

Smart Analog IC 500

Amplifier Selection - Example Implementation:

Connection of Differential Amplifier (Configuration 2) and Motion Sensor

Introduction

This application note provides an example implementation for connecting Smart Analog IC 500 to a motion sensor (pyroelectric infrared 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 differential amplifier, which is one of the amplifier configurations (configuration 2) introduced in the application note *Smart Analog Selecting Amplifiers Based on Sensor Type (R02AN0008E)*, to a motion sensor (pyroelectric infrared 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 (motion 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	RE200B made by Nippon Ceramic 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 motion sensors (pyroelectric infrared sensors) is described and the characteristics and specifications of the RE200B motion sensor (pyroelectric infrared sensors) made by Nippon Ceramic Co., Ltd. are also shown below.

2.1 Sensing Mechanism

A motion sensor, which detects the presence of people, has several different types of sensors, such as an infrared sensor, an ultrasonic sensor, and a visible light sensor. A pyroelectric infrared sensor, which is one of the motion sensors, uses the pyroelectric effect of ferroelectric materials. When a ferroelectric material is exposed to infrared rays, it absorbs the thermal energy, which spontaneously changes the polarization of the material. This change in polarization generates an electromotive force (voltage), which is used to detect motion. Motion sensors that use the pyroelectric effect can sense the minute infrared rays radiated from humans.

2.2 Characteristics and Specifications

In this application note, the pyroelectric infrared sensor RE200B (general purpose dual element type) made by Nippon Ceramic 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 RE200B datasheet and are shown in Table 2-1 below. When evaluating the sensor, be sure to download the latest datasheet from the Nippon Ceramic website.

Table 2-1 Pyroelectric Infrared Sensor RE200B Extracted Electrical Characteristics
(Ta = 25°C)

Parameter	Conditions	Rating	Unit
Sensitive area		2 × 1 2 elements	mm
Spectral response		5 to 14	μm
Signal output		3900	mV _{p-p}
Sensitivity	450K, 1Hz	3300	V/W
Noise		80	mV _{p-p}
Offset voltage		0.7	V
Supply voltage		2.2 to 15	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 pyroelectric infrared sensor RE200B (general purpose dual element type) made by Nippon Ceramic Co., Ltd. is connected to a differential amplifier (configuration 2).

The reason of selecting this differential amplifier (configuration 2) is explained below.

- Based on the mechanism described in 2.1 *Sensing Mechanism*, a pyroelectric infrared sensor outputs voltage according to the amount of infrared rays. "Voltage output" was therefore selected in the amplifier selection flowchart.
- To obtain the signal intensity of 3,900 mV_{p-p} shown in Table 2-1, the output signal from RE200B, which detects the infrared ray of 420 K blackbody furnace 400 mm away from the sensor, must be amplified by a gain of 72.5 dB according to the datasheet of RE200B. For this reason, a high gain of at least 21 dB is required for the amplifier. Also, because the output impedance of RE200B whose output is source mode is less than 1 kΩ, a differential amplifier that uses two D/A converter channels was selected in the amplifier selection flowchart.

The route by which the differential amplifier (configuration 2) 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.

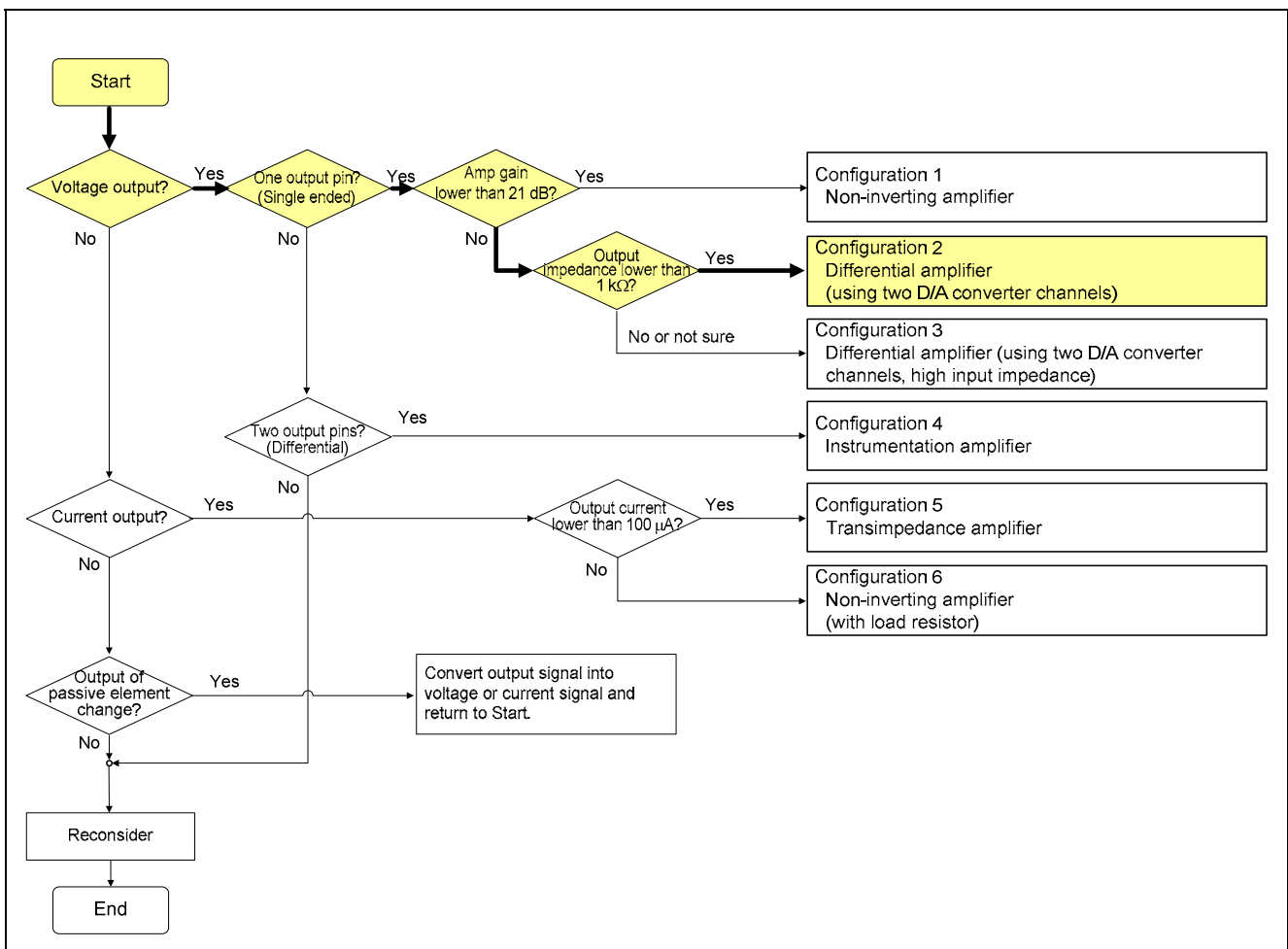


Figure 3-1 Amplifier Configuration Selection Flowchart

4. Connecting Smart Analog IC 500 to the Sensor

Figure 4-1 shows an example of connecting Smart Analog IC 500 to the motion sensor (pyroelectric infrared sensor). The output pin of the motion sensor is connected to the non-inverted input pin of a configurable amplifier in Smart Analog IC 500. In this application note, configurable amplifier Ch1 is used, so the MPXIN20 pin is used as the non-inverted input pin. Figure 4-1 does not show the filter connection to the 5 V power supply line, however, please consider its connection as needed.

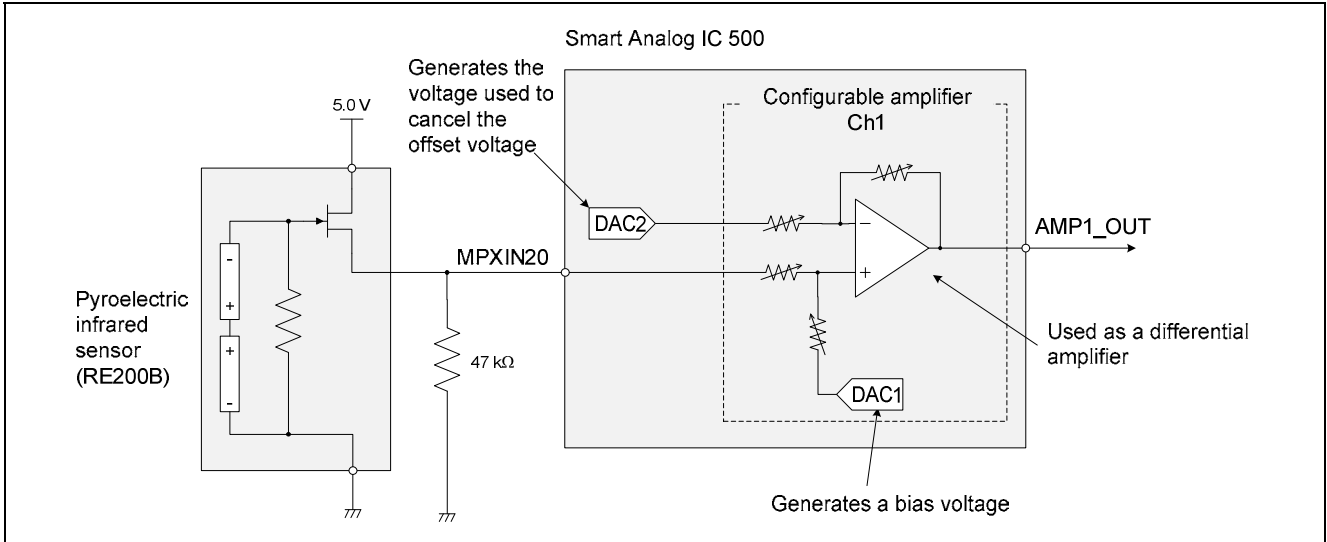


Figure 4-1 Example of Connecting Smart Analog IC 500 to the Motion Sensor

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 2) to the motion sensor (pyroelectric infrared 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)**
This is the configuration selected by using the amplifier selection flowchart.
- **Amplifier gain: 28 dB**
In this application note, the initial gain is set to 21 dB, and the gain is adjusted with checking the waveform. The input voltage to the A/D converter is needed to set not to exceed the reference voltage for A/D converter. On the evaluation board used in this example implementation, 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 over 3.3 V. The gain is therefore set to 28 dB from the result by checking the waveforms.
- **D/A converter Ch1 output voltage: 1.65 V**
Because the pyroelectric infrared sensor outputs positive and negative AC signals, the D/A converter output voltage is set to 1.65 V, which is the middle voltage of 0 to 3.3 V that is the input voltage range of A/D converter.
- **D/A converter Ch2 output voltage: 0.86 V**
D/A converter Ch2 is used to generate the voltage to cancel the offset voltage of the sensor. In the data sheet, the offset voltage is specified as 0.7 V, however, 0.86 V is used in this example implementation because 0.86 V was obtained as a result of measurement under the conditions which the operation had been verified.
- **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.

Open the **AMP1 Config** window to specify detailed settings for configurable amplifier Ch1 and D/A converter Ch1.

- Set SW13, SW01, and SW00 to "short".
- Set MPX1 to "3" (open) and MPX2 to "0" (MPXIN20).
- Set gain control register 1 (GC1) to "11"
- Set D/A converter Ch1 to "84" (1.65 V).
- Set D/A converter Ch1 to "ON".
- Set configurable amplifier Ch1 to "ON".

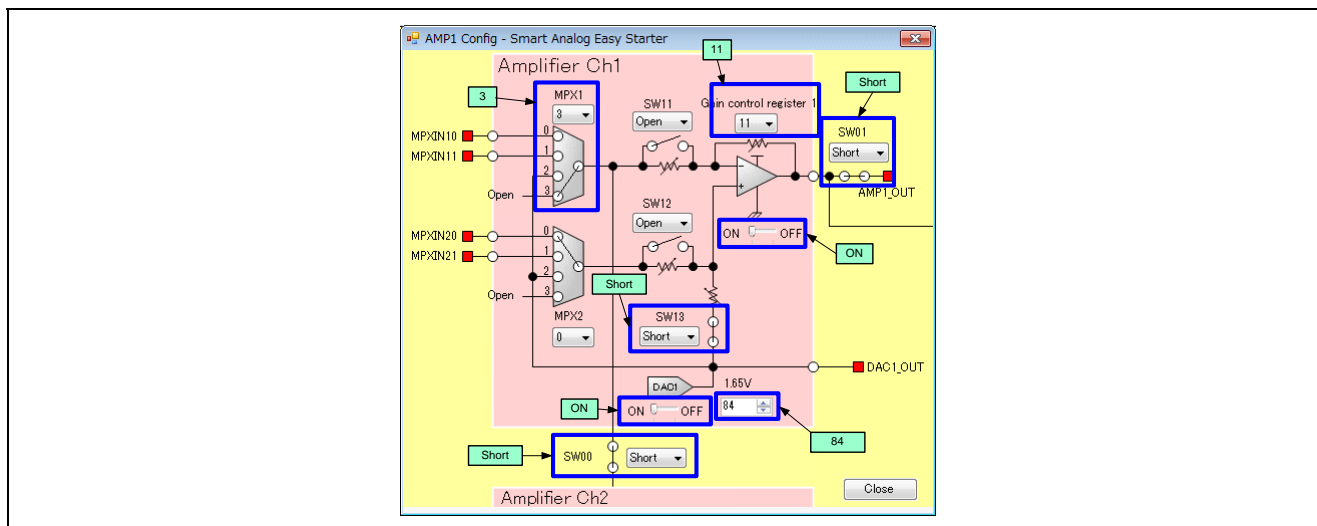


Figure 5-1 Settings in **AMP1 Config** Window

Open the **AMP2 Config** window to specify detailed settings for D/A converter Ch2.

- Set MPX3 to "2" (D/A converter Ch2 output signal).
- Set D/A converter Ch2 to "44" (0.865 V).
- Set D/A converter Ch2 to "ON".

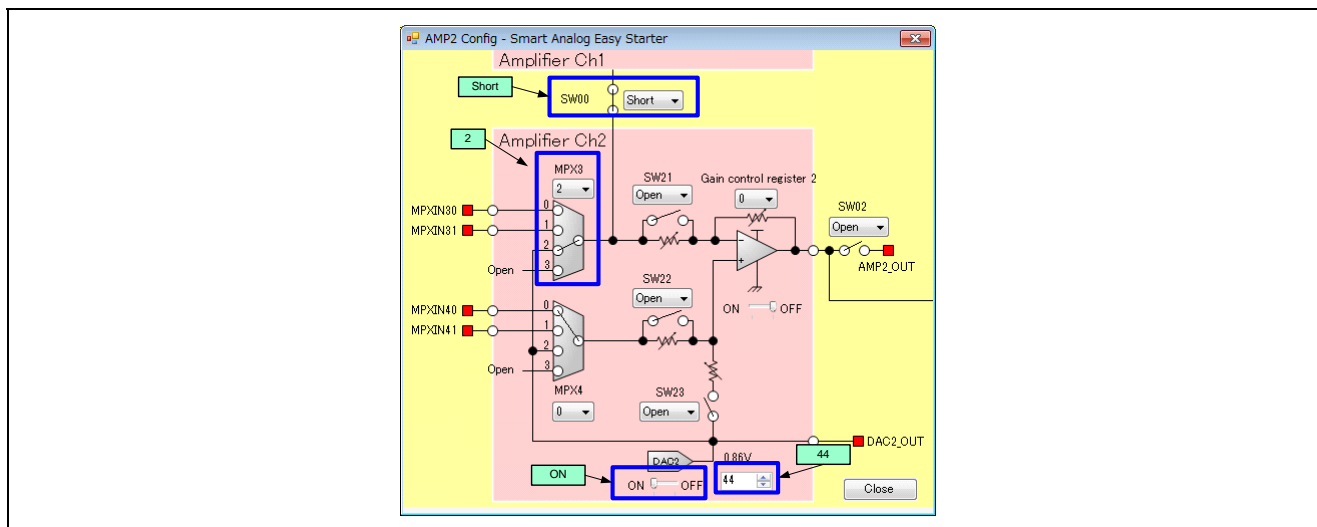


Figure 5-2 Settings in **AMP2 Config** Window

- 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.

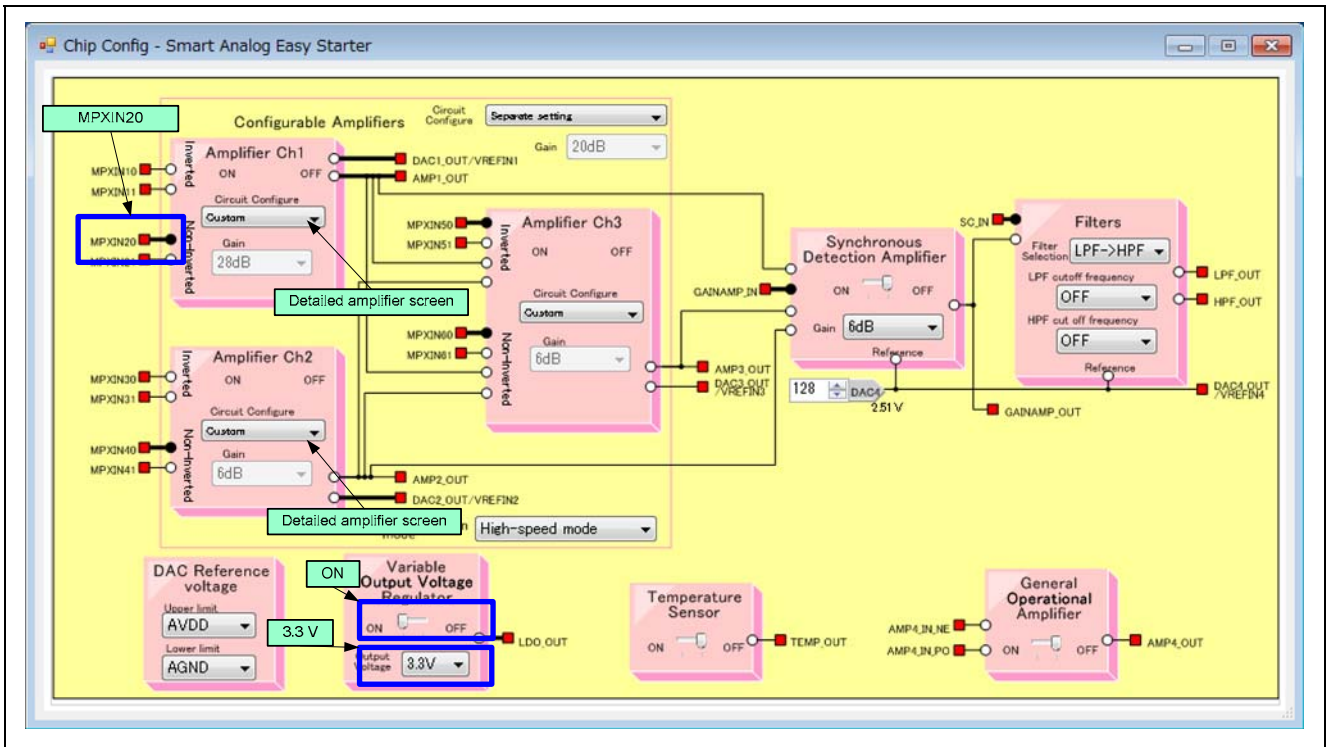


Figure 5-3 Settings in Chip Config Window

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)**
Configurable amplifier Ch1 is used as a voltage follower.
SW11 and SW12 are set to "0" (open) and SW13 is set to "1" (short) in the CONFIG1 register.
MPX11 and MPX10 are set to "1" and MPX20 and MPX21 are set to "0" in the MPX1 register.
MPX31 is set to "1" and MPX30 is set to "0" in the MPX1 register.
SW01 and SW00 are set to "1" (short) in the CONFIG2 register.
AMP1OF is set to "1" (operation enabled) in the PC1 register.
- **Amplifier gain: 28 dB**
The amplifier gain setting is specified as follows:
The GC3 register is set to "0BH".
- **D/A converter Ch1 output voltage: 84 (1.65 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 "54H".
DAC1OF is set to "1" (operation enabled) in the PC1 register.
- **D/A converter Ch2 output voltage: 44 (0.86 V)**
The D/A converter Ch2 setting is specified as follows:
VRT1, VRT0, VRB1, and VRB0 are set to "0" in the DACRC register.
The DAC2C register is set to "2CH".
DAC2OF 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.

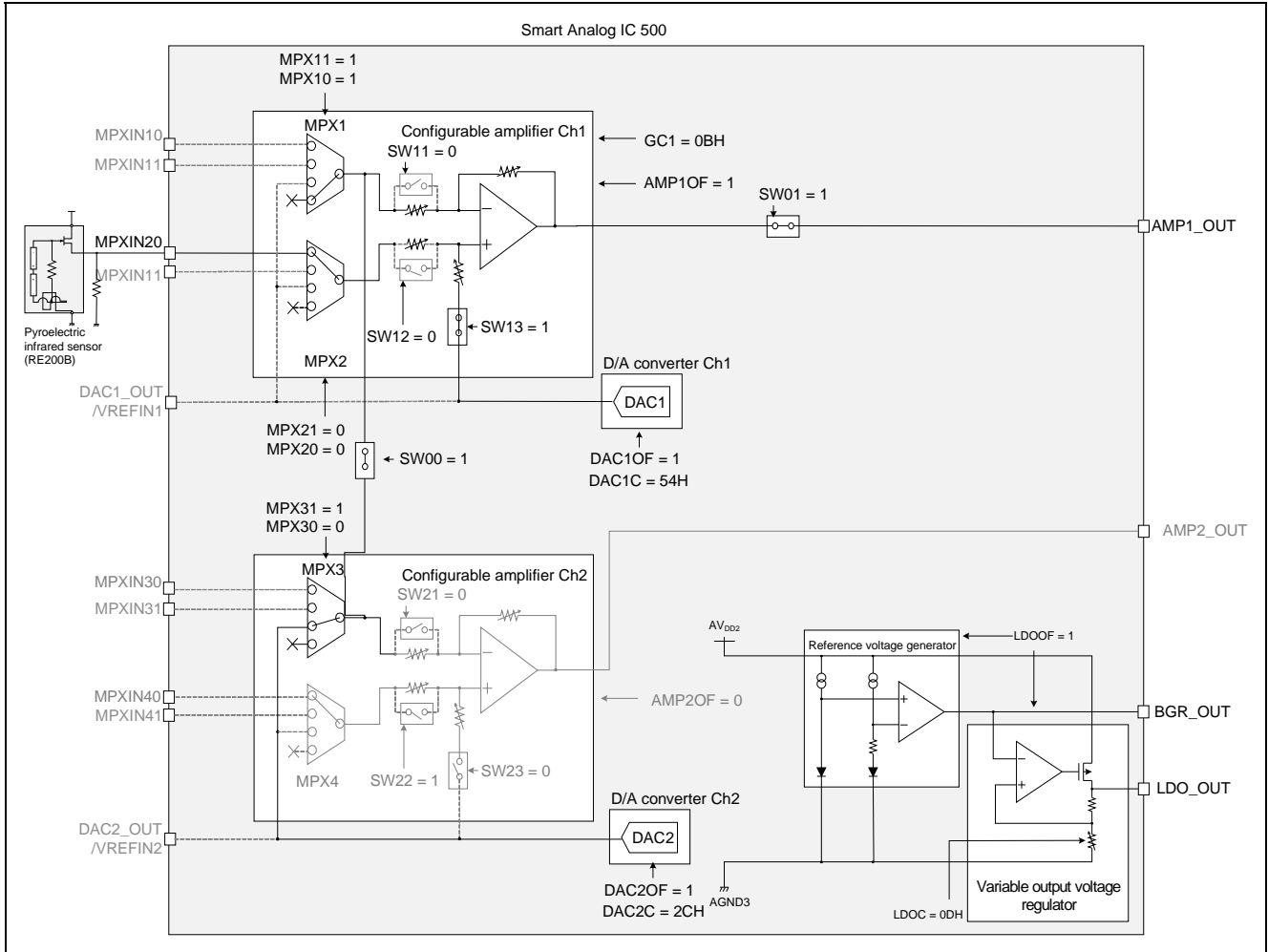


Figure 5-4 Circuit Configuration of Smart Analog IC 500

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	10h
01h	Configuration register 2 (CONFIG2)	R/W	-	SW31	SW32	SW33	-	SW02	SW01	SW00	03h
03h	MPX setting register 1 (MPX1)	R/W	MPX1[1:0]		MPX2[1:0]		MPX3[1:0]		MPX4[1:0]		C8h
04h	MPX setting register 2 (MPX2)	R/W	-	MPX5[2:0]			-	MPX6[2:0]			00h
05h	MPX setting register 3 (MPX3)	R/W	SCF[2:1]		SCF0	MPX7[2:0]				00h	
06h	Gain control register 1 (GC1)	R/W	AMP1[4:0]				AMP2[4:0]				0Bh
07h	Gain control register 2 (GC2)	R/W	AMP3[4:0]				AMP4[4:0]				00h
08h	Gain control register 3 (GC3)	R/W	AMP5[4:0]				AMP6[4:0]				00h
09h	AMP operation mode control register (AOMC)	R/W	CC[1:0]				AMP7[4:0]				00h
0Ah	Gain control register 4 (GC4)	R/W	AMP8[4:0]				AMP9[4:0]				00h
0Bh	LDO control register (LDOC)	R/W	LDO[3:0]				AMP10[4:0]				0Dh
0Ch	DAC reference voltage control register (DACRC)	R/W	VRT[1:0]				VRB[1:0]				00h
0Dh	DAC control register 1 (DAC1C)	R/W	DAC1[7:0]								54h
0Eh	DAC control register 2 (DAC2C)	R/W	DAC2[7:0]								2Ch
0Fh	DAC control register 3 (DAC3C)	R/W	DAC3[7:0]								80h
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	31h
12h	Power control register 2 (PC2)	R/W	-	-	-	GAIN0F	LPFOF	HPFOF	LDO0F	TEMPOF	02h
13h	Reset control register (RC)	R/W	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 when a person passed in front of the sensor under indoor (office) conditions. The A/D conversion interval was set to 100 ms.

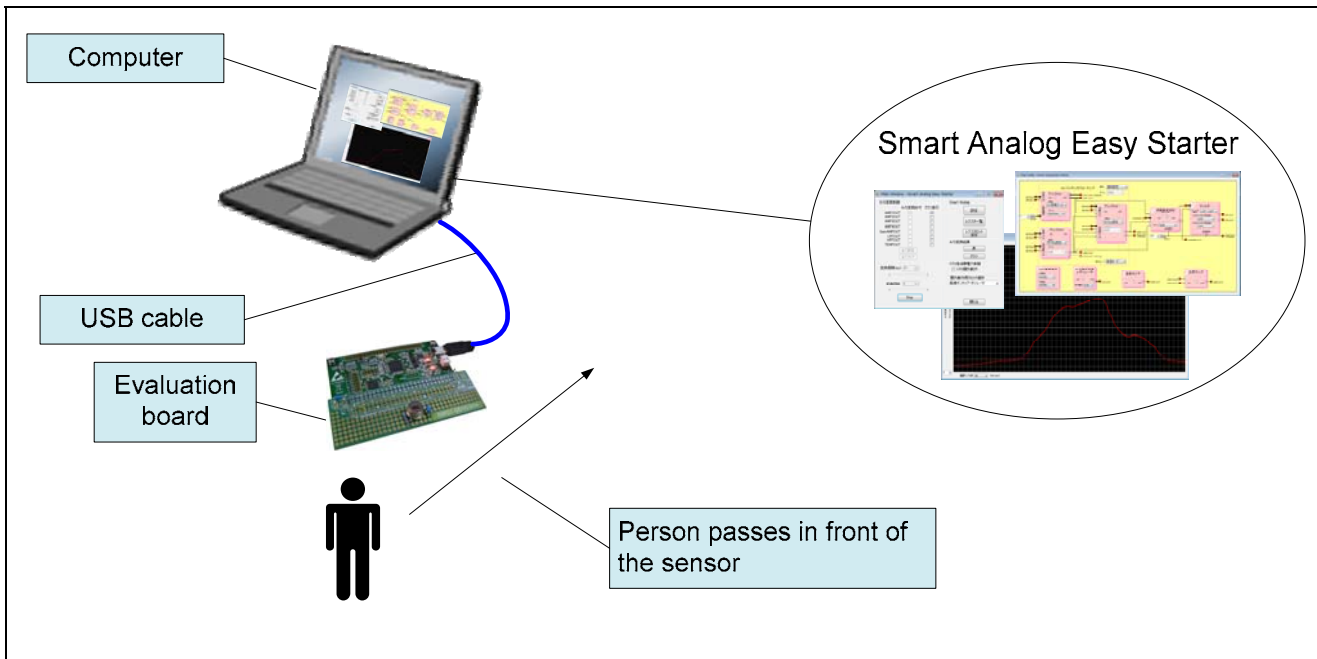


Figure 6-1 Operation Verification Environment

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

Measurement started in a steady state in which no changes in the infrared ray energy occurred in the peripheral environment. When a person passed in front of the sensor, the amount of infrared rays radiated from the person was observed as the waveforms according to the distance between the person and the sensor.

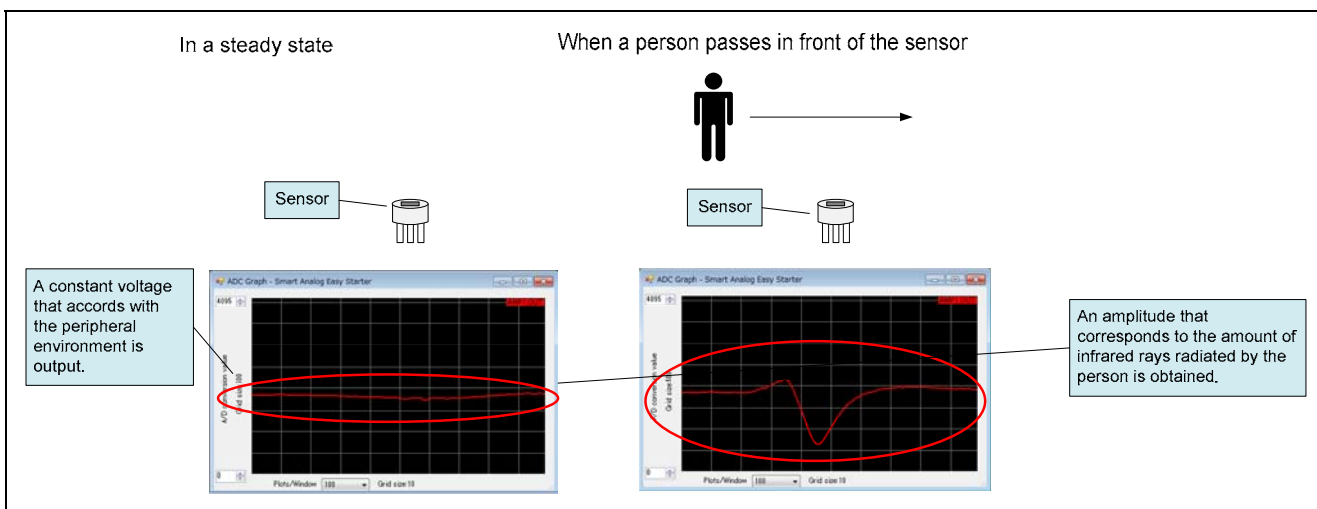


Figure 6-2 Operation Verification Waveforms

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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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.

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Access to reserved addresses is prohibited.

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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.

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