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Smart Analog IC 500

Amplifier Selection - Example Implementation: Connection of Transimpedance Amplifier (Configuration 5) and Photodiode

Introduction

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

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 a transimpedance amplifier, which is one of the amplifier configurations (configuration 5) introduced in the application note *Smart Analog Selecting Amplifiers Based on Sensor Type* (R02AN0008E), to a photodiode. 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 (photodiode 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	S6036 made by Hamamatsu Photonics K.K.
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 photodiodes is described and the characteristics and specifications of the S6036 photodiode made by Hamamatsu Photonics K.K. are shown below.

2.1 Sensing Mechanism

A photodiode is a typical light receiving element. A photodiode generates a current by using the photovoltaic effect, which occurs when a p-n junction is exposed to light. The amount of current generated is linear to the amount of irradiated light. Regular photodiodes consist of two terminals: an anode and a cathode. Current flows from the cathode to the anode by photovoltaic effect.

2.2 Characteristics and Specifications

In this application note, the Si PIN photodiode S6036 made by Hamamatsu Photonics K.K. is used for an example implementation. The sensor characteristics which are required to select the best amplifier configuration have been excerpted from the S6036 datasheet and are shown in Table 2-1 below. When evaluating the sensor, be sure to download the latest datasheet from the Hamamatsu Photonics website.

Table 2-1 Photodiode S6036 Extracted Electrical Characteristics

(Ta = 25°C)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Spectral response range	λ		–	320 to 1100	–	nm
Peak sensitivity wavelength	λp		–	960	–	nm
Photo sensitivity	S	$\lambda = \lambda p$	0.51	0.56	–	A/W
Short circuit current	Isc	100 lx, 2856 K	24	30	–	μA
Dark current	I_D	V_R = 12 V	–	0.1	10	nA

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 Si PIN photodiode S6036 made by Hamamatsu Photonics K.K. is connected to a transimpedance amplifier (configuration 3).

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

- Based on the mechanism described *2.1 Sensing Mechanism*, a photodiode generates a current when it is exposed to light. "Current output" was therefore selected in the amplifier selection flowchart.
- As an example of the system requirements, the measurement range of the intensity of illumination is defined as 100 to 2000 Lx in this application note. According to the spectral response of photo sensitivity in the datasheet, the photo sensitivity at the wave length of 555 nm of the spectral response is about 0.33 A/W, calculating the output current from the that value of photo sensitivity and photo-detection surface of the sensor, the output current is approximately 40 μA when the sensor is exposed to 2000 Lx of light. Therefore, because the output current is less than 100 μA, a transimpedance amplifier was selected in the amplifier selection flowchart.

The route by which the transimpedance amplifier (configuration 5) 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.

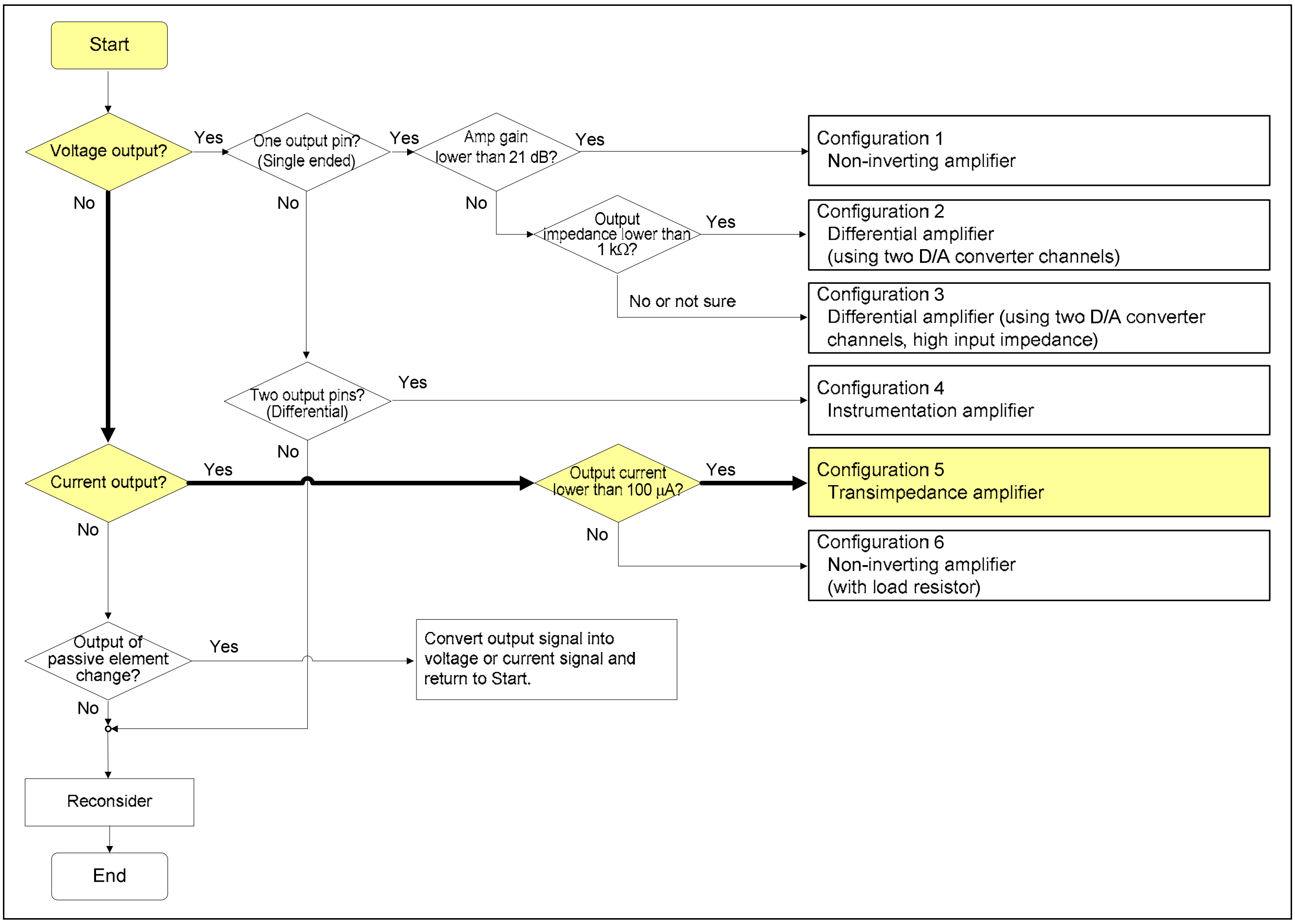

Figure 3-1 Amplifier Configuration Selection Flowchart

4. Connecting Smart Analog IC 500 to the Sensor

Figure 4-1 shows an example of connecting Smart Analog IC 500 to the photodiode. The anode of the photodiode is connected to the ground pin, and the cathode to the inverted input pin of a configurable amplifier in Smart Analog IC 500. In this application note, configurable amplifier Ch1 is used, so the MPXIN10 pin is used as the inverted input pin.

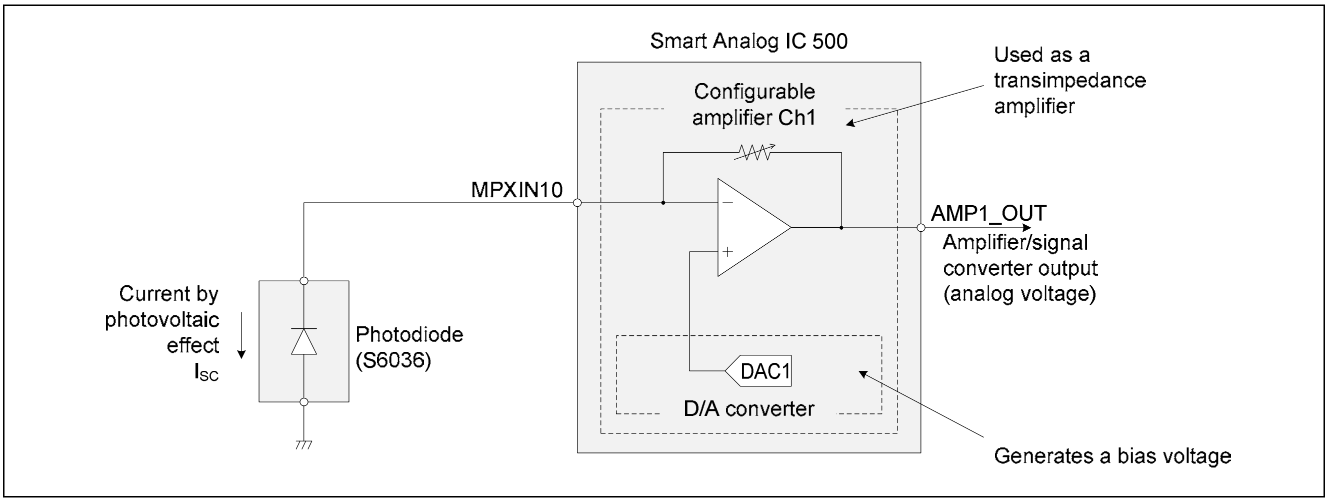

Figure 4-1 Example of Connecting Smart Analog IC 500 to the Photodiode

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 transimpedance amplifier (configuration 5) to the photodiode 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: Transimpedance amplifier
  This is the configuration selected by using the amplifier selection flowchart.

- Amplifier gain: 20 kΩ
  When the intensity of illumination is 100 to 2000 Lx, which is the requirement of the system, the maximum output current is 40 μA. 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. Considering both the setting error of the feedback resister (±35%, including the temperature dependence from the datasheet) and the margin for the range of intensity of illumination, the gain is set to 20 kΩ.

- D/A converter output voltage: 0.10 V
  The response speed of the circuit is higher as the induced voltage to the photodiode is higher. In this application note, however, not considering the response speed of the circuit for the requirement of the system, the output voltage from the D/A converter is set to be 0.1 V. According to the datasheet of the photodiode, the capacitance of the pins is about 50 pF under the condition described above.

- Amplifier input pin: MPXIN10 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 "transimpedance amplifier" as the configuration of configurable amplifier Ch1.
- Set the gain of configurable amplifier Ch1 to "20 kΩ".
- Set the output voltage of D/A converter Ch1 to "5" (0.10 V).
- Specify the MPXIN10 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.

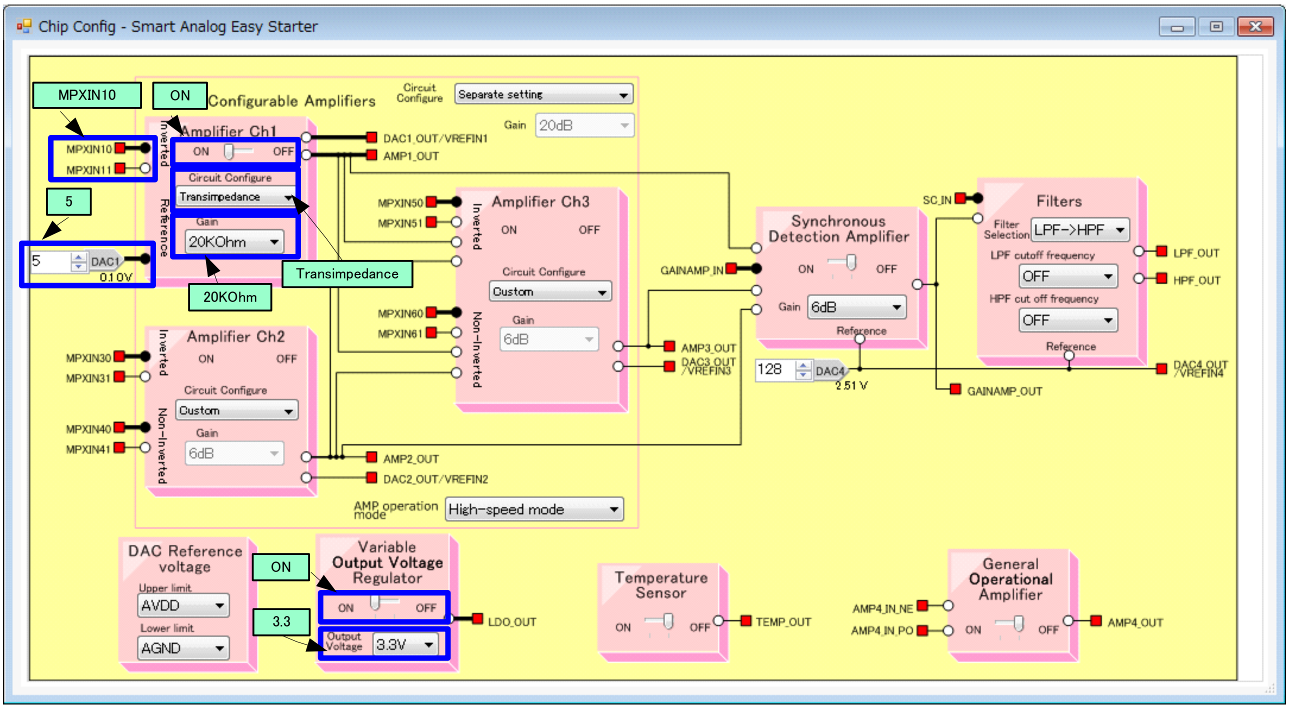

Figure 5-1 Settings in **Chip Config** Window

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: Transimpedance amplifier
  Configurable amplifier Ch1 is used as a transimpedance amplifier.
  - SW11, SW12, and SW13 are set to "1" (short) in the CONFIG1 register.
  - MPX21 is set to "1" 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: 20 kΩ
  The amplifier feedback resistance is specified as follows:
  - AMPG14, AMPG13, AMPG12, AMPG11, and AMPG10 are set to "0" in the GC1 register.

- D/A converter output voltage: 5 (0.10 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 "05H".
  - DAC1OF is set to "1" (operation enabled) in the PC1 register.

- Amplifier input pin: MPXIN10 pin
  The amplifier input pin setting is specified as follows:
  - MPX11, MPX10, and MPX20 are set to "0" and MPX21 is set to "1" 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.

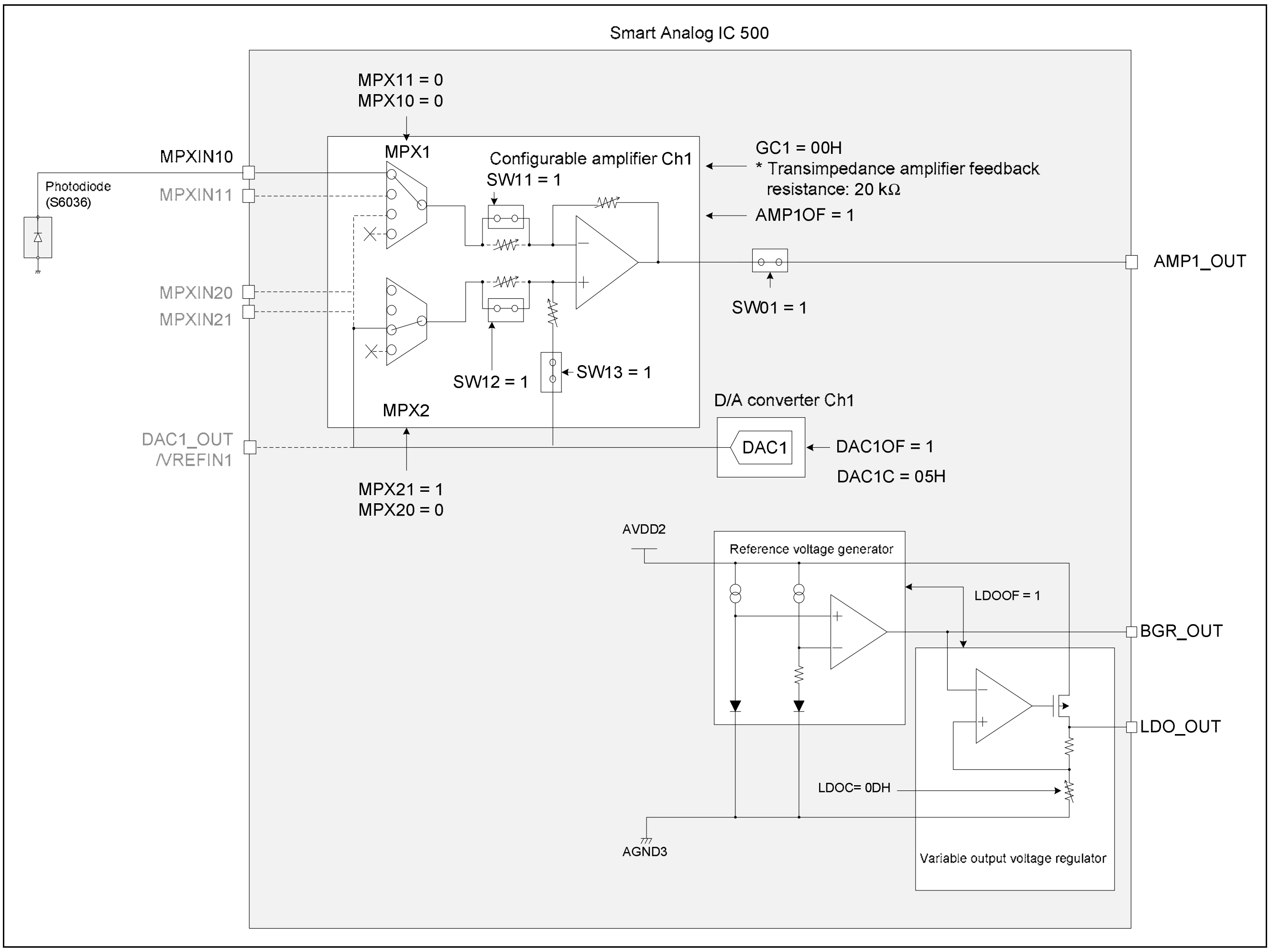

Figure 5-2 Circuit Configuration of Smart Analog IC 500

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 D7	D6	D5	D4	D3	D2	D1	D0	HEX
00h	Configuration register 1	R/W	–	SW11	SW12	SW13	–	SW21	SW22	SW23	70h
	(CONFIG1)		0	1	1	1	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]		20h
	(MPX1)		0	0	1	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]					00h
	(GC1)		0	0	0	0	0	0	0	0	
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]								05h
	(DAC1C)		0	0	0	0	0	1	0	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	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 under indoor (office) conditions that the output voltage changed according to the amount of light irradiated on the photo-detection surface of the sensor. The A/D conversion interval was set to 100 ms.

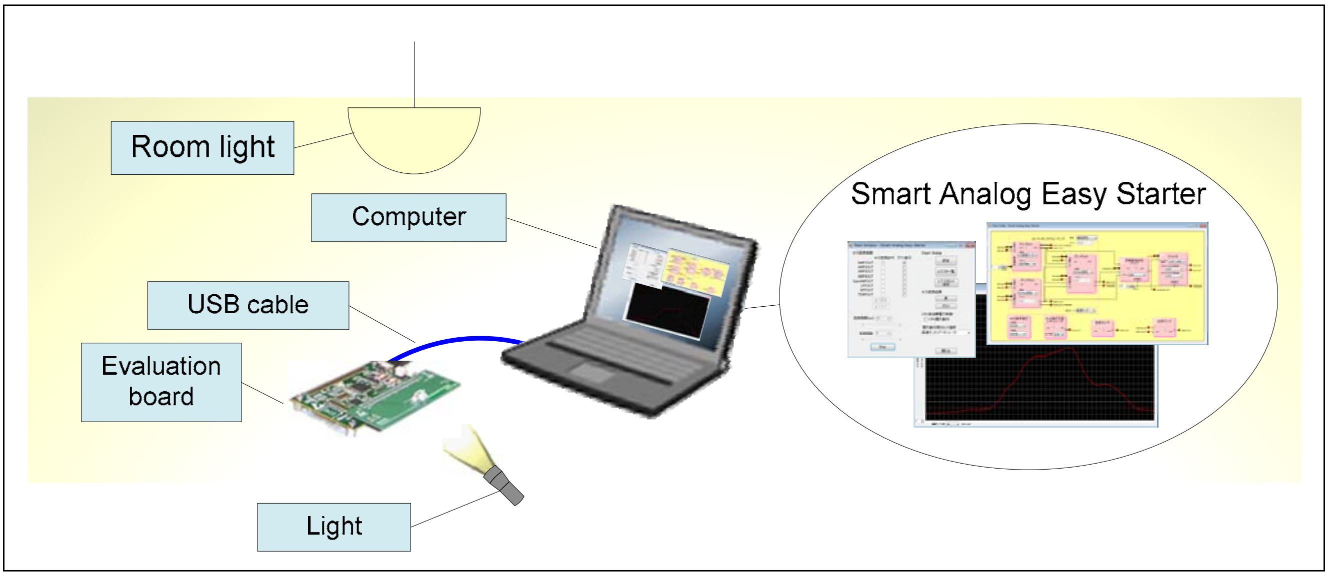

Figure 6-1 Operation Verification Environment

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

Measurement started under the condition of room light only without a handy light. When an additional light by the handy light was used to irradiate a stronger light (brighter than the room light) on the photo-detection surface of the sensor, it was observed that the output voltage rose depending on the distance between the sensor and the handy light above the initial state of room light only without handy light.

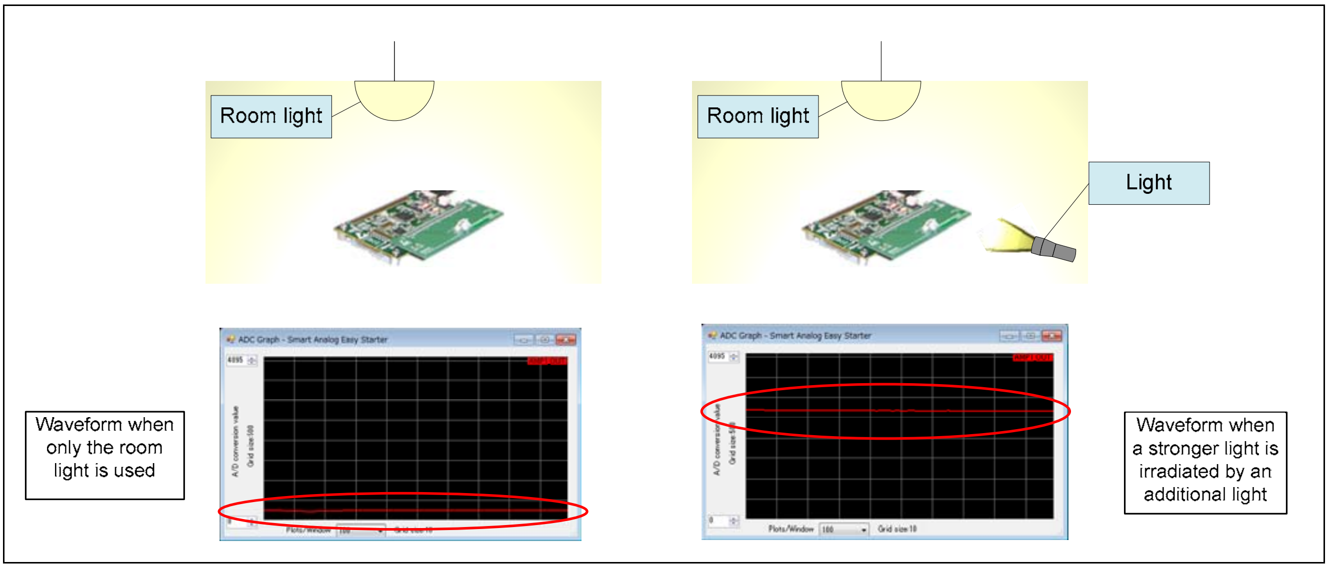

Figure 6-2 Operation Verification Waveforms

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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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