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H8S/2200 Series

Measuring Voltages by A/D Conversion

Introduction

An analog input signal is converted into a digital value using the H8S/2215's A/D converter in single mode or scan mode.

Target Device

H8S/2215

Contents

1. Overview

The A/D conversion function of the H8S/2215 is used to convert an analog input signal into a digital value.

2. Configuration

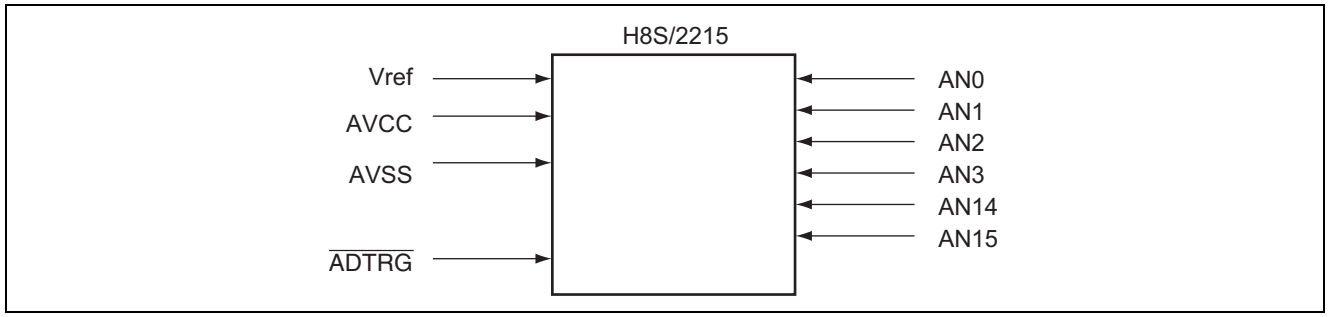


Figure 1 Pins Used for Voltage Measurement by A/D Conversion

Table 1 Pin Configuration

Pin Name	Symbol	Setting	Rating
Analog power supply pin	AVCC	3.3 V	2.7 to 3.6 V
Analog ground pin	AVSS	Ground	
Reference voltage pin	Vref	3.3 V	0 V to AVCC
Analog input pin 0	AN0	0 to Vref	0 to Vref
Analog input pin 1	AN1	0 to Vref	0 to Vref
Analog input pin 2	AN2	0 to Vref	0 to Vref
Analog input pin 3	AN3	0 to Vref	0 to Vref
Analog input pin 14	AN14	0 to Vref	0 to Vref
Analog input pin 15	AN15	0 to Vref	0 to Vref
A/D external trigger input pin	$\overline{\text{ADTRG}}$	Trigger on the falling edge	External trigger input pin for starting A/D conversion

3. Sample Programs

3.1 Functions

1. Sets the contents specified by a structure (adc_parm) in the corresponding resisters in the H8 microcomputer.
2. Starts and stops A/D conversion.
3. Checks the end of A/D conversion.
4. Reads the A/D-converted data.

3.2 Program Incorporation

1. Incorporate sample program 2-A: #define definitions.
2. Incorporate sample program 2-B: common variable definitions.
3. Incorporate sample program 2-C: prototype declarations.
4. Sample program 2-D
   A. Add ADI reset vector.
   B. Add common subroutines.
   C. Add interrupt handling routines.

3.3 Modifications to Sample Programs

Without modifications to the sample program, the system may not run. Modifications must be made according to your program and system environment.

1. The sample programs can be used without further changes if you use the I/O register structure definition file, which is available free of charge from the following Renesas web site:
   http://www.renesas.com/eng/products/mpumcu/tool/crosstool/iodef/index.html
   When you create structure definitions by yourself, modify the I/O register structures used in the sample program as appropriate.

3.4 Using the Sample Programs

Subroutines provided in the sample programs are described below. These subroutines should be used in combination according to the A/D conversion function usages. Examples of usage are shown in section 3.5, Description of Operation.

1. The contents specified by a structure (adc_parm) are set into the corresponding registers in the H8 microcomputer.

- Subroutine name: int com_adc_set_parm ()

Return Value	Description
NORMAL_END (0)	Normal termination
ADC_BUSY (-1)	Cannot set because A/D conversion is being performed.
ADC_PARM_ERR (-2)	Parameter error • In single mode, a value from 4 to 13 was attempted to be set in adc_parm.ch_no. • In scan mode, a value of 4 or greater was attempted to be set in adc_parm.ch_no.

- Before the above subroutine is called, A/D conversion mode should be specified in structure adc_parm.

Variable Name	Setting
adc_parm.ch_no	Specifies the channel(s) for A/D conversion. When adc_parm.mode = ADC_SINGLE_MODE (single mode): **ADC_CH_AN0** (0): Analog input channel AN0 **ADC_CH_AN1** (1): Analog input channel AN1 **ADC_CH_AN2** (2): Analog input channel AN2 **ADC_CH_AN3** (3): Analog input channel AN3 **ADC_CH_AN14** (14): Analog input channel AN14 **ADC_CH_AN15** (15): Analog input channel AN15 When adc_parm.mode = ADC_SCAN_MODE (scan mode): **ADC_CH_AN0** (0): Analog input channel AN0 **ADC_CH_AN0_1** (1): Analog input channels AN0, 1 **ADC_CH_AN0_2** (2): Analog input channels AN0, 1, 2 **ADC_CH_AN0_3** (3): Analog input channels AN0, 1, 2, 3
adc_parm.mode	Specifies A/D conversion mode. **ADC_SINGLE_MODE** (0): Single mode A/D conversion is performed only once for an analog input channel specified by adc_parm.ch_no. **ADC_SCAN_MODE** (1): Scan mode A/D conversion is performed repeatedly for the analog input channel(s) specified by adc_parm.ch_no. A/D conversion continues until stopped by subroutine com_adc_control (ADC_STOP). When multiple analog input channels are specified, A/D conversion is performed starting from the channel with the smallest number. Example: when adc_parm.ch_no = ADC_CH_AN0_1: A/D conversion is performed in this order: AN0, AN1, AN0, …….
adc_parm.action	Specifies the method of stating A/D conversion. **ADC_MANUAL_TRG** (0): Start by software. A/D conversion is started by subroutine com_adc_control (ADC_START). **ADC_TPU_TRG** (1): Start by TPU timer interrupt A/D conversion is started if the TTGE bit in TIER is set to 1 when the TGFA flag in TSR is set to 1 due to occurrence of TGRA input capture/compare-match in TPU0, TPU1, or TPU2. The methods of setting the TPU registers are omitted in this Application Note. See the H8S/2215 Hardware Manual. **ADC_TMR_TRG** (2): Start by TMR timer interrupt A/D conversion is only started by TMR_0 compare-match A. A/D conversion is started if the ADTE bit is set to 1 when CMFA flag in TCSR_0 is set to 1 due to occurrence of TMR_0 compare-match A. The methods of setting the TMR registers are omitted in this Application Note. See the H8S/2215 Hardware Manual. **ADC_EXT_TRG** (3): Start by external trigger (ADTRG) A/D conversion is started when the signal level on the external input pin (ADTRG) changes from high to low.
Adc_parm.end_int	Enables/disables generation of an interrupt at the end of A/D conversion. ADC_DISABLE (0): Generates an interrupt. ADC_ENABLE (1): Does not generate an interrupt.

Variable Name	Setting
adc_parm.ad_time	Sets A/D conversion time. **ADC_530_STATE** (0): 530 clock cycles **ADC_266_STATE** (1): 266 clock cycles **ADC_134_STATE** (2): 134 clock cycles **ADC_68_STATE** (3): 68 clock cycles This variable should be set so that the A/D conversion time will be 8.4 μs or longer according to the operating frequency of the microcomputer. Example: When φ = 16 MHz: A/D conversion time = (8.4 μs / 62.5 ns) cycles = 134.4 clock cycles → Setting value = ADC_266_STATE

2. Starts or stops A/D conversion.

- Subroutine name: void com_adc_control (unsigned char control kind)

Argument	Setting
control_kind	**ADC_START** (0): Start A/D conversion. **ADC_STOP** (1): Stop A/D conversion. The A/D conversion end flag (ADCSR (ADF)) is reset when AD conversion is stopped.

3. Checks if the A/D conversion has ended.

- Subroutine name: int com_adc_check (void)

Return Value	Description
ADC_NO_EXE (0)	A/D conversion is not performed or A/D conversion is in progress.
ADC_END (1)	A/D conversion has ended.

4. Reads the A/D converted data.

- Subroutine name: unsigned int com_adc_read_data (unsigned char ch_no)

Argument	Setting
ch_no	Specifies an analog input channel to be read out. **ADC_CH_AN0** (0): analog input channel AN0 **ADC_CH_AN1** (1): analog input channel AN1 **ADC_CH_AN2** (2): analog input channel AN2 **ADC_CH_AN3** (3): analog input channel AN3 **ADC_CH_AN14** (14): analog input channel AN14 **ADC_CH_AN15** (15): analog input channel AN15

Return Value	Description
16-bit data	A/D converted data of the specified channel (upper 6 bits are '0').

3.5 Description of Operation

3.5.1 Coding Examples

There may be various cases of A/D conversion processing depending on the combination of conversion mode, starting method, and use of the A/D conversion-end interrupt. Coding examples are shown below along with description of operation.

1. When A/D conversion for the analog input channel (AN0) is started by software, and an end interrupt is not used:

```
int ret ;
unsigned int ad0_data ;

// Set specifications of A/D conversion processing
adc_parm.ch_no   = ADC_CH_AN0 ;
adc_parm.mode    = ADC_SINGLE_MODE ;
adc_parm.action  = ADC_MANUAL_TRG ;
adc_parm.end_int = ADC_DISABLE ;
adc_parm.ad_time = ADC_266_STATE ;

// Place the above parameter values into the corresponding ADC registers
ret = com_adc_set_parm() ;

if (ret!=0){                                          // Setting error
// Add error processing here
}
else {
    com_adc_control(ADC_START) ;                      // Start A/D conversion
    while(com_adc_check() == ADC_NO_EXE){             // Wait until A/D conversion ends
    }
    com_adc_control(ADC_STOP) ;                       // Stop A/D conversion
    // In single mode, A/D converter automatically stops when A/D conversion ends.
    // Since the ADF bit in the ADCSR register, which indicates that A/D conversion has ended,
    // is not reset, this subroutine is called to reset ADF.

  ad0_data = com_adc_read_data(ADC_CH_AN0) ;          // Read A/D converted data
}
```

2. When A/D conversion for the analog input channel (AN0) is started by the external trigger (ADTRG), and an end interrupt is used:

```
int ret ;
// Set specifications of A/D conversion processing
adc_parm.ch_no   = ADC_CH_AN0 ;
adc_parm.mode    = ADC_SINGLE_MODE ;
adc_parm.action  = ADC_EXT_TRG ;
adc_parm.end_int = ADC_ENABLE ;
adc_parm.ad_time = ADC_266_STATE ;

// Place the above parameter values into the corresponding ADC registers
ret = com_adc_set_parm() ;

if (ret!=0){ // Setting error
// Add error processing here
}
// If the setting is correct, wait for external trigger (ADTRG) input.
// A/D conversion is started when the ADTRG pin level changes from high to low.

ADI interrupt handling routine
// When A/D conversion ends, an ADI interrupt is generated and execution
// jumps to the ADI interrupt handling routine directed by the interrupt vector.
#pragma interrupt(h8s_adi)
void h8s_adi(void)
{
unsigned int ad0_data ;

com_adc_control(ADC_STOP) ; // Stop A/D conversion
    // In single mode, A/D converter automatically stops when A/D conversion ends.
    // Since the ADF bit in the ADCSR register, which indicates that A/D conversion has ended,
    // is not reset, this subroutine is called to reset ADF.

  ad0_data = com_adc_read_data(ADC_CH_AN0) ; // Read A/D converted data
}
```

3. When A/D conversion for multiple analog input channels (AN0, 1) is started by software and repeated with use of an end interrupt:

```
int ret ;
// Set specifications of A/D conversion processing
adc_parm.ch_no = ADC_CH_AN0_1 ;
adc_parm.mode = ADC_SCAN_MODE ;
adc_parm.action = ADC_MANUAL_TRG ;
adc_parm.end_int = ADC_ENABLE ;
adc_parm.ad_time = ADC_266_STATE ;

// Place the above parameter values into the corresponding ADC registers
ret = com_adc_set_parm() ;

if (ret!=0){ // Setting error
// Add error processing here
}
else {
  com_adc_control(ADC_START) ; // Start A/D conversion
}

ADI interrupt handling routine
// When A/D conversion ends, an ADI interrupt is generated and execution jumps to
// the ADI interrupt handling routine directed by the interrupt vector.
// In scan mode, A/D conversion is repeated, and ADI interrupt handling routine is
// always called when A/D conversion ends.
// To stop A/D conversion, call subroutine com_adc_control(ADC_STOP).
#pragma interrupt(h8s_adi)
void h8s_adi(void)
{
unsigned int ad0_data , ad1_data;

  ad0_data = com_adc_read_data(ADC_CH_AN0) ; // Read A/D converted data
  ad1_data = com_adc_read_data(ADC_CH_AN1) ; // Read A/D converted data
}
```

3.5.2 Output Value of A/D-Converted Results

The output value of the A/D-converted results for an analog input voltage can be given by the following formula.

A/D-converted value = (analog input voltage / Vref) * 1024

For conversion accuracy, see sections 16.7 and 24.6 of the H8S/2215 Hardware Manual.

3.5.3 A/D Conversion Time

The A/D conversion time should be set in the structure (adc_parm.ad_time) so as to be 8.4 μs or longer according to the operating frequency of the microcomputer.

For details on the conversion time, see sections 16.5.3 and 24.6 of the H8S/2215 Hardware Manual.

3.5.4 A/D Converter Usage Notes

Since the A/D converter deals with analog signals, there are many things to be noted when designing a board.

For details, see section 16.8 of the H8S/2215 Hardware Manual.

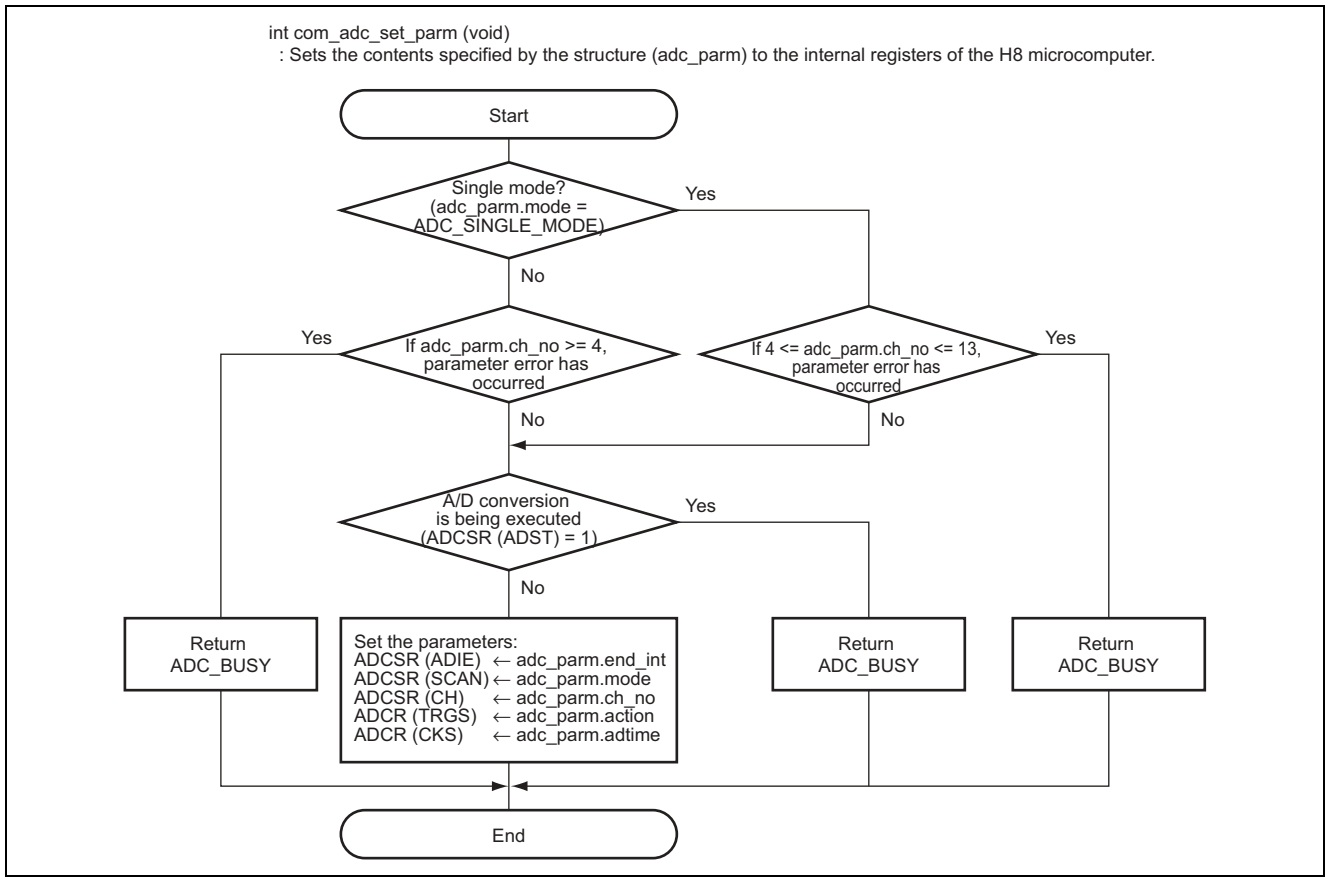
3.6 List of Registers Used

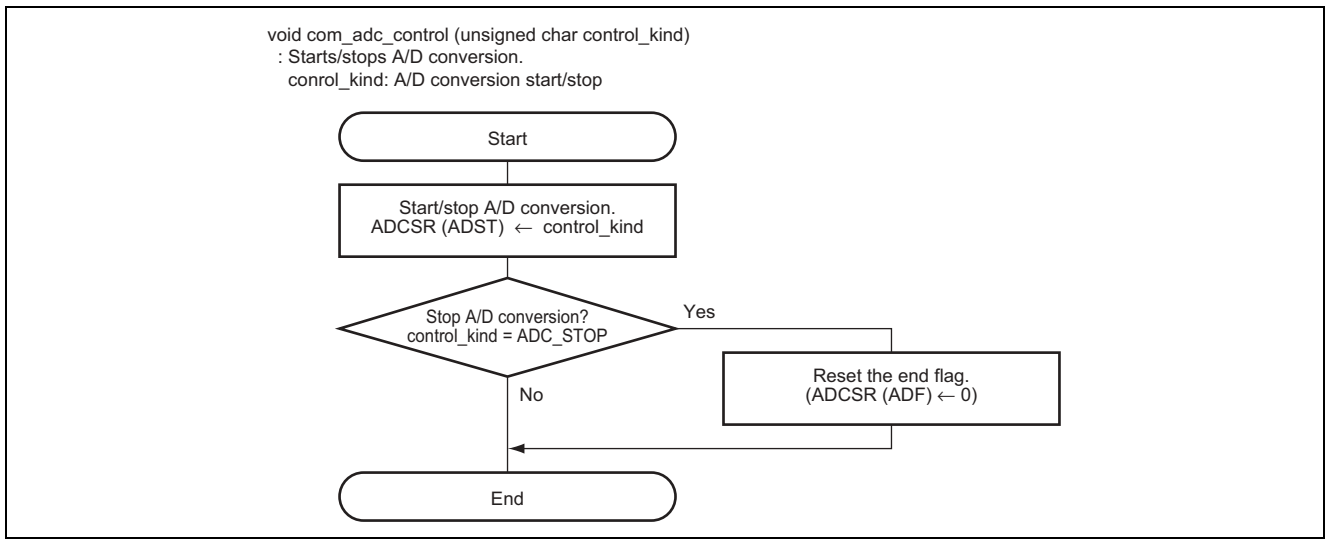
The internal registers of the H8 microcomputer used in the sample program are listed below. For detailed information, refer to the H8S/2215 Hardware Manual.

Name	Summary
A/D data registers (ADDRA to ADDRD)	• Area for storing A/D conversion results
A/D control/status register (ADCSR)	• Indicates that A/D conversion has ended. • Enables A/D conversion interrupt. • Starts A/D conversion. • Specifies A/D conversion mode. • Selects the channel(s) for which A/D conversion is performed.
A/D control register (ADCR)	• Selects A/D conversion starting method. • Sets A/D conversion time.

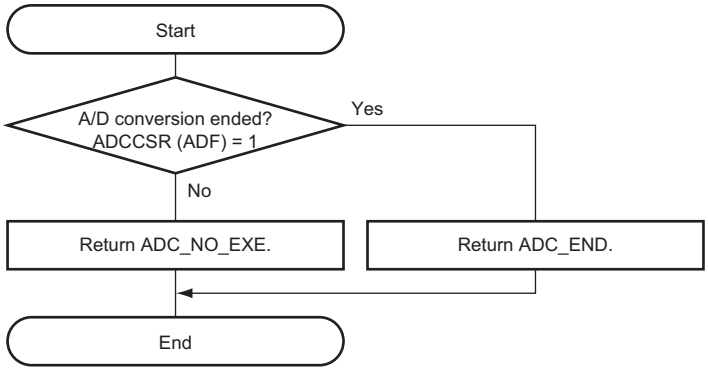
3.7 Flowcharts

Processing flows of the sample program are shown below.

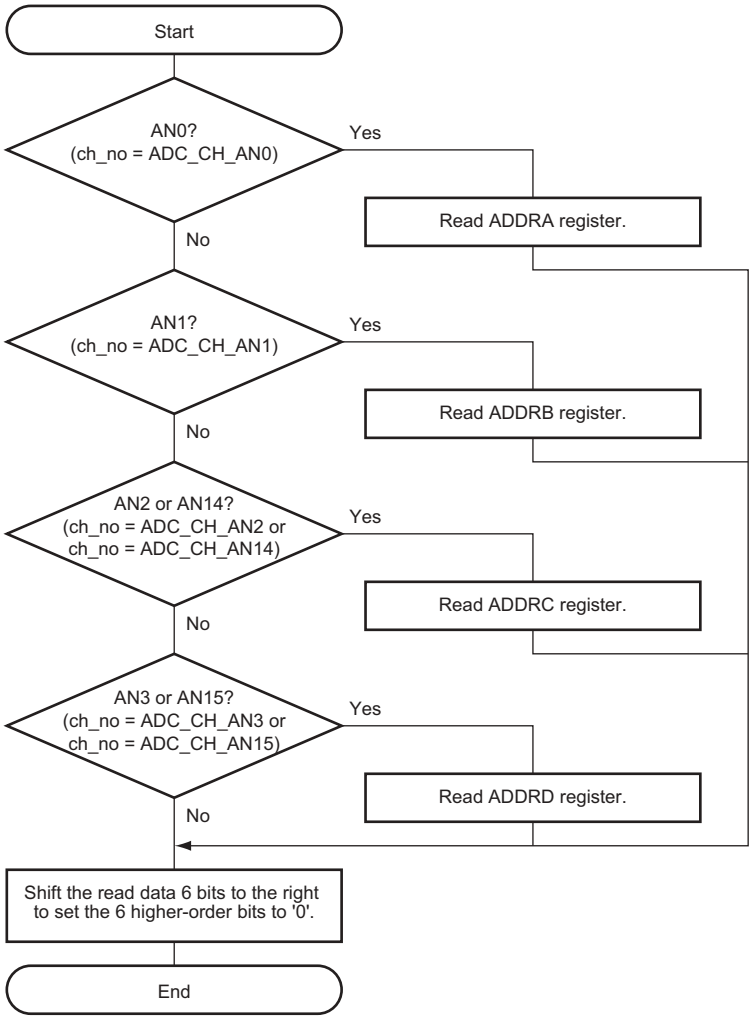




int com_adc_check (void)
: Checks the end of A/D conversion.



unsigned int com_adc_read_data (unsigned char ch_no)
: Reads out A/D converted data.
Ch_no: Specifies an analog input channel to be read.



4. Reference Document

- H8S/2215 Series Hardware Manual (published by Renesas Technology Corp.)

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