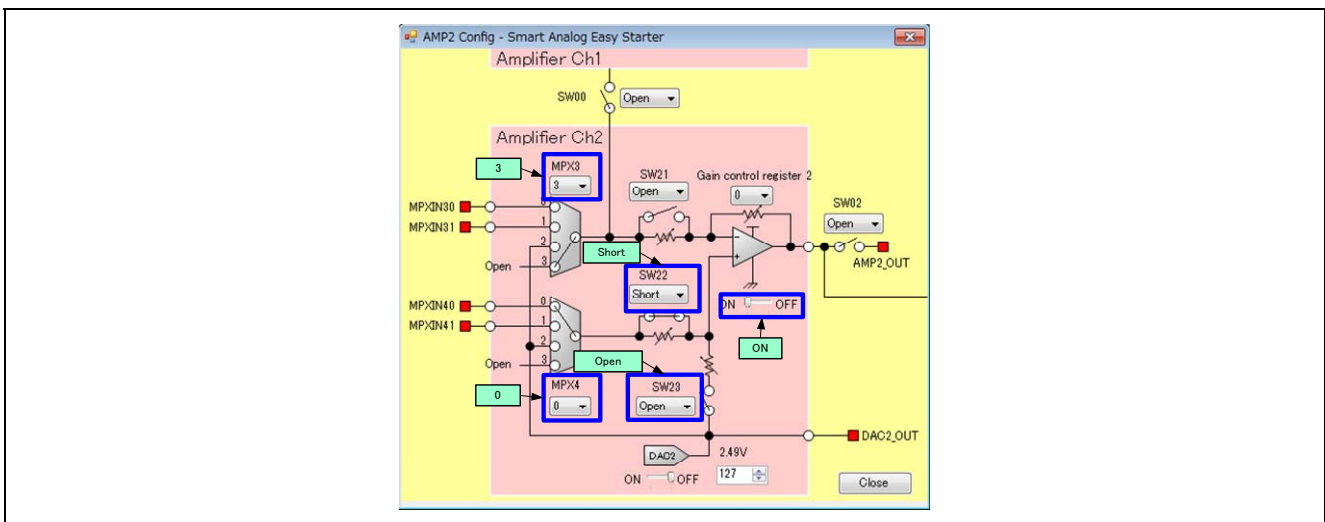


Figure 5-2 Settings in **AMP2 Config** Window

- Specify "differential amplifier" as the configuration of configurable amplifier Ch3.
- Set the gain of configurable amplifier Ch3 to "30 dB".
- Set the output voltage of D/A converter Ch3 to "84" (1.65 V).
- Specify "configurable amplifier Ch2 output signal" for the inverted input pin.
- Specify "configurable amplifier Ch1 output signal" for the non-inverted input pin.
- Set configurable amplifier Ch3 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.

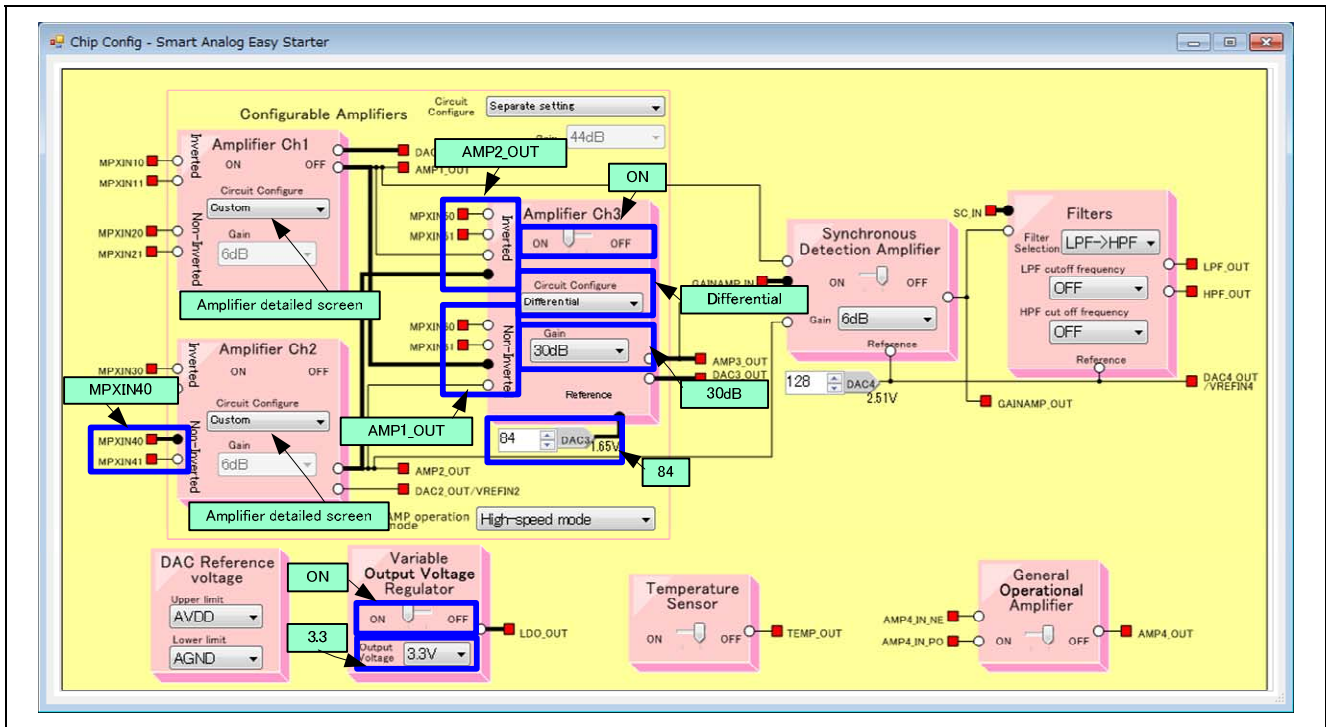


Figure 5-3 Settings in Chip Config Window



### 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: Differential amplifier (using two D/A converter channels and with high impedance)  
Configurable amplifier Ch1 is used as a voltage follower.
  - SW11 is set to "0" (open) and SW12 and SW13 are set to "1" (short) in the CONFIG1 register.
  - MPX11, MPX10, and MPX21 are set to "1" and MPX20 is set to "0" in the MPX1 register.
  - AMP1OF is set to "1" (operation enabled) in the PC1 register.Configurable amplifier Ch2 is used as a voltage follower.
  - SW21 and SW23 are set to "0" (open) and SW22 is set to "1" (short) in the CONFIG1 register.
  - MPX31 and MPX30 are set to "1" in the MPX1 register.
  - AMP2OF is set to "1" (operation enabled) in the PC1 register.Configurable amplifier Ch3 is used as a differential amplifier.
  - SW31 and SW32 are set to "0" (open) and SW33 is set to "1" (short) in the CONFIG2 register.
  - MPX52, MPX62, and MPX60 are set to "0" and MPX51, MPX50, and MPX61 are set to "1" in the MPX2 register.
  - AMP3OF is set to "1" (operation enabled) in the PC1 register.
- Amplifier gain: 30 dB  
The amplifier gain setting is specified as follows:
  - The GC3 register is set to "0CH".
- D/A converter Ch1 output voltage: 128 (2.51 V)  
The D/A converter Ch1 setting is specified as follows:
  - VRT1, VRT0, VRB1, and VRB0 are set to "0" in the DACRC register.
  - The DAC1C register is set to "80H".
  - DAC1OF is set to "1" (operation enabled) in the PC1 register.
- 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 DAC1C register is set to "54H".
  - DAC3OF is set to "1" (operation enabled) in the PC1 register.
- Amplifier input pin: MPXIN40 pin  
The amplifier input pin setting is specified as follows:
  - 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.

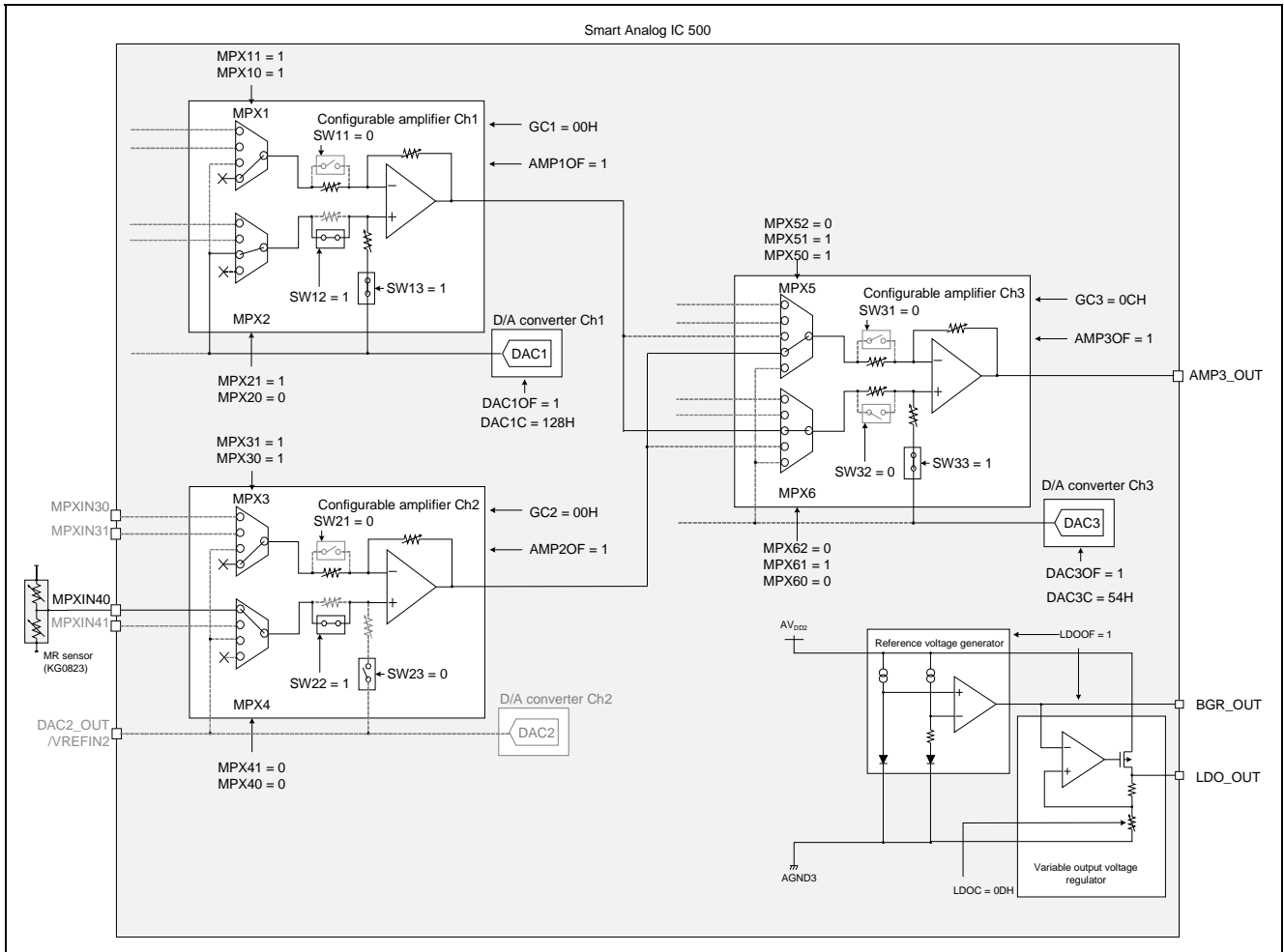


Figure 5-4 Circuit Configuration of Smart Analog IC 500

5.4 List of Register Settings

Figure 5-5 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)*.

Address	Register	R/W	Data								HEX	
			D7	D6	D5	D4	D3	D2	D1	D0		
00h	Configuration register 1 (CONFIG1)	R/W	-	SW11	SW12	SW13	-	SW21	SW22	SW23	32h	
01h	Configuration register 2 (CONFIG2)	R/W	-	SW31	SW32	SW33	-	SW02	SW01	SW00	10h	
03h	MPX setting register 1 (MPX1)	R/W	MPX1[1:0]		MPX2[1:0]		MPX3[1:0]		MPX4[1:0]		ECh	
04h	MPX setting register 2 (MPX2)	R/W	-	MPX5[2:0]			-	MPX6[2:0]			32h	
05h	MPX setting register 3 (MPX3)	R/W	0	0	SCF[2:1]		SCF0	MPX7[2:0]			00h	
06h	Gain control register 1 (GC1)	R/W	0	0	0	AMPG1[4:0]				00h		
07h	Gain control register 2 (GC2)	R/W	0	0	0	AMPG2[4:0]				00h		
08h	Gain control register 3 (GC3)	R/W	0	0	0	AMPG3[4:0]				0Ch		
09h	AMP operation mode control register (AOMC)	R/W	0	0	-	-	-	CC[1:0]			00h	
0Ah	Gain control register 4 (GC4)	R/W	0	0	0	AMP4[4:0]				00h		
0Bh	LDO control register (LDOC)	R/W	0	0	0	0	1	1	0	1	0Dh	
0Ch	DAC reference voltage control register (DACRC)	R/W	0	0	0	0	VRT[1:0]		VRB[1:0]		00h	
0Dh	DAC control register 1 (DAC1C)	R/W	DAC1[7:0]									80h
0Eh	DAC control register 2 (DAC2C)	R/W	DAC2[7:0]									7Fh
0Fh	DAC control register 3 (DAC3C)	R/W	DAC3[7:0]									54h
10h	DAC control register 4 (DAC4C)	R/W	DAC4[7:0]									80h
11h	Power control register 1 (PC1)	R/W	DAC40F	DAC30F	DAC20F	DAC10F	AMP40F	AMP30F	AMP20F	AMP10F	57h	
12h	Power control register 2 (PC2)	R/W	-	-	-	GAIN0F	LPFOF	HPFOF	LDOOF	TEMPOF	02h	
13h	Reset control register (RC)	R/W	0	0	0	0	0	0	0	RESET	00h	

Figure 5-5 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 distance between the sensor and a magnet when a magnet was brought closer to the sensor from above and from the side. The A/D conversion interval was set to 100 ms.

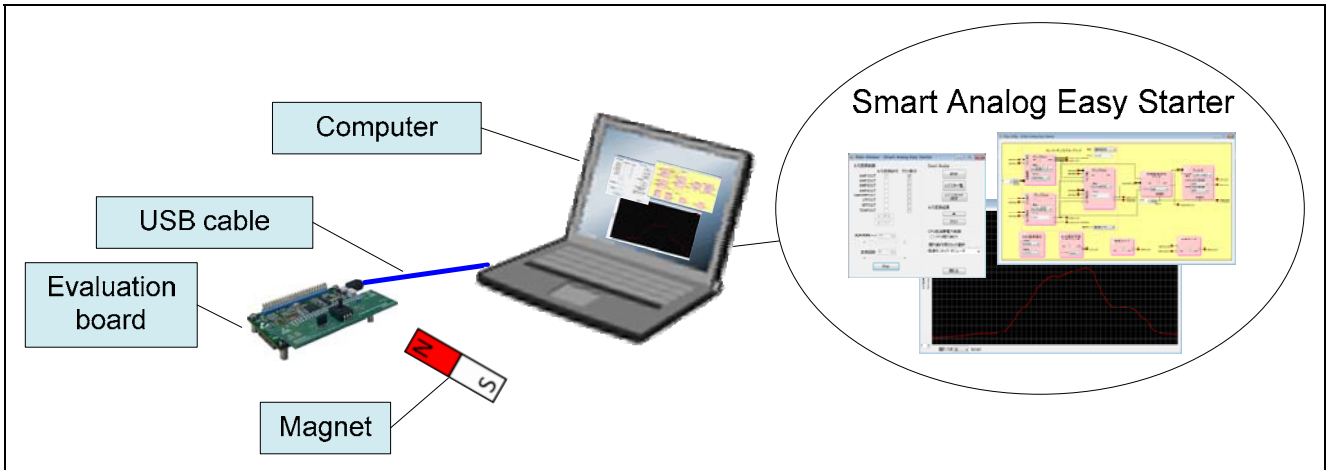


Figure 6-1 Operation Verification Environment

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 above, 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 side, it was observed that the output voltage fell below the initial state of no magnetic field applied.

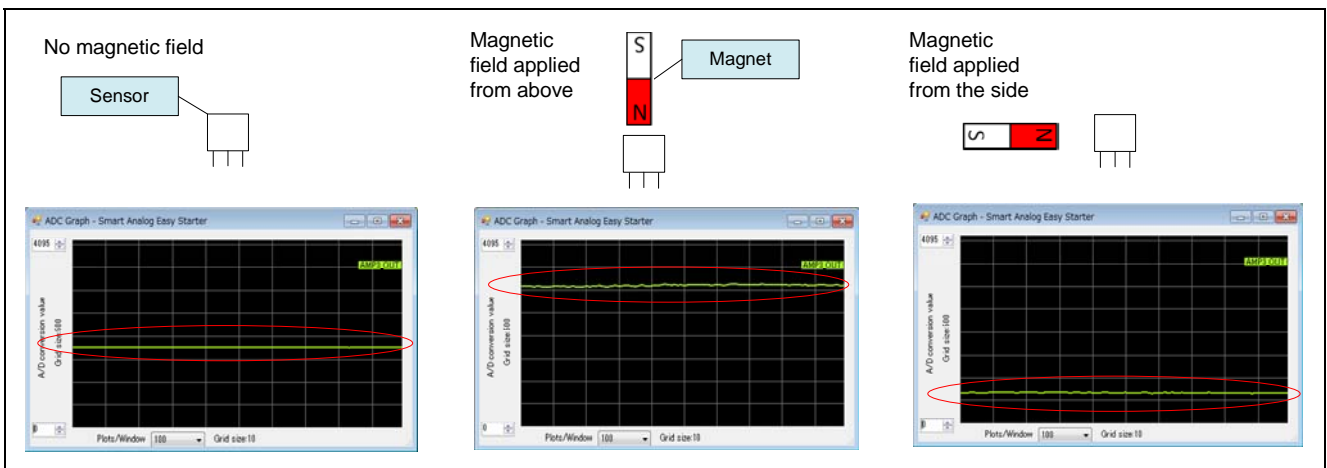


Figure 6-2 Operation Verification Waveforms

## Smart Analog

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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

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### 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.

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