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RAA730502

Monolithic Programmable Analog IC

R02DS0010EJ0120

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Overview

The RAA730502 is a monolithic programmable analog IC with a range of on-chip circuits such as high-speed instrumentation amplifiers with comparators, D/A converters, and a temperature sensor, allowing the RAA730502 to be used as an analog front-end device for sensing current in motor control applications. The RAA730502 uses a Serial Peripheral Interface (SPI) to allow external devices to control each on-chip circuit, enabling a more compact package and a reduction in the number of control pins. The compact package used by the RAA730502—a 48-pin LQFP—in turns enables a more compact set design.

Features

- On-chip high-speed instrumentation amplifier with comparator × 4 ch
- On-chip D/A converter × 5 ch
- On-chip temperature sensor × 1 ch
- On-chip SPI × 1 ch
- Includes a low-current mode.
- Operating voltage range: $3.0\text{ V} \leq V_{DD} \leq 5.5\text{ V}$
- Operating temperature range: $-40^{\circ}\text{C} \leq T_A \leq 105^{\circ}\text{C}$
- Package: 48-pin plastic LQFP (fine pitch) (7 × 7)

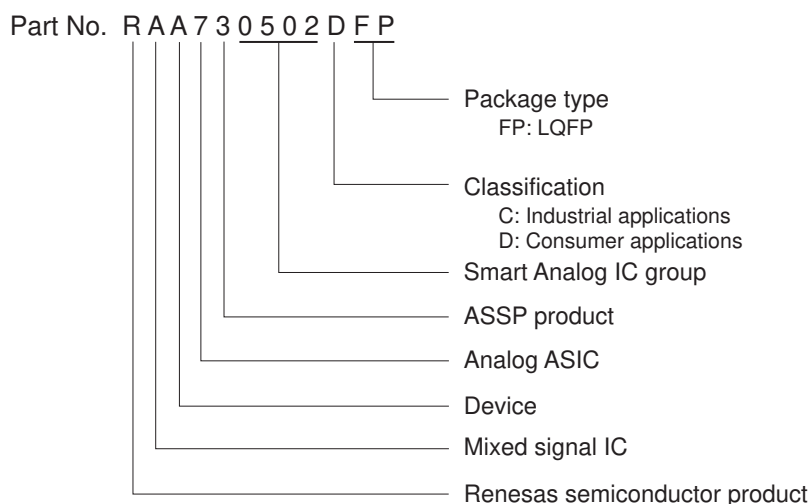
Applications

Home appliances

- Air purifiers
- Air conditioners
- Refrigerators
- Dishwashers
- Electric bicycles

Ordering Information

Pin count	Package	Part Number
48 pins	48-pin plastic LQFP (fine pitch) (7 × 7)	RAA730502CFP, RAA730502DFP



How to Read This Manual

It is assumed that the readers of this manual have general knowledge of electrical engineering, electronic circuits.

- To gain a general understanding of functions:
 - Read this manual in the order of the CONTENTS.
- To check the revised points :
 - The mark <R> shows major revised points. The revised points can be easily searched by copying an “<R>” in the PDF file and specifying it in the “Find what: ” field.

Conventions

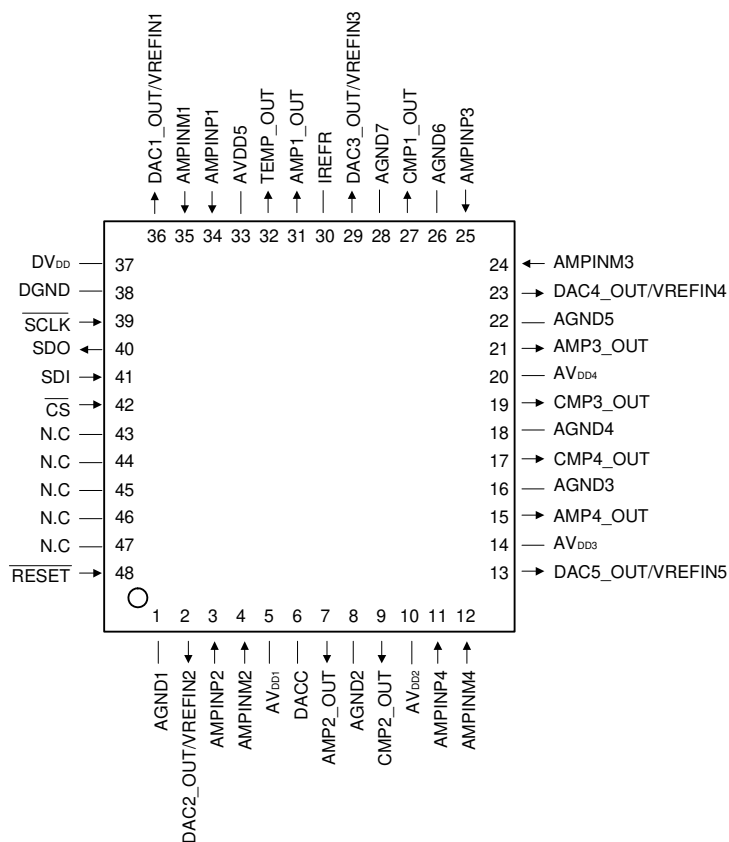
Data significance	: Higher digits on the left and lower digits on the right
Active low representations	: $\overline{\text{xxx}}$ (overscore over pin and signal name)
Note	: Footnote for item marked with Note in the text
Caution	: Information requiring particular attention
Remark	: Supplementary information
Numerical representations	: Binary ...xxxx or xxxxB Decimal ...xxxx Hexadecimal ...xxxxH

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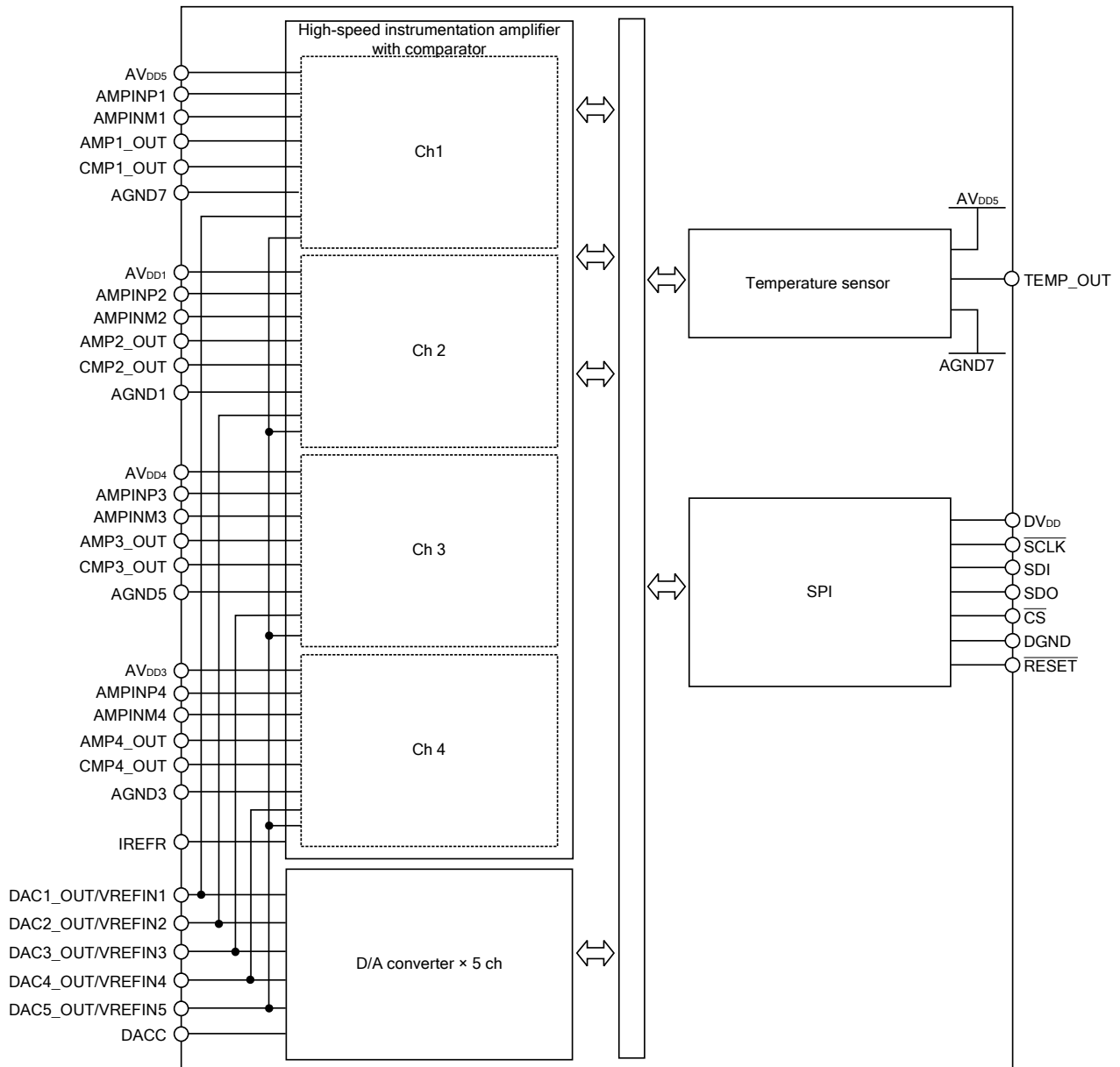
1. Pin Configuration

1.1 Pin Layout



- Cautions**
1. Make the potential of AGND1, AGND2, AGND3, AGND4, AGND5, AGND6, AGND7, and DGND the same.
 2. Make the potential of AV_{DD1}, AV_{DD2}, AV_{DD3}, AV_{DD4}, AV_{DD5}, and DV_{DD} the same.
 3. Connect the DACC pin to AGND2 via a capacitor (100 nF: recommended).
 4. Connect the IREFR pin to AGND7 via a resistor (56 kΩ: recommended).
 5. Connect N.C to AGND1.

1.2 Block Diagram



1.3 Pin Functions

Table 1-1. Pin Functions (1/2)

Pin No.	Pin Name	I/O	Pin Functions
1	AGND1	–	GND pin for Ch2 high-speed instrumentation amplifier with comparator
2	DAC2_OUT/ VREFIN2	Input/ output	D/A converter Ch2 output pin/ Ch2 high-speed instrumentation amplifier reference voltage input pin
3	AMPINP2	Input	Ch2 high-speed instrumentation amplifier with comparator input pin (+)
4	AMPINM2	Input	Ch2 high-speed instrumentation amplifier with comparator input pin (-)
5	AV _{DD1}	–	Power supply pin for Ch2 high-speed instrumentation amplifier with comparator
6	DACC	Output	Pin for connecting stabilizing capacitor to D/A converter resistor arrays
7	AMP2_OUT	Output	High-speed instrumentation amplifier Ch2 output pin
8	AGND2	–	GND pin for D/A converter
9	CMP2_OUT	Output	Comparator Ch2 output pin
10	AV _{DD2}	–	Power supply pin for D/A converter
11	AMPINP4	Input	Ch4 high-speed instrumentation amplifier with comparator input pin (+)
12	AMPINM4	Input	Ch4 high-speed instrumentation amplifier with comparator input pin (-)
13	DAC5_OUT/ VREFIN5	Input/ output	D/A converter Ch5 output pin/comparator reference voltage input pin
14	AV _{DD3}	–	Power supply pin for Ch4 high-speed instrumentation amplifier with comparator
15	AMP4_OUT	Output	High-speed instrumentation amplifier Ch4 output pin
16	AGND3	–	GND pin for Ch4 high-speed instrumentation amplifier with comparator
17	CMP4_OUT	Output	Comparator Ch4 output pin
18	AGND4	–	GND pin for Ch2 high-speed instrumentation amplifier with comparator
19	CMP3_OUT	Output	Comparator Ch3 output pin
20	AV _{DD4}	–	Power supply pin for Ch3 high-speed instrumentation amplifier with comparator
21	AMP3_OUT	Output	High-speed instrumentation amplifier Ch3 output pin
22	AGND5	–	GND pin for Ch3 high-speed instrumentation amplifier with comparator
23	DAC4_OUT/ VREFIN4	Input/ output	D/A converter Ch4 output pin/ Ch4 high-speed instrumentation amplifier reference voltage input pin
24	AMPINM3	Input	Ch3 high-speed instrumentation amplifier with comparator input pin (-)
25	AMPINP3	Input	Ch3 high-speed instrumentation amplifier with comparator input pin (+)
26	AGND6	–	GND pin for temperature sensor
27	CMP1_OUT	Output	Comparator Ch1 output pin
28	AGND7	–	GND pin for temperature sensor
29	DAC3_OUT/ VREFIN3	Input/ output	D/A converter Ch3 output pin/ Ch3 high-speed instrumentation amplifier reference voltage input pin
30	IREFR	Output	Pin for connecting a resistor to stabilize the internal reference current
31	AMP1_OUT	Output	High-speed instrumentation amplifier Ch1 output pin
32	TEMP_OUT	Output	Temperature sensor output pin
33	AV _{DD5}	–	Power supply pin for Ch1 high-speed instrumentation amplifier with comparator
34	AMPINP1	Input	Ch1 high-speed instrumentation amplifier with comparator input pin (+)
35	AMPINM1	Input	Ch1 high-speed instrumentation amplifier with comparator input pin (-)

Table 1-1. Pin Functions (2/2)

Pin No.	Pin Name	I/O	Pin Functions
36	DAC1_OUT/ VREFIN1	Input/ output	D/A converter Ch1 output pin/ Ch1 high-speed instrumentation amplifier reference voltage input pin
37	DV _{DD}	–	Power supply pin for SPI
38	DGND	–	GND pin for SPI
39	SCLK	Input	Serial clock input pin for SPI
40	SDO	Output	Serial data output pin for SPI
41	SDI	Input	Serial data input pin for SPI
42	$\overline{\text{CS}}$	Input	Chip select input pin for SPI
43	N.C ^{Note}	–	Non-connection
44	N.C ^{Note}	–	
45	N.C ^{Note}	–	
46	N.C ^{Note}	–	
47	N.C ^{Note}	–	
48	$\overline{\text{RESET}}$	Input	External reset input pin

Note Connect to AGND1.

1.4 Connection of Unused Pins

Table 1-2. Connection of Unused Pins

Pin Name	I/O	Recommended Connection of Unused Pins
DAC2_OUT/ VREFIN2	Input/ output	Leave open.
AMPINP2	Input	Directly connect to AGND1.
AMPINM2	Input	
AMP2_OUT	Output	Leave open.
CMP2_OUT	Output	
AMPINP4	Input	Directly connect to AGND3.
AMPINM4	Input	
DAC5_OUT/ VREFIN5	Input/ output	Leave open.
AMP4_OUT	Output	
CMP4_OUT	Output	
CMP3_OUT	Output	
AMP3_OUT	Output	
DAC4_OUT/ VREFIN4	Input/ output	
AMPINM3	Input	
AMPINP3	Input	
CMP1_OUT	Output	Leave open.
DAC3_OUT/ VREFIN3	Output	
AMP1_OUT	Output	
TEMP_OUT	Output	
AMPINP1	Input	Directly connect to AGND7.
AMPINM1	Input	
DAC1_OUT/ VREFIN1	Input/ output	Leave open.
\overline{SCLK}	Input	
SDO	Output	
SDI	Input	
\overline{CS}	Input	
N.C	–	Directly connect to AGND1.
\overline{RESET}	Input	Connect to DV _{DD} directly or via a resistor.

1.5 Pin I/O Circuits

Figure 1-1. Pin I/O Circuit Type (1/5)

Pin Name	Equivalent Circuit	Pin Name	Equivalent Circuit
AMPINM1 AMPINP1		AMPINM2 AMPINP2	
AMPINM3 AMPINP3		AMPINM4 AMPINP4	

Figure 1-1. Pin I/O Circuit Type (2/5)

Pin Name	Equivalent Circuit	Pin Name	Equivalent Circuit
AMP1_OUT		AMP2_OUT	
AMP3_OUT		AMP4_OUT	

Figure 1-1. Pin I/O Circuit Type (3/5)

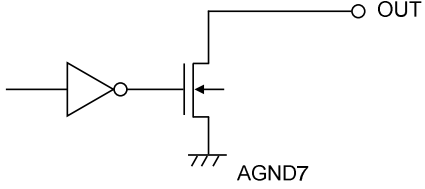
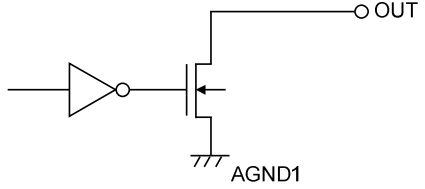
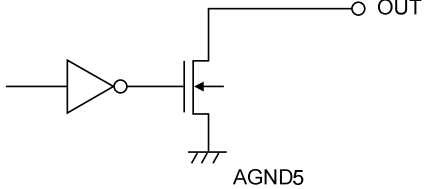
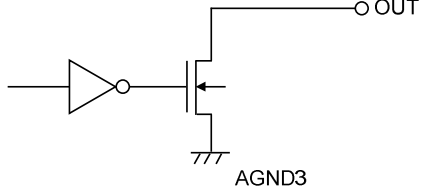
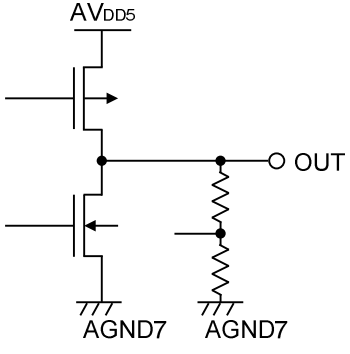
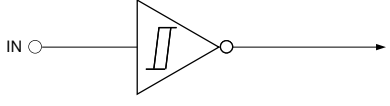
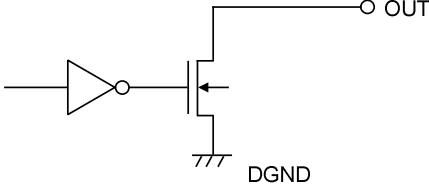
Pin Name	Equivalent Circuit	Pin Name	Equivalent Circuit
CMP1_OUT		CMP2_OUT	
CMP3_OUT		CMP4_OUT	

Figure 1-1. Pin I/O Circuit Type (4/5)

Pin Name	Equivalent Circuit	Pin Name	Equivalent Circuit
DAC1_OUT/ VREFIN1 DAC2_OUT/ VREFIN2		DAC3_OUT/ VREFIN3 DAC4_OUT/ VREFIN4	
DAC5_OUT/ VREFIN5		SCLK SDI CS	

Figure 1-1. Pin I/O Circuit Type (5/5)

Pin Name	Equivalent Circuit	Pin Name	Equivalent Circuit
TEMP_OUT		RESET	 <p>Schmitt-triggered input with hysteresis characteristics</p>
SDO			

2. High-Speed Instrumentation Amplifiers with Comparators

The RAA730502 has four channels used as high-speed instrumentation amplifiers with comparators.

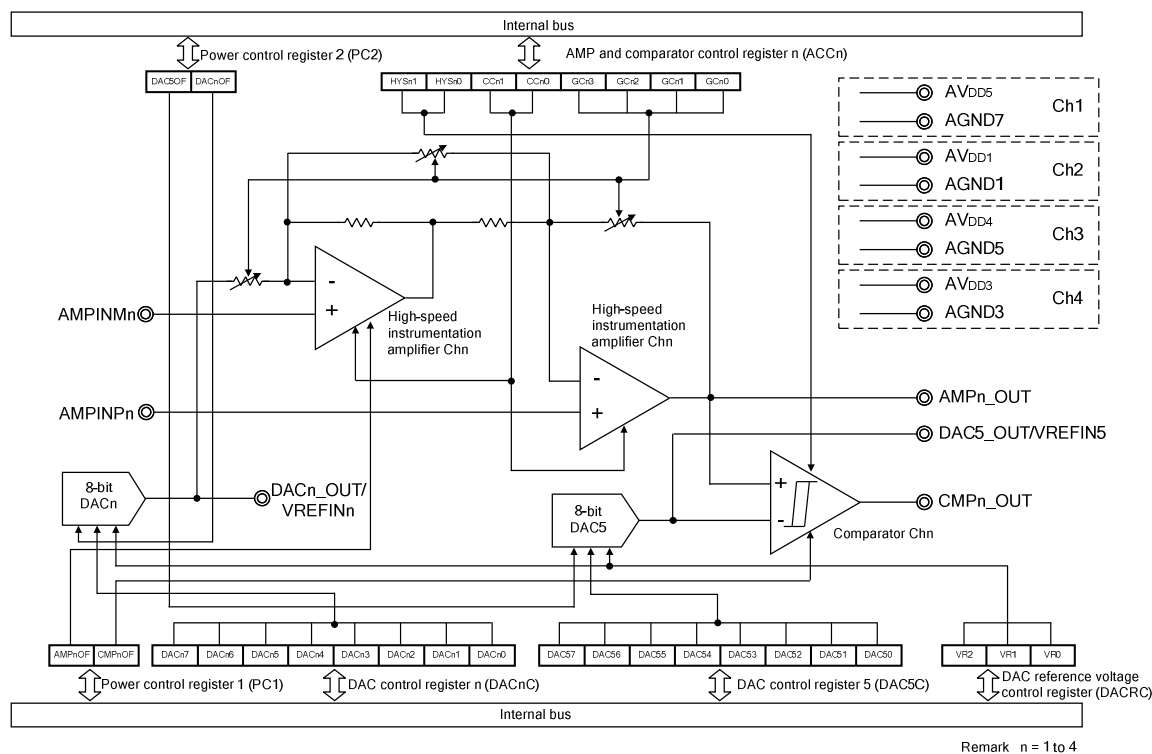
<R> 2.1 Overview of High-Speed Instrumentation Amplifiers with Comparators

Each high-speed instrumentation amplifier with comparator includes a high-speed instrumentation amplifier block and a comparator block.

- High-speed instrumentation amplifier block
 - The gain can be specified between 10 dB and 34 dB in 13 steps.
 - Four operating modes are available.
 - The reference voltage can be adjusted by using D/A converter Ch1 to Ch4.
 - Includes a power-off function.
- Comparator block
 - The signal output from a high-speed instrumentation amplifier with comparator can be input to the positive (+) pin of the comparator, compared with the D/A converter output, and then output.
 - The reference voltage can be adjusted by using D/A converter Ch5.
 - Includes a power-off function.

And also, the DAC_n_OUT (n = 1 to 5) output signal can be used as the reference voltage for high-speed instrumentation amplifier with comparator. If D/A converters are powered off, the external reference voltage is to be input to DAC_n_OUT/VREFIN_n (n = 1 to 5) pin. For details about use of D/A converter, see 3. D/A Converter.

2.2 Block Diagram



Caution When using the comparators, connect the CMP_n_OUT pin to a pull-up resistor (2.2 kΩ recommended).

Remark n = 1 to 4

2.3 Registers Controlling the High-Speed Instrumentation Amplifiers with Comparators

The high-speed instrumentation amplifiers with comparators are controlled by the following 2 registers:

- AMP and comparator control registers 1, 2, 3, 4 (ACC1, ACC2, ACC3, ACC4)
- Power control register 1 (PC1)

(1) AMP and comparator control registers 1, 2, 3, 4 (ACC1, ACC2, ACC3, ACC4)

This register is used to specify the operating mode and gain of the high-speed instrumentation amplifiers with comparators, and the hysteresis width of the comparators.

Reset signal input clears this register to 00H.

Address: 00H (n = 1), 01H (n = 2), 02H (n = 3), 03H (n = 4) After reset: 00H R/W

	7	6	5	4	3	2	1	0
ACCn	HYSn1	HYSn0	CCn1	CCn0	GCn3	GCn2	GCn1	GCn0

HYSn1	HYSn0	Hysteresis width (Typ.)
0	0	200 mV
0	1	100 mV
1	0	50 mV
1	1	No hysteresis

CCn1	CCn0	Operating mode of high-speed instrumentation amplifiers with comparators
0	0	High-speed mode
0	1	Mid-speed mode 2
1	0	Mid-speed mode 1
1	1	Low-speed mode

GCn3	GCn2	GCn1	GCn0	Gain of high-speed instrumentation amplifiers with comparators (Typ.)
0	0	0	0	10 dB
0	0	0	1	12 dB
0	0	1	0	14 dB
0	0	1	1	16 dB
0	1	0	0	18 dB
0	1	0	1	20 dB
0	1	1	0	22 dB
0	1	1	1	24 dB
1	0	0	0	26 dB
1	0	0	1	28 dB
1	0	1	0	30 dB
1	0	1	1	32 dB
1	1	0	0	34 dB
Other than above				Setting prohibited

Remark n = 1 to 4

(2) Power control register 1 (PC1)

This register is used to enable or disable operation of the high-speed instrumentation amplifiers with comparators.

Use this register to stop unused functions to reduce power consumption and noise.

When using one of Ch1 to Ch4 high-speed instrumentation amplifiers with comparators, be sure to set the control bit that corresponds to the comparators Ch1 to Ch4 and high-speed instrumentation amplifiers Ch1 to Ch4 to 1.

Reset signal input clears this register to 00H.

Address: 0AH After reset: 00H R/W

	7	6	5	4	3	2	1	0
PC1	CMP4OF	CMP3OF	CMP2OF	CMP1OF	AMP4OF	AMP3OF	AMP2OF	AMP1OF

CMP4OF	Operation of comparator Ch4
0	Stop operation of comparator Ch4.
1	Enable operation of comparator Ch4.

CMP3OF	Operation of comparator Ch3
0	Stop operation of comparator Ch3.
1	Enable operation of comparator Ch3.

CMP2OF	Operation of comparator Ch2
0	Stop operation of comparator Ch2.
1	Enable operation of comparator Ch2.

CMP1OF	Operation of comparator Ch1
0	Stop operation of comparator Ch1.
1	Enable operation of comparator Ch1.

AMP4OF	Operation of high-speed instrumentation amplifier Ch4
0	Stop operation of high-speed instrumentation amplifier Ch4.
1	Enable operation of high-speed instrumentation amplifier Ch4.

AMP3OF	Operation of high-speed instrumentation amplifier Ch3
0	Stop operation of high-speed instrumentation amplifier Ch3.
1	Enable operation of high-speed instrumentation amplifier Ch3.

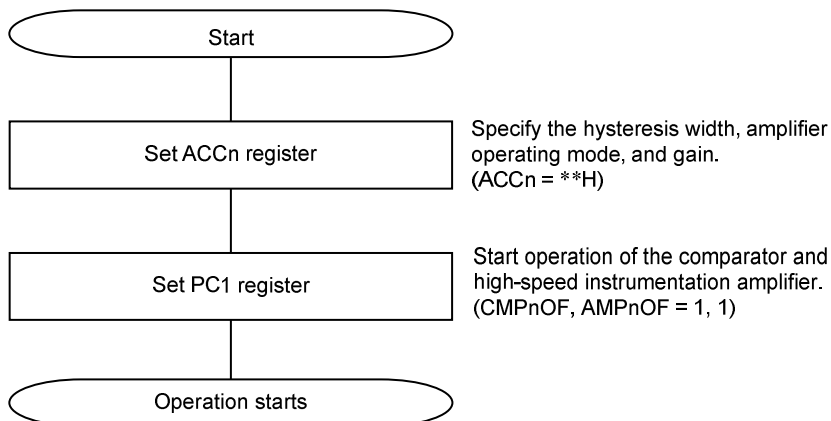
AMP2OF	Operation of high-speed instrumentation amplifier Ch2
0	Stop operation of high-speed instrumentation amplifier Ch2.
1	Enable operation of high-speed instrumentation amplifier Ch2.

AMP1OF	Operation of high-speed instrumentation amplifier Ch1
0	Stop operation of high-speed instrumentation amplifier Ch1.
1	Enable operation of high-speed instrumentation amplifier Ch1.

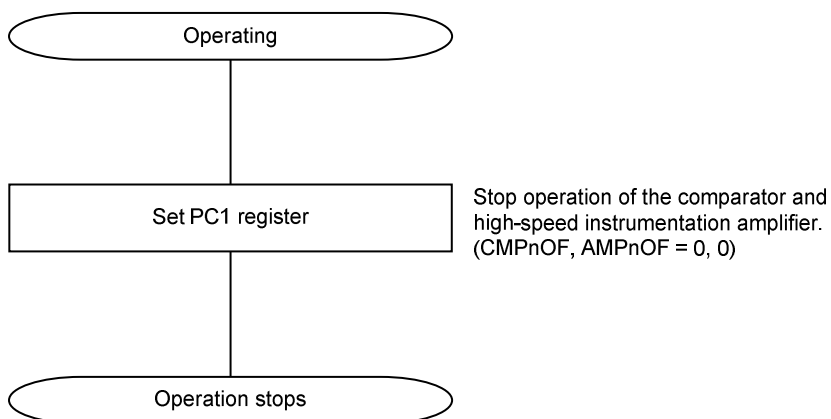
2.4 Procedure for Operating the High-Speed Instrumentation Amplifiers with Comparators

Follow the procedures below to start and stop the high-speed instrumentation amplifiers with comparators.

Example of procedure for starting the high-speed instrumentation amplifiers with comparators



Example of procedure for stopping the high-speed instrumentation amplifiers with comparators



Remark *: don't care
n = 1 to 4

3.3 Registers Controlling the D/A Converters

The D/A converters are controlled by the following 3 kinds of registers:

- DAC control registers 1, 2, 3, 4, 5 (DAC1C, DAC2C, DAC3C, DAC4C, DAC5C)
- DAC reference voltage control register (DACRC)
- Power control register 2 (PC2)

(1) DAC control registers 1, 2, 3, 4, 5 (DAC1C, DAC2C, DAC3C, DAC4C, DAC5C)

This register is used to specify the analog voltage to be output to the DACn_OUT pin.

The DACn_OUT output signal can be used as the reference voltage for the high-speed instrumentation amplifiers with comparators.

Reset signal input sets this register to 80H.

Address: 04H (n = 1), 05H (n = 2), 06H (n = 3), 07H (n = 4), 08H (n = 5) After reset: 80H R/W

	7	6	5	4	3	2	1	0
DACnC	DACn7	DACn6	DACn5	DACn4	DACn3	DACn2	DACn1	DACn0

Remark 1. n = 1 to 5

2. To calculate the output voltage, see **3. 1 Overview of D/A converter features.**

<R> (2) DAC reference voltage control register (DACRC)

This register is used to specify the upper (VRT) and lower (VRB) limits of the reference voltage for D/A converters Ch1 to Ch5.

Reset signal input clears this register to 00H.

Address: 09H After reset: 00H R/W

	7	6	5	4	3	2	1	0
DACRC	0	0	0	0	0	VR2	VR1	VR0

VR2	VR1	VR0	Reference voltage upper limit (Typ.)		Reference voltage lower limit (Typ.)	
			D/A converters Ch1, Ch2	D/A converters Ch3 to Ch5	D/A converters Ch1, Ch2	D/A converters Ch3 to Ch5
0	0	0	AV _{DD1}	AV _{DD4}	AGND1	AGND5
0	0	1	AV _{DD1} × 1/5	AV _{DD4} × 1/5	AGND1	AGND5
0	1	0	AV _{DD1} × 2/5	AV _{DD4} × 2/5	AV _{DD1} × 1/5	AV _{DD4} × 1/5
0	1	1	AV _{DD1} × 3/5	AV _{DD4} × 3/5	AV _{DD1} × 2/5	AV _{DD4} × 2/5
1	0	0	AV _{DD1} × 4/5	AV _{DD4} × 4/5	AV _{DD1} × 3/5	AV _{DD4} × 3/5
1	0	1	AV _{DD1}	AV _{DD4}	AV _{DD1} × 4/5	AV _{DD4} × 4/5
1	1	0	AV _{DD1} × 4/5	AV _{DD4} × 4/5	AV _{DD1} × 1/5	AV _{DD4} × 1/5
1	1	1	Setting prohibited			

Remark Bits 7 to 3 are fixed to 0. (Prohibited to be set to 1.)

(3) Power control register 2 (PC2)

This register is used to enable or disable operation of the D/A converters and temperature sensor.

Use this register to stop unused functions to reduce power consumption and noise.

When using one of D/A converter channels Ch1 to Ch5, be sure to set the control bit that corresponds to the channel (bits 4 to 0) to 1.

Reset signal input clears this register to 00H.

Address: 0BH After reset: 00H R/W

	7	6	5	4	3	2	1	0
PC2	0	0	TEMPOF	DAC5OF	DAC4OF	DAC3OF	DAC2OF	DAC1OF

DAC5OF	Operation of D/A converter Ch5
0	Stop operation of D/A converter Ch5.
1	Enable operation of D/A converter Ch5.

DAC4OF	Operation of D/A converter Ch4
0	Stop operation of D/A converter Ch4.
1	Enable operation of D/A converter Ch4.

DAC3OF	Operation of D/A converter Ch3
0	Stop operation of D/A converter Ch3.
1	Enable operation of D/A converter Ch3.

DAC2OF	Operation of D/A converter Ch2
0	Stop operation of D/A converter Ch2.
1	Enable operation of D/A converter Ch2.

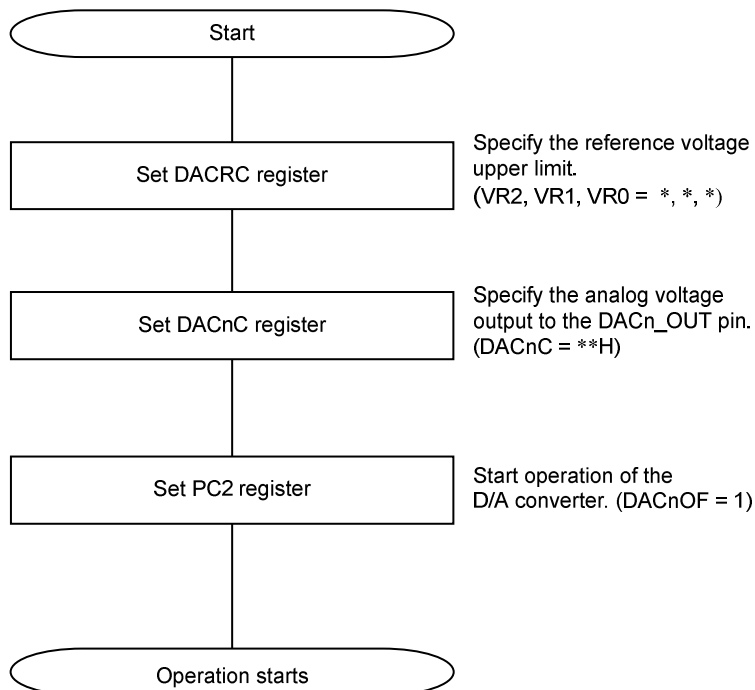
DAC1OF	Operation of D/A converter Ch1
0	Stop operation of D/A converter Ch1.
1	Enable operation of D/A converter Ch1.

Remark Bits 7 and 6 are fixed to 0. (Prohibited to be set to 1.)

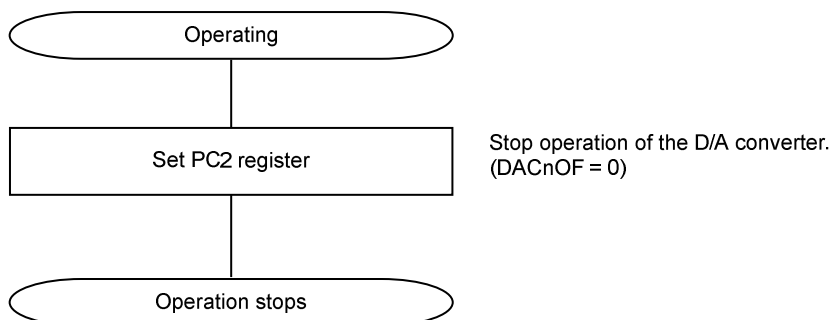
3.4 Procedure for Operating the D/A Converters

Follow the procedures below to start and stop the D/A converters.

Example of procedure for starting the D/A converters



Example of procedure for stopping the D/A converters



Remark *: don't care
n = 1 to 5

3.5 Notes on Using the D/A Converters

Observe the following points when using the D/A converters:

- (1) Only a very small current can flow from the DACn_OUT pin because the output impedance of the D/A converters is high. If the load input impedance is low, insert a follower amplifier between the load and the DACn_OUT pin. Also, make sure that the wiring between the pin and the follower amplifier or load is as short as possible (because of the high output impedance). If it is not possible to keep the wiring short, take measures such as surrounding the pin with a ground pattern.
- (2) If inputting an external reference power supply to the VREFINn pin, be sure to set the DACnOF bit to 0.

Remark n = 1 to 5

4. Temperature Sensor

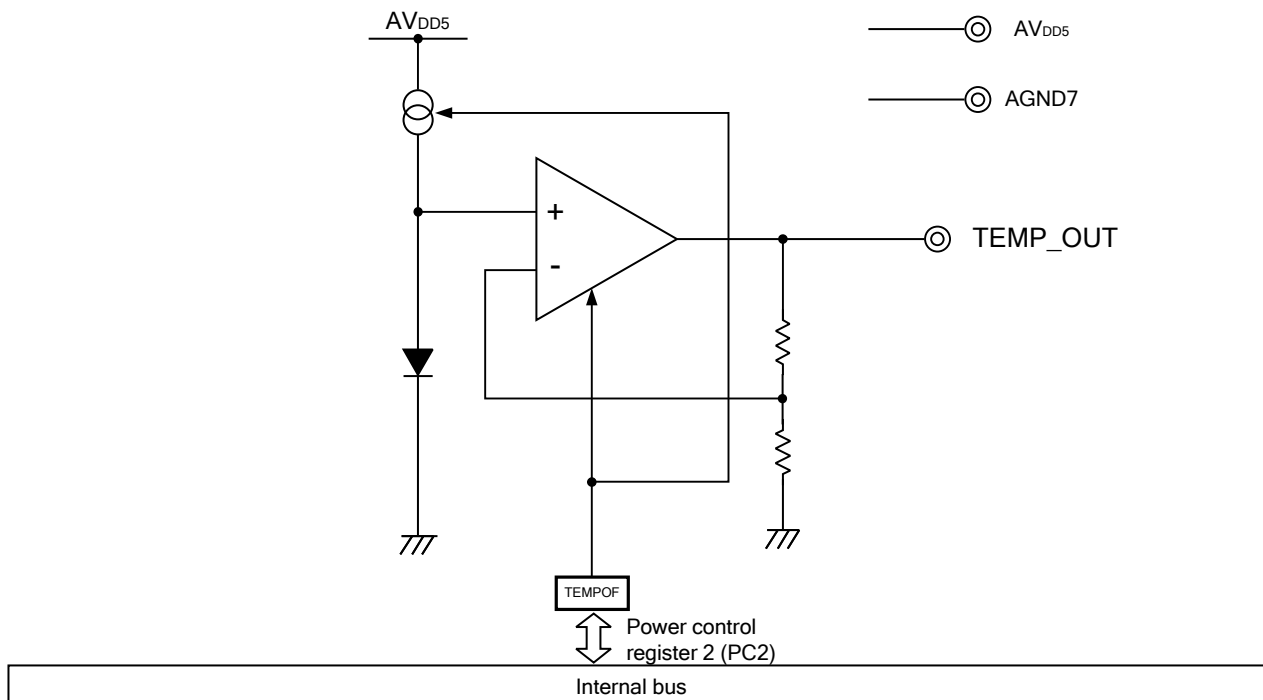
The RAA730502 has one on-chip temperature sensor channel.

4.1 Overview of Temperature Sensor Features

The temperature sensor have the following features:

- Output voltage temperature coefficient: $-5\text{mV}/^\circ\text{C}$ (Typ.)
- Includes a power-off function.

4.2 Block Diagram



4.3 Registers Controlling the Temperature Sensor

The temperature sensor is controlled by the following register:

- Power control register 2 (PC2)

(1) Power control register 2 (PC2)

This register is used to enable or disable operation of the temperature sensor and D/A converter. Use this register to stop unused functions to reduce power consumption and noise.

When selecting the signal to be input to the temperature sensor, be sure to set bit 5 to 1.

Reset signal input clears this register to 00H.

Address: 0BH After reset: 00H R/W

	7	6	5	4	3	2	1	0
PC2	0	0	TEMPOF	DAC5OF	DAC4OF	DAC3OF	DAC2OF	DAC1OF

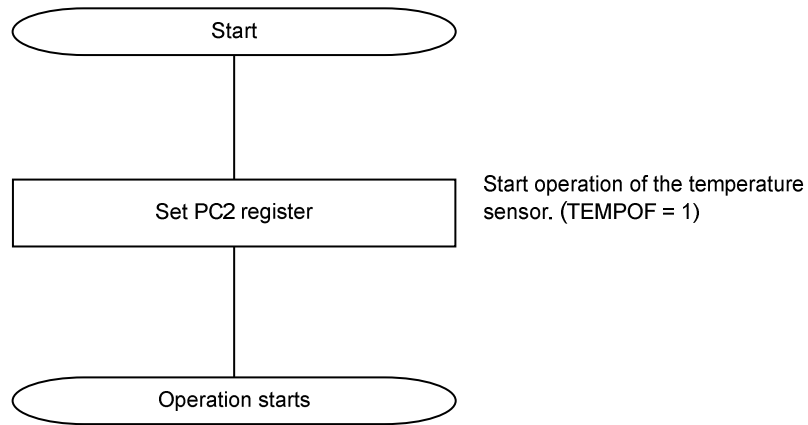
TEMPOF	Operation of temperature sensor
0	Stop operation of the temperature sensor.
1	Enable operation of the temperature sensor.

Remark Bits 7 and 6 are fixed to 0. (Prohibited to be set to 1.)

4.4 Procedure for Operating the Temperature Sensor

Follow the procedures below to start and stop the temperature sensor.

Example of procedure for starting the temperature sensor



Example of procedure for stopping the temperature sensor

