
Smart Analog IC 300

R02AN0016EJ0100

Rev.1.00

Selecting Amplifiers Based on Sensor Type

Mar. 29, 2013

Introduction

This application note explains how to select the configuration of the configurable amplifiers in Smart Analog IC 300 according to the sensor output circuit and its characteristics, and provides a description of each amplifier configuration.

Target Device

Smart Analog IC 300 (RAA730300)

Contents

1. Overview	2
2. Procedure for Evaluating Sensors to Be Connected to Smart Analog ICs	3
3. Flowchart for Selecting the Configurable Amplifier Configuration	6
4. Examples of Typical Amplifier Configurations Using Smart Analog IC 300.....	7

1. Overview

1.1 General

Smart Analog is a group of products whose circuits and characteristics can be reconfigured by using software to enable support of many different types of sensors and drivers.

Smart Analog IC 300, which is a member of the Smart Analog group, provides three configurable amplifier channels whose circuitry and characteristics can be reconfigured to allow a range of sensors to be connected. This reconfiguration work can be easily carried out on your computer GUI by using Smart Analog Easy Starter provided by Renesas.

It is important to note, however, that because there are so many different types of sensors in existence, a certain amount of knowledge of sensor technologies and experience is required to select the best amplifier configuration for each sensor. Taking a long time to consider which amplifier configuration should be used might impact the smooth development of your sensor system.

This application note explains how to select the configuration of the configurable amplifiers incorporated in Smart Analog IC 300 based on the specifications and characteristics of the sensor to be connected in your system.

Sensors output many different kinds of data, including current and voltage values, and changes in resistance and capacitance. Only current and voltage output signals can be connected to Smart Analog IC 300. Other types of output signals must be externally converted into voltage or current signals before being input to Smart Analog IC 300.

This application note also provides a flowchart to show how to select the best configurable amplifier configuration for each type of sensor. The flowchart provides six possible configurations. These configurations differ depending on the output signal type, and the output current and output resistance of the sensor.

1.2 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 Ver. 2.0 (R02AN0017E)

2. Procedure for Evaluating Sensors to Be Connected to Smart Analog ICs

2.1 Procedure from acquiring to evaluating the sensor

The procedure from when you decide on the sensor to use to when evaluation of the connection between the sensor and your Smart Analog IC is complete is described below.

- (1) Check your system requirements (required specifications).
Example: Measurement range, use environment
- (2) Obtain the sensor data sheet.
Confirm the required items in the sensor data sheet.
Example: Sensor output type, sensitivity, output resistance
- (3) Determine the parameters of the analog circuit.
Example: Gain, bias voltage
- (4) Determine the required amplifier configuration by referring to the flowchart shown in Figure 3-1.
- (5) Consider the connection between the sensor output pins and the Smart Analog IC input pins, and connect the sensor to the evaluation board.
- (6) Design the configurable amplifier configuration and required analog parameters by using the GUI software Smart Analog Easy Starter and evaluate the sensor.

Figure 2-1 shows the sensor evaluation flowchart.

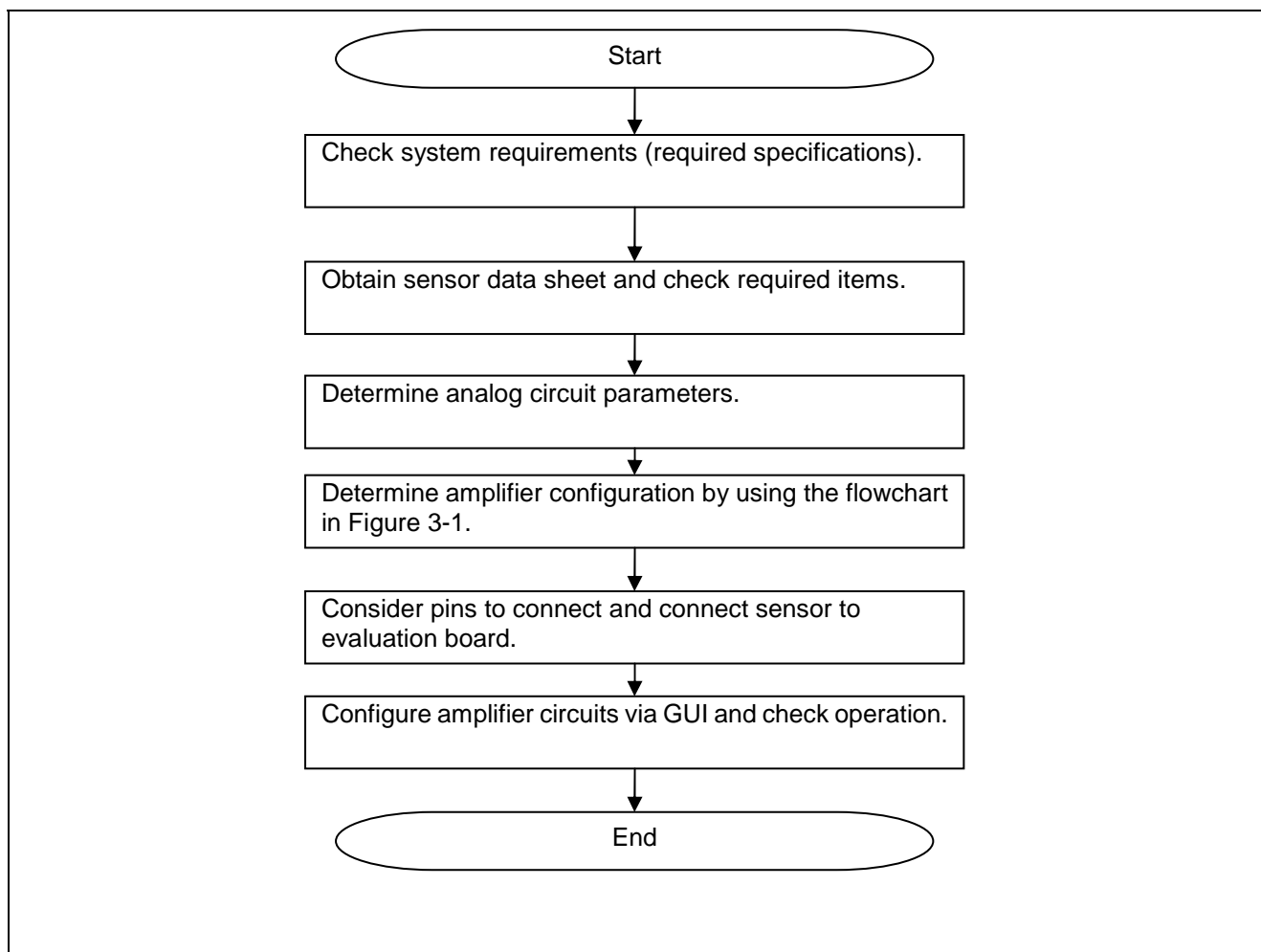


Figure 2-1 Sensor Evaluation Flowchart

2.2 Types of Sensors That Can Be Connected to Smart Analog IC 300

The sensors shown in Table 2-1 can be connected to Smart Analog IC 300.

Sensors detect physical quantities such as luminance, force, magnetism, and temperature and output that data as electrical signals. Sensors output various types of signals, which can differ even among sensors that detect the same physical quantities due to the sensing mechanism and sensor configuration.

Table 2-1 Examples of Physical Quantities Detected by Sensors and Sensor Output Types

Physical Quantity (Detection Target)	Sensor	Output Signal Type	Example Application
Light	Motion sensor	Voltage	Security equipment
	Photodiode, UV sensor, infrared sensor, color sensor	Current	Smoke detectors, street lights, backlight control
	CdS cell	Resistance change	
Sound	Ultrasound sensor	Voltage	Distance measurement, sound detectors
	Microphone	Current	
Temperature	Thermocouple, semiconductor temperature sensor	Voltage	Thermometers
	Thermistor	Resistance change	
	Temperature transducer	Current	
Humidity, gas, odor	Gas sensor, odor sensor	Voltage	Alcohol detectors, gas leak detectors, hygrometers
	Humidity sensor	Resistance change, capacitance change	
Force	Load cell	Voltage	Scales, weight scales, barometers
	Air pressure sensor	Voltage (Differential outputs)	
Magnetism, current	Hall element	Voltage (Differential outputs)	Motors, voltmeters
	MR sensor	Voltage	
	Current transformer (CT)	Current	
Angular velocity	Gyro sensor	Voltage	Robots, cameras, attitude control

Sensors that output voltage signals and current signals can be connected to Smart Analog IC 300. For sensors with other types of output signals, the signals must be externally converted into voltage or current signals before being input to Smart Analog IC 300. An example of how to convert the output of a piezoresistive sensor into a voltage output signal is shown below. A resistor is externally attached to the piezoresistive sensor as shown in Figure 2-2, configuring a resistor divider.

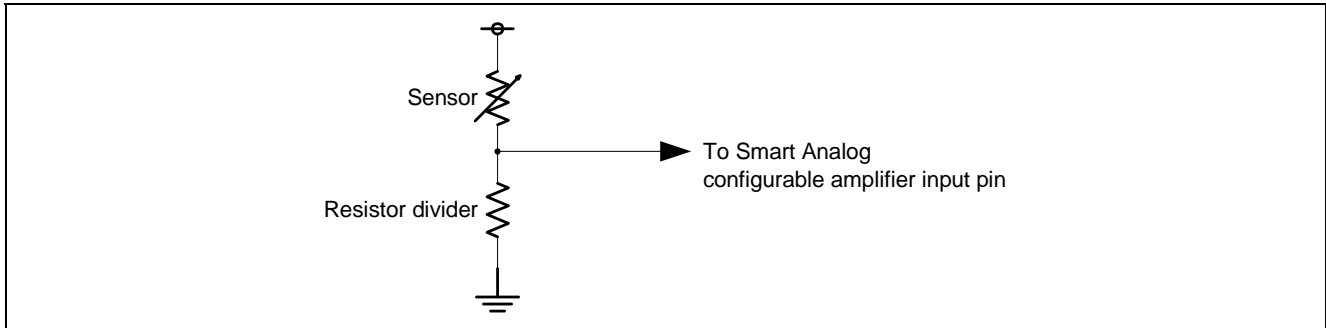


Figure 2-2 Example of Converting Piezoresistive Sensor

In order to determine the configuration of the configurable amplifiers in Smart Analog IC 300, it is necessary to identify the type of signal output by the sensor. If this information is not included in the sensor's data sheet, determine the output type by referring to Table 2-1. If the type of signal output by the sensor is not a voltage or current signal, convert the signal into a voltage or current signal by using an external component.

3. Flowchart for Selecting the Configurable Amplifier Configuration

The flowchart for selecting the configurable amplifier configuration is shown in Figure 3-1 below. This flowchart is provided for illustrative purposes to show how to select the amplifier configuration based on the specifications and characteristics of the sensor used. Note that the ideal configuration of the configurable amplifiers in Smart Analog IC 300 will differ depending on factors such as the output range, accuracy (current value, etc.), and equivalent circuits of the sensor, even for sensors that output the same type of signal (i.e., current output).

The following sensor data must be known to use this flowchart. Aspects of the flowchart such as the decision points might differ depending on your system specifications. Care is therefore required when using this flowchart to select an amplifier configuration.

- Sensor output signal type (current output or voltage output)
- Number of signals output by the sensor (Does the sensor have one output pin or two?)
- Gain required to amplify the signal output by the sensor (Higher or lower than 21 dB?)
- Output impedance of the sensor (Higher or lower than 1 kΩ?)
- Output current of the sensor (Higher or lower than 80 μA?)

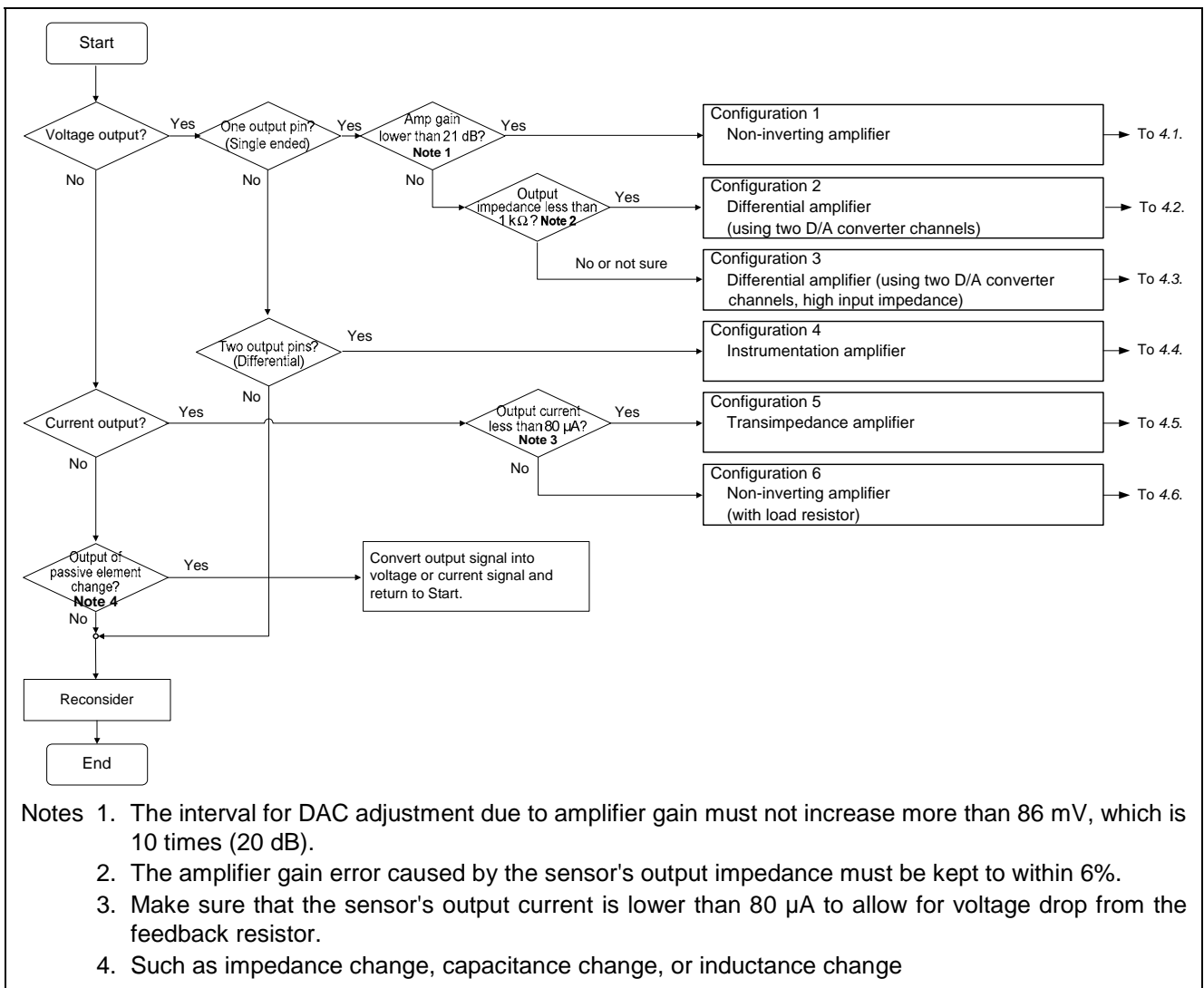


Figure 3-1 Selecting a Configurable Amplifier

4. Examples of Typical Amplifier Configurations Using Smart Analog IC 300

Smart Analog IC 300 has three on-chip configurable amplifier channels. The configurable amplifiers can be used independently or in combination. When operating a single amplifier, five amplifier configurations can be realized: a non-inverting amplifier, an inverting amplifier, a differential amplifier, a transimpedance amplifier, and a general amplifier. When operating amplifiers in combination, configurations such as an instrumentation amplifier and a differential amplifier with high input impedance can be realized.

This section describes the features of each of the configurations shown in Figure 3-1.

4.1 Non-Inverting Amplifier

A non-inverting amplifier amplifies the signal connected to the non-inverted input pin without inverting the signal, using the value of the inverted input pin as a reference. Because a non-inverting amplifier can directly receive the input signal at its input pin, the input impedance is high. This makes a non-inverting amplifier ideal for amplifying sensor signals whose output includes a resistance value.

- Advantages
 - Because the input impedance is high, a non-inverting amplifier is ideal for connecting to sensors whose output signals include resistance values.
 - Can be configured by using a single configurable amplifier channel.
- Disadvantages
 - The amplifier also amplifies the reference voltage output from the D/A converter. Therefore the step of D/A converter increases in proportion to the gain value.
 - The D/A converter is connected to the inverted input pin of the configurable amplifier, so when adjusting the output voltage by using the D/A converter, the voltage can only be adjusted downward.

Figure 4-1 shows a circuit diagram of a non-inverting amplifier that is configured by using configurable amplifier Ch1 and D/A converter Ch5 in Smart Analog IC 300.

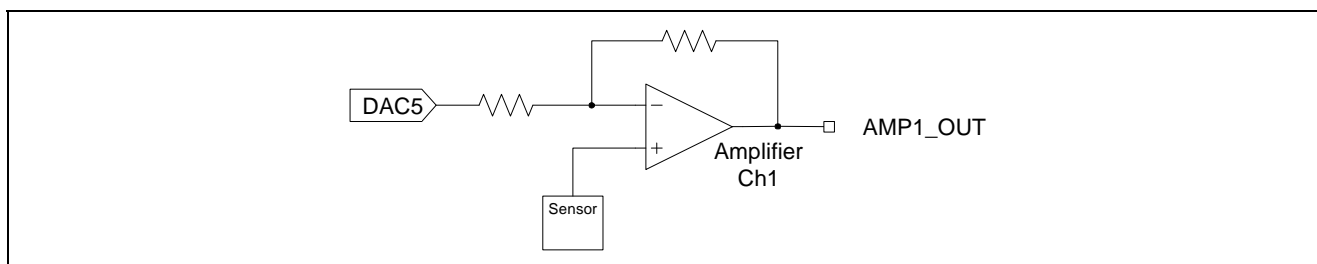


Figure 4-1 Non-Inverting Amplifier Circuit Diagram

4.2 Differential Amplifier (Using Two D/A Converter Channels)

A differential amplifier amplifies the difference between two input signals and outputs the result. Differential amplifiers are ideal for eliminating the offset voltage from sensors that include offset voltage. In this example, a single-ended output sensor is connected to the positive input of the differential amplifier and a D/A converter is connected to the negative input, and the amplifier is used as a non-inverting amplifier.

- Advantages
 - The output voltage can be easily adjusted even when the gain is high.
 - Can be configured by using a single configurable amplifier channel.
- Disadvantages
 - Because the input impedance is low, an error occurs in the gain when connecting to sensors whose output signals include resistance values.

Figure 4-2 shows a circuit diagram of a differential amplifier configuration implemented by using configurable amplifier Ch1 and D/A converter channels Ch1 and Ch5 in Smart Analog IC 300 being used as a non-inverting amplifier from the viewpoint of the sensor.

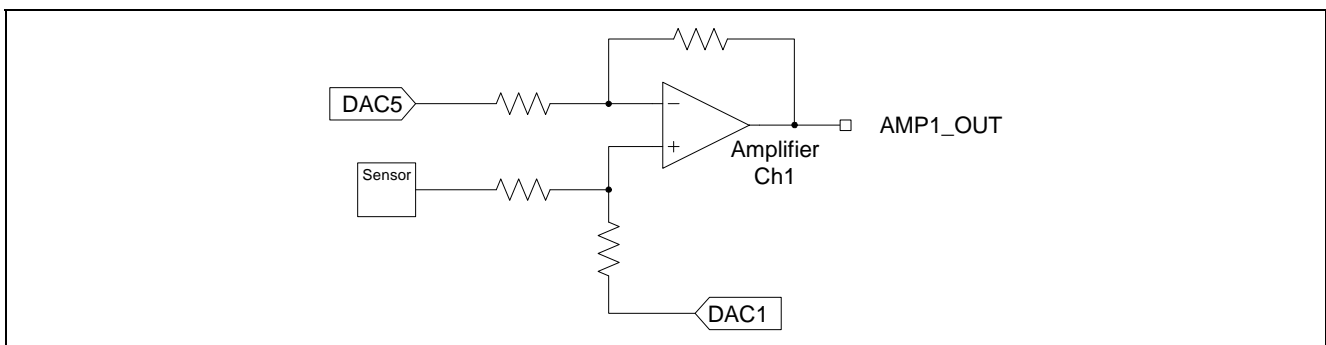


Figure 4-2 Circuit Diagram of Differential Amplifier (Using Two D/A Converter Channels)

4.3 Differential Amplifier (Using Two D/A Converter Channels and with High Impedance)

By using two configurable amplifier channels, a differential amplifier that combines the advantages of the non-inverting amplifier shown in Figure 4-1 and the differential amplifier shown in Figure 4-2 can be configured. A sensor is connected to one input of the differential amplifier and a D/A converter is connected to the other input, and the amplifier is used as a non-inverting amplifier.

- Advantages
 - Because the input impedance is high, this differential amplifier is ideal for connecting to sensors whose output signals include resistance values.
 - The output voltage can be easily adjusted even when the gain is high.
- Disadvantages
 - Two configurable amplifier channels are required.

Figure 4-3 shows a circuit diagram of a differential amplifier configuration implemented by using configurable amplifier channels Ch1 and Ch3 and D/A converter channels Ch3 and Ch7 in Smart Analog IC 300 being used as a non-inverting amplifier from the viewpoint of the sensor.

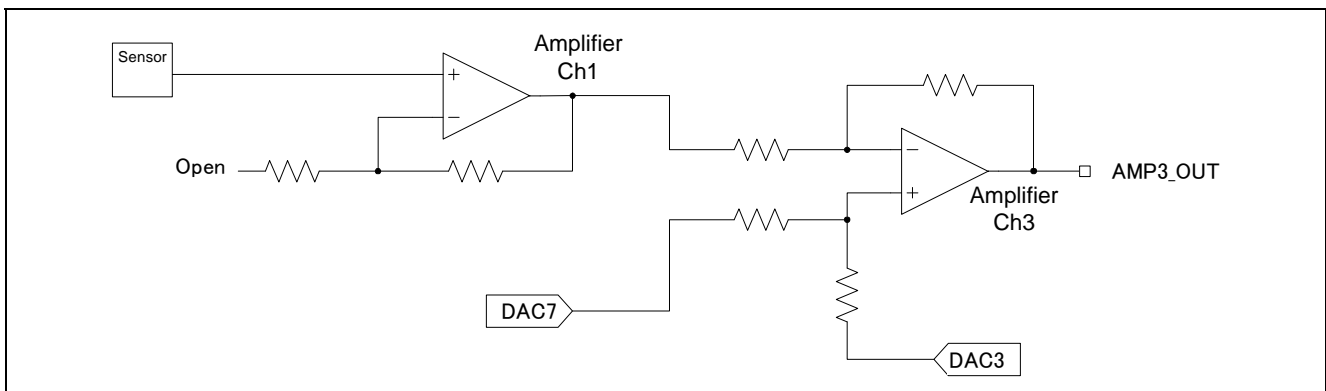


Figure 4-3 Circuit Diagram of Differential Amplifier (Using Two Configurable Amplifier Channels)

4.4 Instrumentation Amplifier

An instrumentation amplifier amplifies the difference between signals input to the amplifier in the same way as a differential amplifier, but like a non-inverting amplifier, it can also receive input signals directly at its input pin. This makes an instrumentation amplifier ideal for sensors whose output signals are differential outputs that include a resistance value, such as Wheatstone bridge sensors.

- Advantages
 - Because the input impedance is high, an instrumentation amplifier is ideal for connecting to sensors whose output signals include resistance values.
 - Can reject common-phase noise. (A high common mode rejection ratio (CMRR) can be obtained.)
- Disadvantages
 - Three configurable amplifier channels are required.

Figure 4-4 shows a circuit diagram of an instrumentation amplifier that is configured by using configurable amplifier channels Ch1 to Ch3 and D/A converter Ch3 in Smart Analog IC 300.

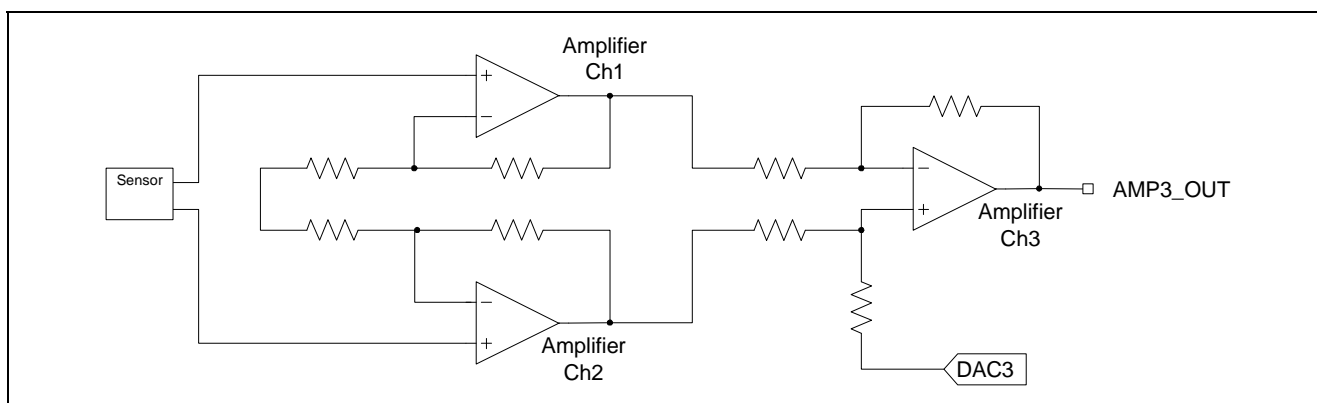


Figure 4-4 Instrumentation Amplifier Circuit Diagram

4.5 Transimpedance Amplifier

A transimpedance amplifier, also known as an impedance converting amplifier, converts a current input signal into a voltage value. This kind of amplifier is ideal for cases when you need to adjust the sensor's operating point for sensors that output current signals.

- Advantages
 - Can adjust the sensor's operating point.
- Disadvantages
 - If the sensor's output current is large, the voltage loss from the feedback resistor is also large.
 - Variation in feedback resistance leads to variation in gain.

Figure 4-5 shows a circuit diagram of a transimpedance amplifier that is configured by using configurable amplifier Ch1 and D/A converter Ch5 in Smart Analog IC 300.

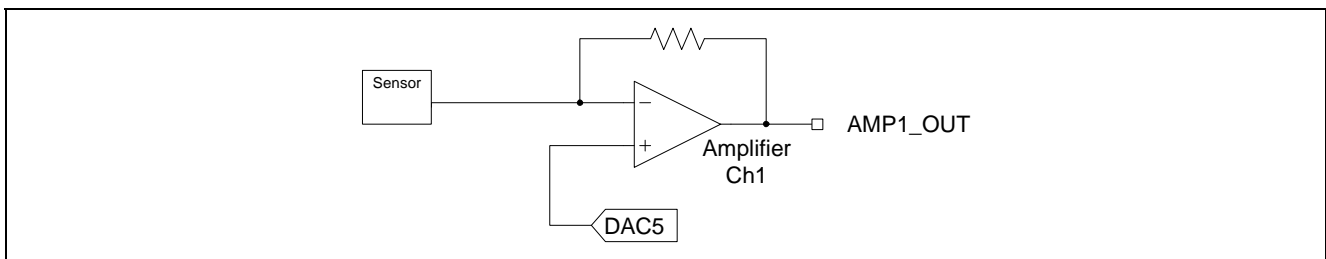


Figure 4-5 Transimpedance Amplifier Circuit Diagram

4.6 Non-Inverting Amplifier (with Load Resistor)

This amplifier is configured by externally connecting a resistor to the non-inverting amplifier shown in Figure 4-1. By using the external resistor as the sensor's load resistor, a current sensor can be used as a voltage sensor. This kind of amplifier is more effective than the transimpedance amplifier shown in Figure 4-5 for sensors that have a large output current, because the external resistance value can be selected.

- Advantages
 - Smaller gain error than the transimpedance amplifier shown in Figure 4-5.
- Disadvantages
 - An external resistor is required.
 - Current flows to the sensor even when the configurable amplifier is off.

Figure 4-6 shows a circuit diagram of a non-inverting amplifier that is configured by using configurable amplifier Ch1 and D/A converter Ch5 in Smart Analog IC 300.

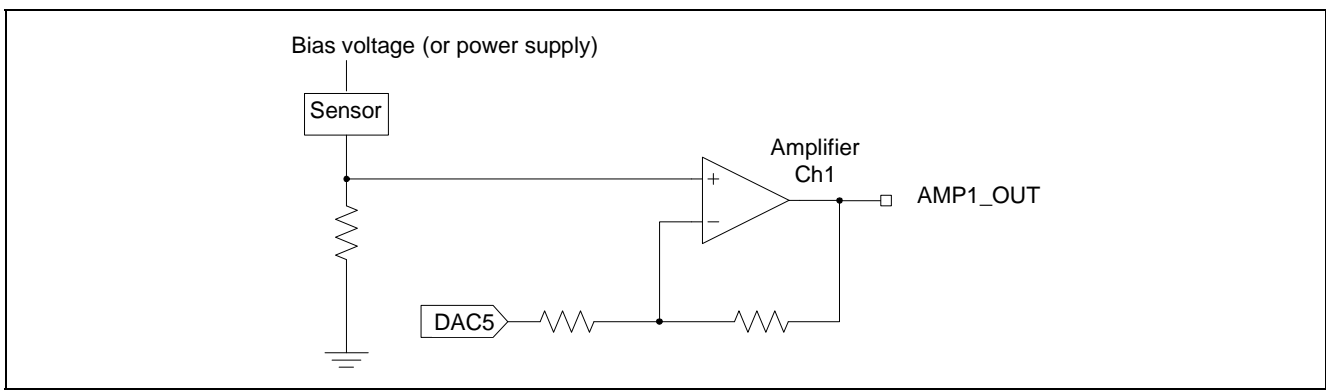


Figure 4-6 Circuit Diagram of Non-Inverting Amplifier (with Load Resistor)

Website and Support

Renesas Electronics Website

<http://www.renesas.com/>

Inquiries

<http://www.renesas.com/contact/>

Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Mar. 29, 2013	—	First edition issued.

All trademarks and registered trademarks are the property of their respective owners.

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.

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation of these circuits, software, and information in the design of your equipment. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from the use of these circuits, software, or information.
 2. Renesas Electronics has used reasonable care in preparing the information included in this document, but Renesas Electronics does not warrant that such information is error free. Renesas Electronics assumes no liability whatsoever for any damages incurred by you resulting from errors in or omissions from the information included herein.
 3. Renesas Electronics does not assume any liability for infringement of patents, copyrights, or other intellectual property rights of third parties by or arising from the use of Renesas Electronics products or technical information described in this document. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
 4. You should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from such alteration, modification, copy or otherwise misappropriation of Renesas Electronics product.
 5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The recommended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.
"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; and industrial robots etc.
"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control systems; anti-disaster systems; anti-crime systems; and safety equipment etc.
Renesas Electronics products are neither intended nor authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems, surgical implantations etc.), or may cause serious property damages (nuclear reactor control systems, military equipment etc.). You must check the quality grade of each Renesas Electronics product before using it in a particular application. You may not use any Renesas Electronics product for any application for which it is not intended. Renesas Electronics shall not be in any way liable for any damages or losses incurred by you or third parties arising from the use of any Renesas Electronics product for which the product is not intended by Renesas Electronics.
 6. You should use the Renesas Electronics products described in this document within the range specified by Renesas Electronics, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas Electronics shall have no liability for malfunctions or damages arising out of the use of Renesas Electronics products beyond such specified ranges.
 7. Although Renesas Electronics endeavors to improve the quality and reliability of its products, semiconductor products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Further, Renesas Electronics products are not subject to radiation resistance design. Please be sure to implement safety measures to guard them against the possibility of physical injury, and injury or damage caused by fire in the event of a Renesas Electronics product, such as safety design for hardware and software including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult, please evaluate the safety of the final products or systems manufactured by you.
 8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. Please use Renesas Electronics products in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. Renesas Electronics assumes no liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
 9. Renesas Electronics products and technology may not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You should not use Renesas Electronics products or technology described in this document for any purpose relating to military applications or use by the military, including but not limited to the development of weapons of mass destruction. When exporting the Renesas Electronics products or technology described in this document, you should comply with the applicable export control laws and regulations and follow the procedures required by such laws and regulations.
 10. It is the responsibility of the buyer or distributor of Renesas Electronics products, who distributes, disposes of, or otherwise places the product with a third party, to notify such third party in advance of the contents and conditions set forth in this document, Renesas Electronics assumes no responsibility for any losses incurred by you or third parties as a result of unauthorized use of Renesas Electronics products.
 11. This document may not be reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
 12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products, or if you have any other inquiries.
- (Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its majority-owned subsidiaries.
(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.



SALES OFFICES

Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com>" for the latest and detailed information.

Renesas Electronics America Inc.

2880 Scott Boulevard Santa Clara, CA 95050-2554, U.S.A.
Tel: +1-408-588-6000, Fax: +1-408-588-6130

Renesas Electronics Canada Limited

1101 Nicholson Road, Newmarket, Ontario L3Y 9C3, Canada
Tel: +1-905-898-5441, Fax: +1-905-898-3220

Renesas Electronics Europe Limited

Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH

Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-65030, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.

7th Floor, Quantum Plaza, No.27 ZhiChunLu Haidian District, Beijing 100083, P.R.China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.

Unit 204, 205, AZIA Center, No.1233 Lujiazui Ring Rd., Pudong District, Shanghai 200120, China
Tel: +86-21-5877-1818, Fax: +86-21-6887-7858 / -7898

Renesas Electronics Hong Kong Limited

Unit 1601-1613, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2886-9318, Fax: +852-2886-9022/9044

Renesas Electronics Taiwan Co., Ltd.

13F, No. 363, Fu Shing North Road, Taipei, Taiwan
Tel: +886-2-8175-9600, Fax: +886-2-8175-9670

Renesas Electronics Singapore Pte. Ltd.

80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.

Unit 906, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics Korea Co., Ltd.

11F., Samik Lavied' or Bldg., 720-2 Yeoksam-Dong, Kangnam-Ku, Seoul 135-080, Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5141