Smart Analog IC 500

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Amplifier Selection - Example Implementation: Connection of Non-Inverting Amplifier (Configuration 6) and Temperature Transducer

Introduction

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

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 non-inverting amplifier with a load resistor connected, which is one of the amplifier configurations (configuration 6) introduced in the application note *Smart Analog Selecting Amplifiers Based on Sensor Type (R02AN0008E)*, to a temperature transducer IC. 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 (temperature transducer IC 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	AD592ANZ made by Analog Devices, Inc.
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 temperature transducer ICs is described and the characteristics and specifications of the AD592ANZ made by Analog Devices, Inc. are shown below.

2.1 Sensing Mechanism

A transducer is one of the converters, generally. There are various types of transducers, which include the sensors that convert the physical quantity of an element such as temperature, strain, pressure, or light, to an electric signal such as voltage, current, or resistance. A temperature transducer is a device that converts temperature to an electric signal. Typical temperature transducers are thermocouples and thermistors.

In this application note, a temperature transducer IC is used. A temperature transducer IC generates a current proportional to temperature based on the characteristics of silicon transistors. When the temperature is constant, a temperature transducer behaves as a high-impedance constant current source. The linearity of the current output for temperature is maintained within the provided temperature range.

2.2 Characteristics and Specifications

In this application note, the temperature transducer IC AD592ANZ made by Analog Devices, Inc. is used for an example implementation. The sensor characteristics which are required to select the best amplifier configuration have been excerpted from the AD592ANZ datasheet and are shown in Table 2-1 below. When evaluating the sensor, be sure to download the latest datasheet from the Analog Devices website.

Table 2-1 Temperature Transducer IC AD592ANZ Extracted Electrical Characteristics

Parameter	Conditions	Min.	Typ.	Max.	Unit
Nominal current output	25°C (298.2 K)	–	298.2	–	μA
Temperature coefficient	–	–	1	–	μA/K
Operating temperature	–	–25	–	105	°C
Operating voltage range	–	4	–	30	V

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 AD592ANZ made by Analog Devices, Inc. is connected to a non-inverting amplifier with a load resistor (configuration 6).

The reason of selecting this non-inverting amplifier (configuration 6) is explained below.

- A temperature transducer IC outputs current proportional to the absolute temperature. "Current output" was therefore selected in the amplifier selection flowchart.
- As an example of the system requirements, the range of the temperature detected by the temperature transducer IC is defined as –20°C to +105°C in this application note. Checking the output current of the AD592ANZ at 25°C (298.2 K) from the datasheet, it is 298.2 μA and can be considered to be more than 100 μA in the temperature range defined above. Therefore, a non-inverting amplifier with a load resistor (configuration 6) was selected in the amplifier selection flowchart.

The route by which the non-inverting amplifier with a load resistor (configuration 6) 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.

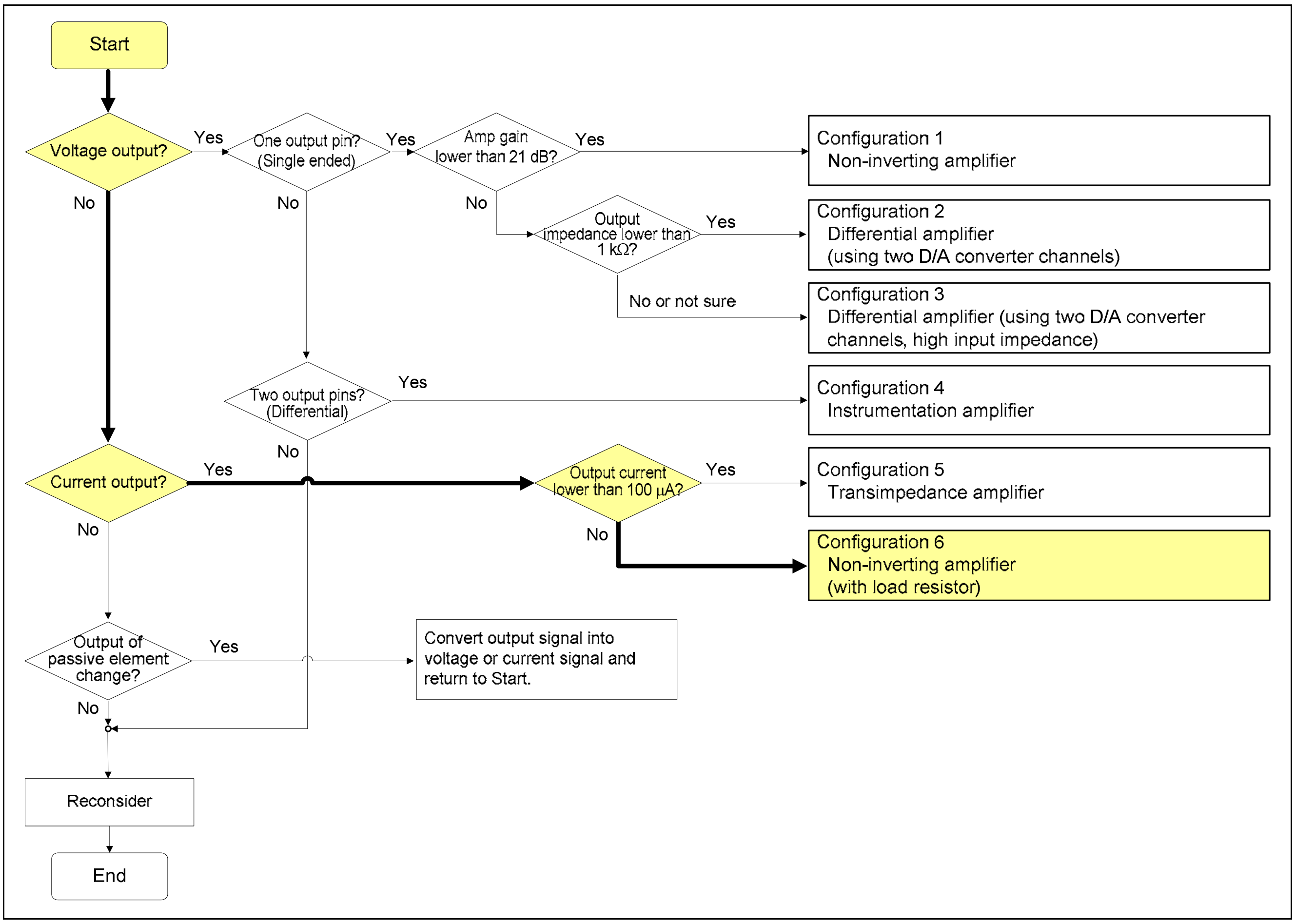

Figure 3-1 Amplifier Configuration Selection Flowchart

4. Connecting Smart Analog IC 500 to the Sensor

Figure 4-1 shows an example of connecting Smart Analog IC 500 to the temperature transducer IC. The output of the temperature transducer IC is connected to the non-inverted input pin of a configurable amplifier in Smart Analog IC 500. Connect a load resistor to the non-inverted input pin. The current output from the temperature transducer IC is converted to voltage by using this load resistor.

In this application note, configurable amplifier Ch2 is used, so the MPXIN40 pin is used as the non-inverted input pin. The resistance of the load resistor is 1 kΩ.

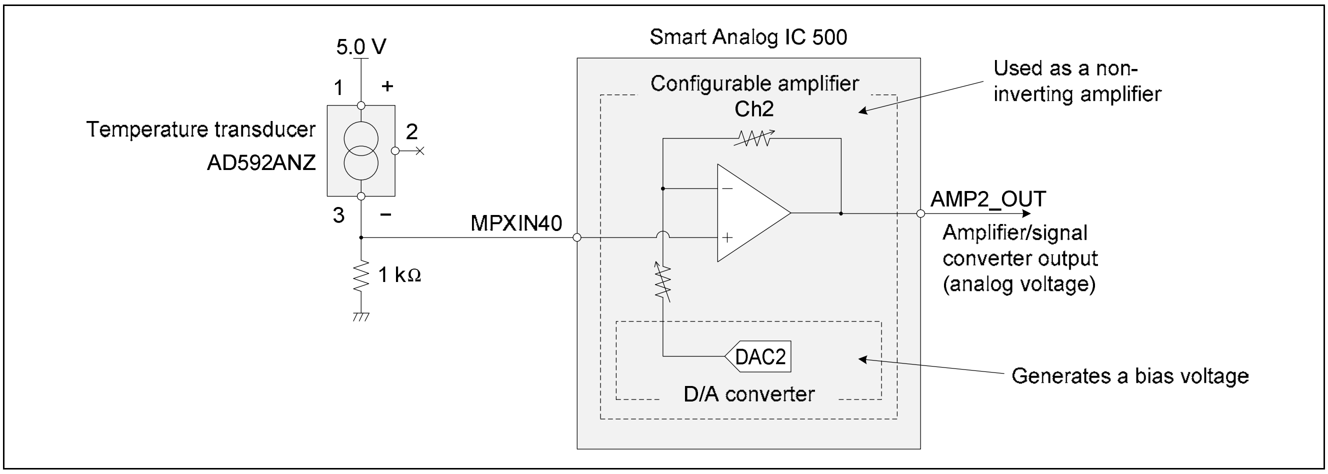

Figure 4-1 Example of Connecting Smart Analog IC 500 to the Temperature Transducer IC

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 with a load resistor (configuration 6) to the temperature transducer IC 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: 28 dB
  When the measured temperature is in the range of −20°C to +105°C which is the requirement of the system and the load resister of the temperature transducer IC is 1 kΩ, the range of input voltage to the configurable amplifier is about 0.125 V (0.253 to 0.378 V). 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 28 dB.

- D/A converter output voltage: 0.26 V
  In this application note, the D/A converter output voltage is set to 0.26 V so that the amplifier outputs 0 V (minimum input voltage to A/D converter) at –20°C, and 3.3 V (maximum input voltage to A/D converter) at +105°C.

- 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.

- Specify "non-inverting amplifier" as the configuration of configurable amplifier Ch2.
- Set the gain of configurable amplifier Ch2 to "28 dB".
- Set the upper and lower limits of the reference voltage for the D/A converter to 3/5 AV_{DD} and AGND, respectively.
- Set the output voltage of D/A converter Ch2 to "22" (0.26 V).
- Specify the MPXIN40 pin as the pin connecting the sensor to the Smart Analog IC.
- Set configurable amplifier Ch2 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.

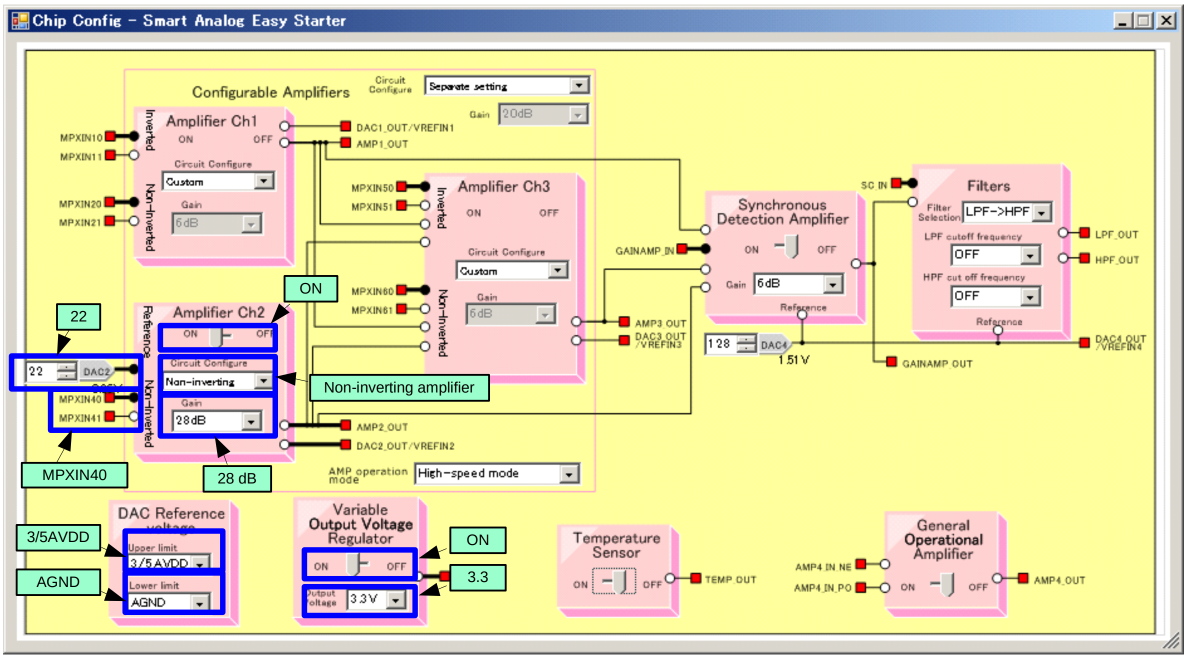

Figure 5-1 Settings in **Chip Config** Window

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 Ch2 is used as a non-inverting amplifier.
  — SW21 and SW23 are set to "0" (open) and SW22 is set to "1" (short) in the CONFIG1 register.
  — MPX31 is set to "1" and MPX30 is set to "0" in the MPX1 register.
  — SW02 is set to "1" (short) in the CONFIG2 register.
  — AMP2OF is set to "1" (operation enabled) in the PC1 register.

- Amplifier gain: 28 dB
  The amplifier gain is specified as follows:
  — The GC2 register is set to "0BH".

- D/A converter output voltage: 0.26 V
  The D/A converter setting is specified as follows:
  — VRT1, VRT0, VRB1, and VRB0 are set to "0" in the DACRC register.
  — The DAC2C register is set to "16H".
  — DAC2OF 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.

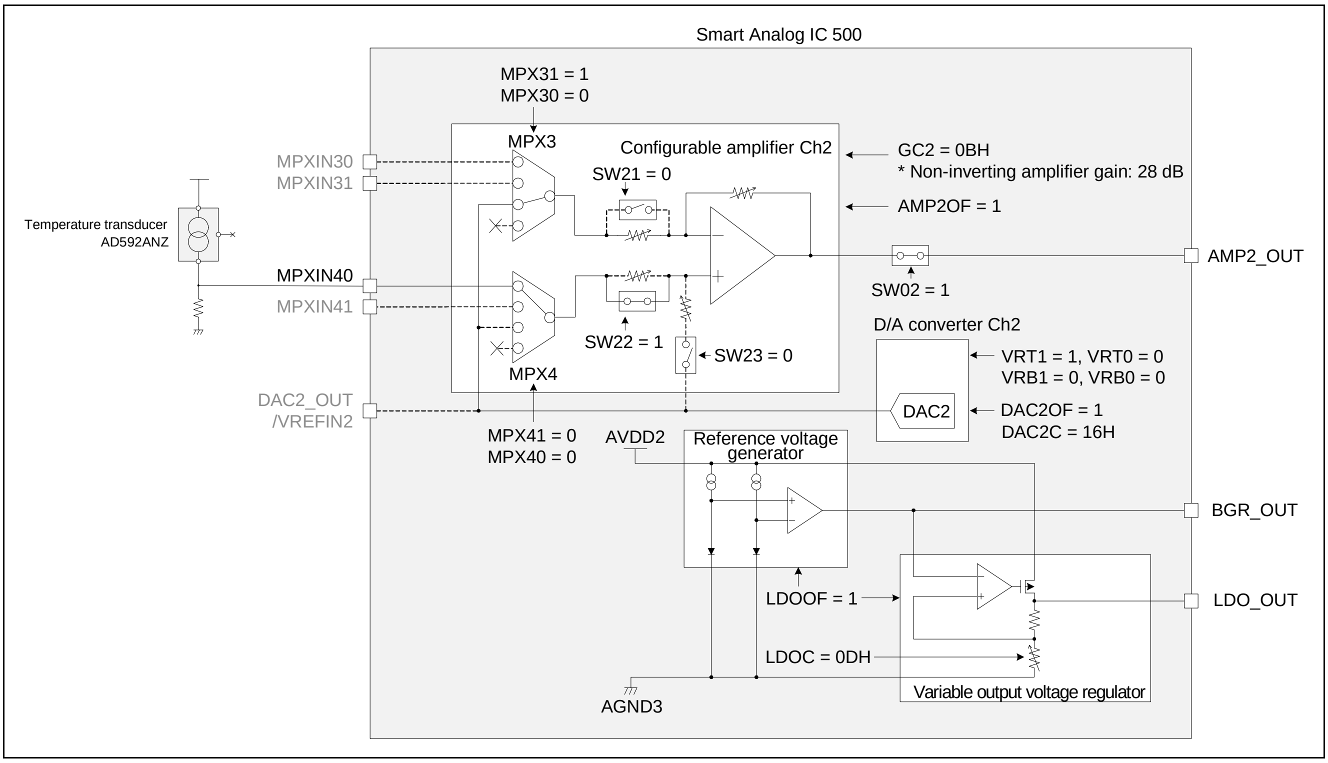

Figure 5-2 Circuit Configuration of Smart Analog IC 500

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	02h
	(CONFIG1)		0	0	0	0	0	0	1	0	
01h	Configuration register 2	R/W	–	SW31	SW32	SW33	–	SW02	SW01	SW00	04h
	(CONFIG2)		0	0	0	0	0	1	0	0	
03h	MPX setting register 1	R/W	MPX1[1:0]		MPX2[1:0]		MPX3[1:0]		MPX4[1:0]		08h
	(MPX1)		0	0	0	0	1	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]					0Bh
	(GC2)		0	0	0	0	1	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]		08h
	(DACRC)		0	0	0	0	1	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]								16h
	(DAC2C)		0	0	0	1	0	1	1	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	22h
	(PC1)		0	0	1	0	0	0	1	0	
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) condition that the output voltage from amplifier changed according to the temperature detected by the sensor which was changed by blowing hot air from a dryer. The A/D conversion interval was set to 100 ms.

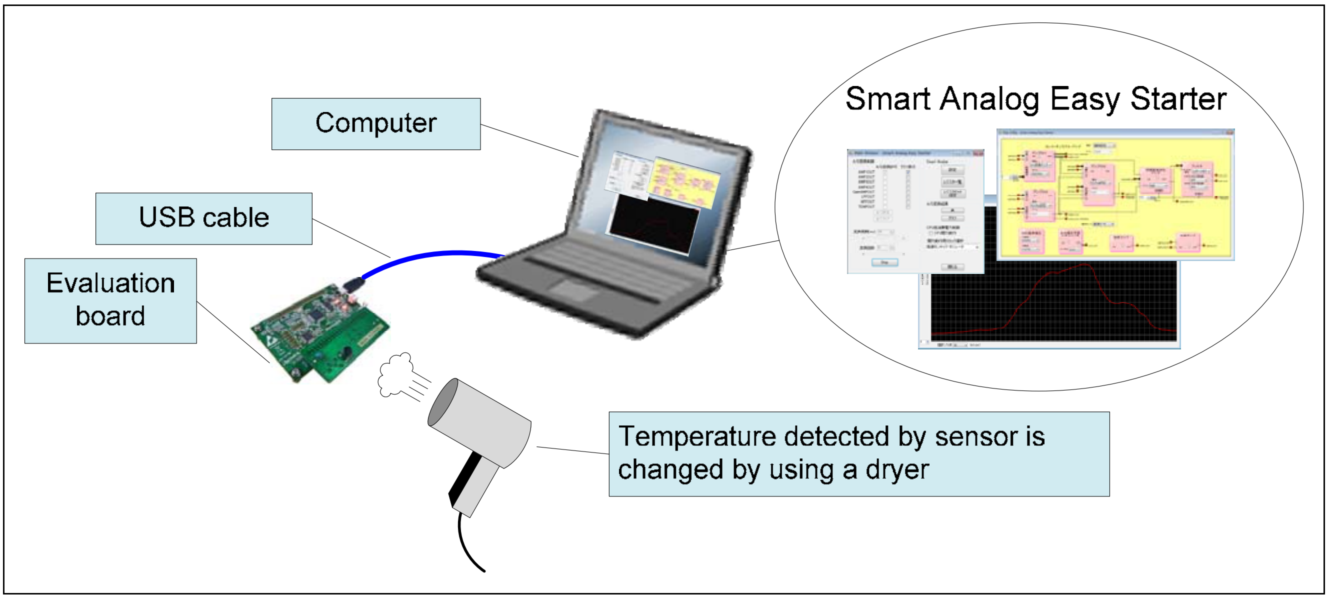

Figure 6-1 Operation Verification Environment

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

Measurement started under the condition of room temperature without a dryer. When the temperature detected by the sensor was changed by using a dryer, it was observed that the output voltage changed depending on the distance and the angle between the sensor and the dryer and rose above the initial state of room temperature without a dryer.

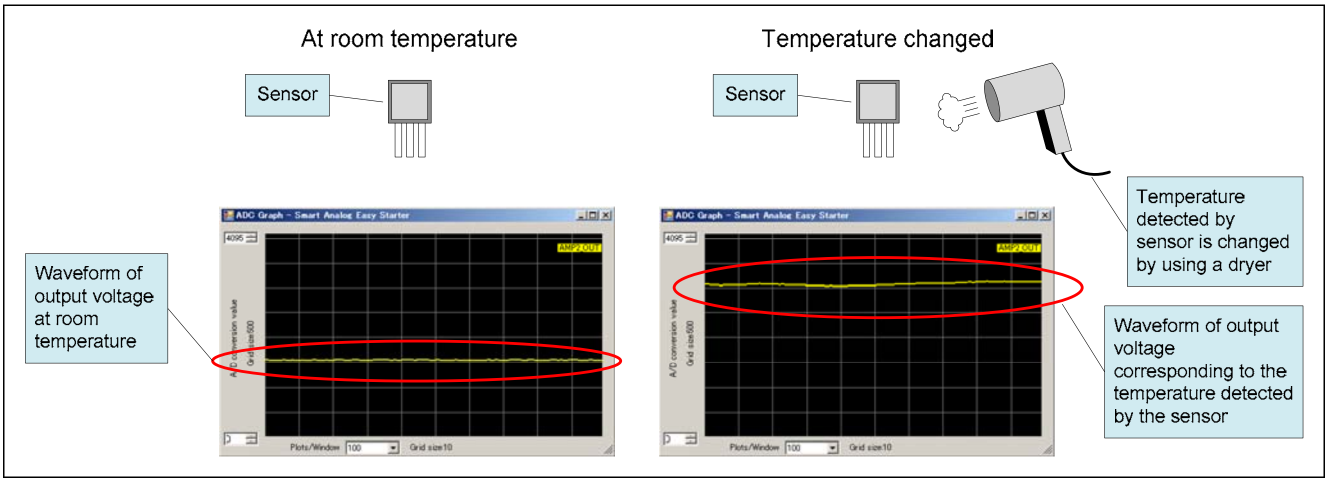

Figure 6-2 Operation Verification Waveforms

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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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