Module Introduction

Purpose
- This training module provides an overview of the analog interfaces that H8S MCUs provide.

Objective
- Review the features and understand the operation of the A/D converter, D/A converter, and 14-bit PWM.

Content
- 25 pages
- 4 questions

Learning Time
- 35 minutes
A/D Converter

- Successive-approximation type
- Up to 16-channels, each with 10-bit resolution
- High-speed conversion
  - 8.4μs/channel at 16 MHz (H8S/2239)
- Built-in sample-and-hold function
- Two modes of operation
  - Single mode: Single-channel conversion
  - Scan mode: Sequential conversion on multiple channels
- Three kinds of trigger
  - Software, timer, ADTRG_ pin
- Interrupt generated at end of conversion
A/D Converter Circuit

Diagram showing the A/D Converter Circuit with components such as Analog power supply, Reference voltage, 10-bit D/A, Conversion results registers, Module data bus, and Control and status registers.
Successive-Approximation Process

AVcc = Vcc = Vref = 5V

AN0 Input = 3V

AVss = Vss = 0V

First Comparison

Second Comparison

Third Comparison

Successive-comparison Register

ADDRA

Sent to ADDRA at end of conversion

Lower 6 bits are always 0
Single-Mode Operation

Note: * Vertical arrows (↑↓) indicate instructions executed by software.
Scan-Mode Operation

Continuous A/D conversion execution

Set\(^*1\)

Clear\(^*1\)

ADST

ADF

State of channel 0 (AN0)

Idle

A/D conversion 1

Idle

A/D conversion 4

Idle

State of channel 1 (AN1)

Idle

A/D conversion 2

Idle

A/D conversion 5\(^*2\)

Idle

State of channel 2 (AN2)

Idle

A/D conversion 3

Idle

State of channel 3 (AN3)

Idle

Transfer

A/D conversion result 1

A/D conversion result 4

ADDRA

ADDRA

A/D conversion result 2

ADDRC

A/D conversion result 3

ADDRD

Notes:

\(^*1\) Vertical arrows (↑) indicate instructions executed by software.

\(^*2\) Data currently being converted is ignored.
Which statement about the A/D converter in H8S MCUs is false? Select the correct answer and then click Done.

- The A/D converter has one operating mode
- It uses a successive-approximation algorithm
- MCUs in the H8S series have A/D converters with 4, 8, 12, or 16 channels
- The A/D converter in H8S devices has 10-bit resolution
Conversion Precision

The total error (absolute precision) is ±4 LSB.
A/D Design Tips

- Be sure to use good analog design practices when applying the A/D converter.
- Keep the input source impedance below 5000 ohms.
  - This ensures that the sampling capacitor will charge to the correct voltage before the A/D starts a conversion.
- Always use a low-pass filter on the input.
D/A Converter

- Converts digital signals into analog outputs
- Contains up to six D/A channels, each with 8-bit resolution
- Has an output voltage range of 0V to Vref
- Has a hold function in Software Standby mode

**H8S MCUs have R-2R type D/A converters.**

![R-2R D/A Circuit](image)
D/A Converter Function

The Module STOP bit is set by reset or Hardware Standby.

Legend:
- DACR: D/A control register
- DADR0: D/A data register 0
- DADR1: D/A data register 1
D/A Control Registers

**Bit**

<table>
<thead>
<tr>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
</table>

**Initial value**

| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Read/Write**

| R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W |

**Bit**

<table>
<thead>
<tr>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
</table>

**Initial value**

| DAOE1 | DAOE0 | DAE | — | — | — | — | — |

**Read/Write**

| R/W | R/W | R/W | — | — | — | — | — |

**Bit**

<table>
<thead>
<tr>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
</table>

**Initial value**

<table>
<thead>
<tr>
<th>MSTP15</th>
<th>MSTP14</th>
<th>MSTP13</th>
<th>MSTP12</th>
<th>MSTP11</th>
<th>MSTP10</th>
<th>MSTP9</th>
<th>MSTP8</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Read/Write**

| R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W |
D/A Operation

- **DADR0 write cycle**
- **DACR write cycle**
- **DADR0 write cycle**
- **DACR write cycle**

- **Address**
- **Conversion data (1)**
- **Conversion data (2)**

- **DAOE0**

- **DA0**
  - **High-Impedance state**
  - **Conversion result (1)**
  - **Conversion result (2)**

- **t_{DCONV}**: D/A conversion time
D/A Converter Applications

- Digital servo tracking at 100Hz
- Software-programmable power supply
- Simple sound generator
- Modem
- Text-to-speech
- Generating warning tones
- LCD contrast control
Which of the following statements describe the correct features of the D/A converter in H8S MCUs? Select all that apply and then click Done.

- It provides up to 6 channels
- All of the above
- Two 8-bit registers are used for storing incoming data for the D/A converter
- The D/A converter in H8S MCUs has 8-bit resolution
Pulse Width Modulation

PWM can be used to implement high-resolution D/A converters.

- Effects of capacitance and resistive loading are virtually eliminated.
- Resolution is determined only by the number of bits in counter and compare circuit; semiconductor process technology is not a limiting factor.
- PWM function on H8S MCUs (PWM14) is a 14-bit design.
PWM Conversion Basics

t1 = t2

\[ V_{out} = V_{cc} \times \text{duty cycle} \]

- 2.50 volts
- 0.00 volts

Vout = Vcc x duty cycle
What are the benefits of using a 14-bit PWM circuit as a D/A converter? Select all that apply and then click Done.

- Input data goes to the 8-bit D/A circuit block and is converted into an analog value
- The output from the D/A converter is adjusted according to the outcome of repeated comparisons
- The circuit uses a low-impedance digital driver into a high-impedance analog circuit, virtually eliminating capacitive and resistive loading affects
- Resolution is a function of the number of steps you have in controlling the timer's duty cycle
Reducing Filter Constraints

High frequencies are easier to filter out than low frequencies.
The Module STOP bit is set by reset or Hardware Standby.
# 14-bit PWM Register Set

<table>
<thead>
<tr>
<th>Name</th>
<th>Abbreviation</th>
<th>R/W</th>
<th>Initial value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWM D/A control register</td>
<td>DACR</td>
<td>R/W</td>
<td>H’30</td>
</tr>
<tr>
<td>PWM D/A data register A high</td>
<td>DADRAH</td>
<td>R/W</td>
<td>H’FF</td>
</tr>
<tr>
<td>PWM D/A data register A low</td>
<td>DADRAL</td>
<td>R/W</td>
<td>H’FF</td>
</tr>
<tr>
<td>PWM D/A data register B high</td>
<td>DADRBH</td>
<td>R/W</td>
<td>H’FF</td>
</tr>
<tr>
<td>PWM D/A data register B low</td>
<td>DADRBL</td>
<td>R/W</td>
<td>H’FF</td>
</tr>
<tr>
<td>PWM D/A counter high</td>
<td>DACNTH</td>
<td>R/W</td>
<td>H’00</td>
</tr>
<tr>
<td>PWM D/A counter low</td>
<td>DACNTL</td>
<td>R/W</td>
<td>H’03</td>
</tr>
<tr>
<td>Module stop control register</td>
<td>MSTPCRH</td>
<td>R/W</td>
<td>H’3F</td>
</tr>
<tr>
<td></td>
<td>MSTPCRL</td>
<td>R/W</td>
<td>H’FF</td>
</tr>
</tbody>
</table>
14-bit PWM Operation

1 conversion cycle
(T \times 2^{14} (= 16384))

Basic cycle
(T \times 64 \text{ or } T \times 256)

T: Resolution
\[ T_L = \sum_{n=1}^{m} t_{Ln} \text{ (when OS = 0)} \]
(When CFS = 0, m = 256; when CFS = 1, m = 64)
14-bit PWM D/A Overview

- When the 14-bit PWM is used as a D/A converter, its output pulse is subdivided into multiple base cycles to reduce ripple.

- There are four operating modes. They encompass two resolution settings and two base-cycle settings. The base cycle can be set to $T_{x64}$ or $T_{x256}$, where $T$ is the resolution.
PWM D/A Converter Applications

- H8S Microcontroller
- PWMX Out
- Filter
- Driver
- Voice-coil Motor

Position Feedback

High-Accuracy Digital Servo

Other Applications:
- High-resolution analog outputs
- Radio tuners
- High-resolution, high-precision voltage-to-frequency converters
Is the following statement true or false?

"The PWM circuit's DACNT counter is a 14-bit readable/writable up-counter that increments on an input clock pulse."

- True
- False
Module Summary

- A/D converter
- D/A converter
- 14-bit PWM D/A circuit

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