M16C/65 Group
A/D Converter
Using Single Sweep Mode

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1. Abstract

This document describes the setting procedure to use the A/D converter in single sweep mode.

2. Introduction

The application example described in this document applies to the following microcomputer (MCU):

- MCU: M16C/65 Group

This application note can be used with other M16C Family MCUs which have the same special function registers (SFRs) as the above group. Check the manual for any modifications to functions. Careful evaluation is recommended before using the sample code described in this application note.

3. Operation in Single Sweep Mode

This section describes operation when using the A/D converter in single sweep mode with a software trigger.

(1) When the ADST bit in the ADCON0 register is set to 1 (A/D conversion start), A/D conversion starts. The input voltage of the AN0 pin is converted.

(2) After completing A/D conversion of the AN0 pin, the value in the successive conversion register (conversion result) is transferred to the AD0 register. A/D conversions for selected analog pins are continuously performed in order. Every time A/D conversion for a pin is completed, the conversion result is transferred to the ADi (i = 0 to 7) register corresponding to that pin.

(3) When A/D conversion for all selected analog input pins is completed, the IR bit in the ADIC register becomes 1 (interrupt requested). At the same time, the ADST bit in the ADCON0 register becomes 0 (A/D conversion stop) and A/D conversion stops.

Figure 3.1 shows Operation Timing in Single Sweep Mode.

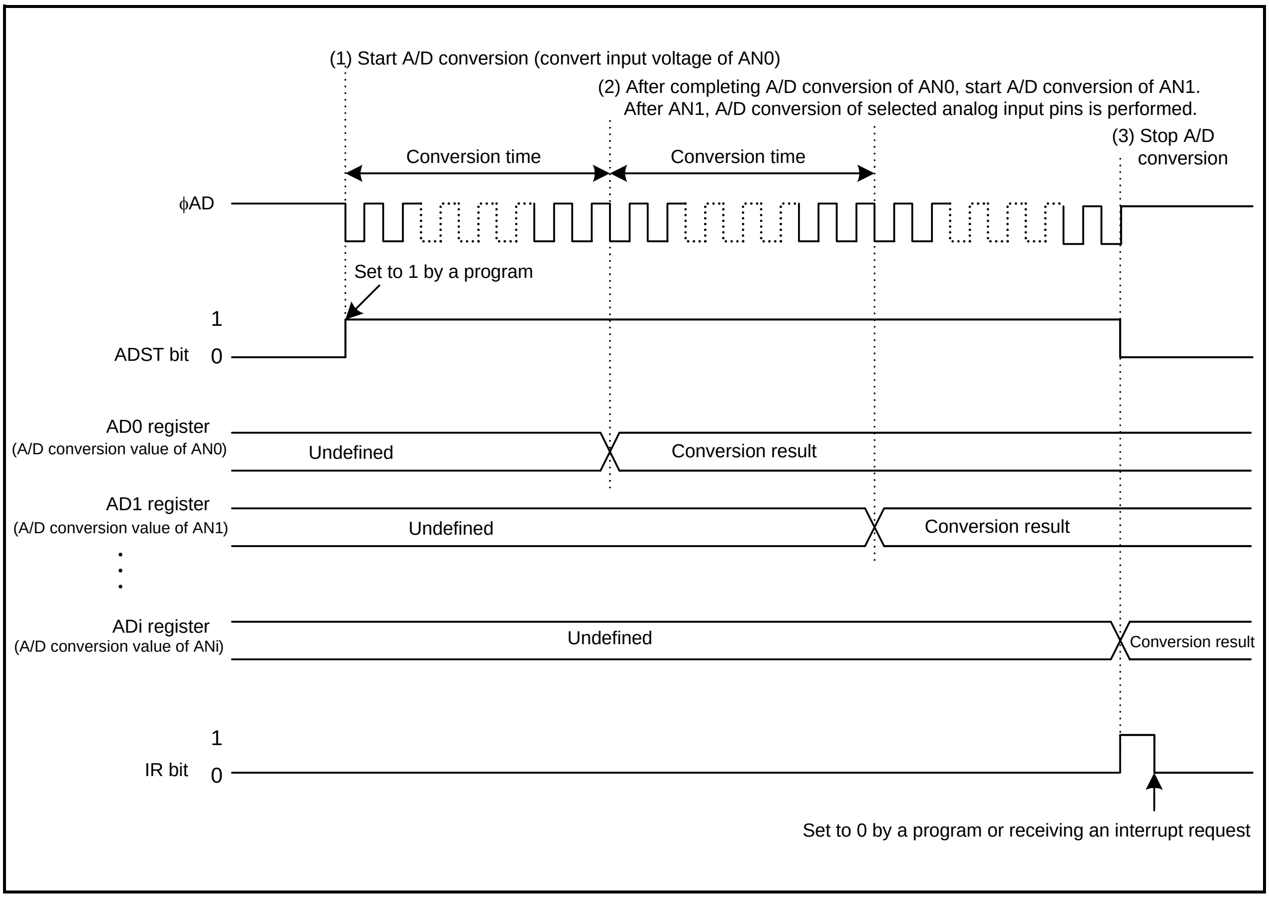

Figure 3.1 Operation Timing in Single Sweep Mode

4. A/D Conversion Time

This section describes how to calculate A/D conversion time.

4.1 A/D Conversion Cycle

Table 4.1 shows Cycles of A/D Conversion Item. A/D conversion time is described below.
Start processing time depends on which ϕAD is selected.
A/D conversion starts after the start processing time elapses by setting the ADST bit in the ADCON0 register to 1 (A/D conversion start). When reading the ADST bit before starting A/D conversion, 0 (A/D conversion stop) is read.
In single sweep mode, inter-execution processing time is inserted between A/D conversions.
The ADST bit becomes 0 at the end processing time and the last A/D conversion result is stored in the ADi register (i = 0 to 7).

- Two pins are selected in single sweep mode:
  Start processing time + (A/D conversion execution time + inter-execution processing time + A/D conversion execution time) + end processing time

Table 4.1 Cycles of A/D Conversion Item

A/D Conversion Item		Number of Cycles
Start processing time	ϕAD = fAD	1 to 2 cycles of fAD
	ϕAD = fAD divided by 2	2 to 3 cycles of fAD
	ϕAD = fAD divided by 3	3 to 4 cycles of fAD
	ϕAD = fAD divided by 4	3 to 4 cycles of fAD
	ϕAD = fAD divided by 6	4 to 5 cycles of fAD
	ϕAD = fAD divided by 12	7 to 8 cycles of fAD
A/D conversion execution time	Open-circuit detection disabled	40 cycles of ϕAD
	Open-circuit detection enabled	42 cycles of ϕAD
Inter-execution processing time		1 cycle of ϕAD
End processing time		2 to 3 cycles of fAD

4.2 Detecting Completion of A/D Conversion

In single sweep mode, use the IR bit in the ADIC register to detect completion of A/D conversion. When not using an interrupt, set the IR bit to 0 by a program after detection.
When 1 is written to the ADST bit in the ADCON0 register, the ADST bit becomes 1 (A/D conversion start) after start processing time elapses (see Table 4.1 "Cycles of A/D Conversion Item"). Therefore when reading the ADST bit immediately after writing 1, 0 (A/D conversion stop) may be read.

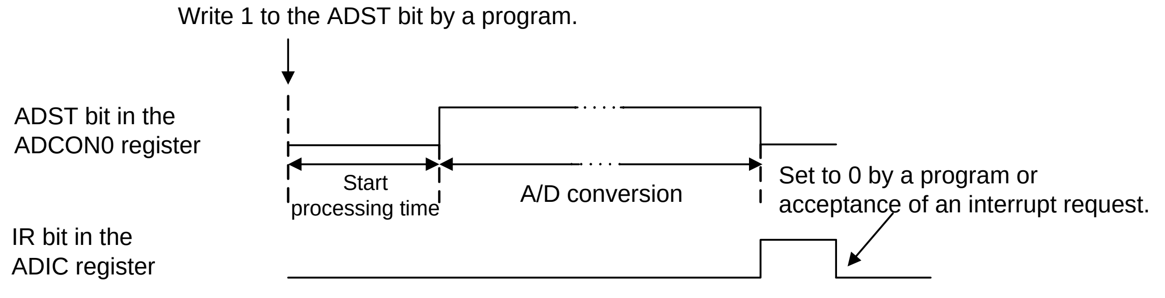

Figure 4.1 ADST Bit Operation

4.3 A/D Operation Clock Frequencies

Table 4.2 lists the A/D Operation Clock Frequencies.

Table 4.2 A/D Operation Clock Frequencies (1)

V_{CC1} = AV_{CC} = 3.0 to 5.5 V ≥ V_{CC2} ≥ V_{REF}, V_{SS} = AV_{SS} = 0 V at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified.

Symbol	Parameter		Measuring Condition	Standard			Unit
				Min.	Typ.	Max.	
ϕAD	A/D operating clock frequency	AN0 to AN7 input, ANEX0 to ANEX1 input	4.0 V ≤ V_{CC1} ≤ 5.5 V	2		25	MHz
			3.2 V ≤ V_{CC1} ≤ 4.0 V	2		16	MHz
			3.0 V ≤ V_{CC1} ≤ 3.2 V	2		10	MHz
		AN0_0 to AN0_7 input, AN2_0 to AN2_7 input	4.0 V ≤ V_{CC2} ≤ 5.5 V	2		25	MHz
			3.2 V ≤ V_{CC2} ≤ 4.0 V	2		16	MHz
			3.0 V ≤ V_{CC2} ≤ 3.2 V	2		10	MHz

Note:

1. Use when AV_{CC} = V_{CC1}.

5. Settings

Figure 5.1 shows the Setting Procedure When Using Single Sweep Mode. Refer to the User's Manual: Hardware for details on registers.

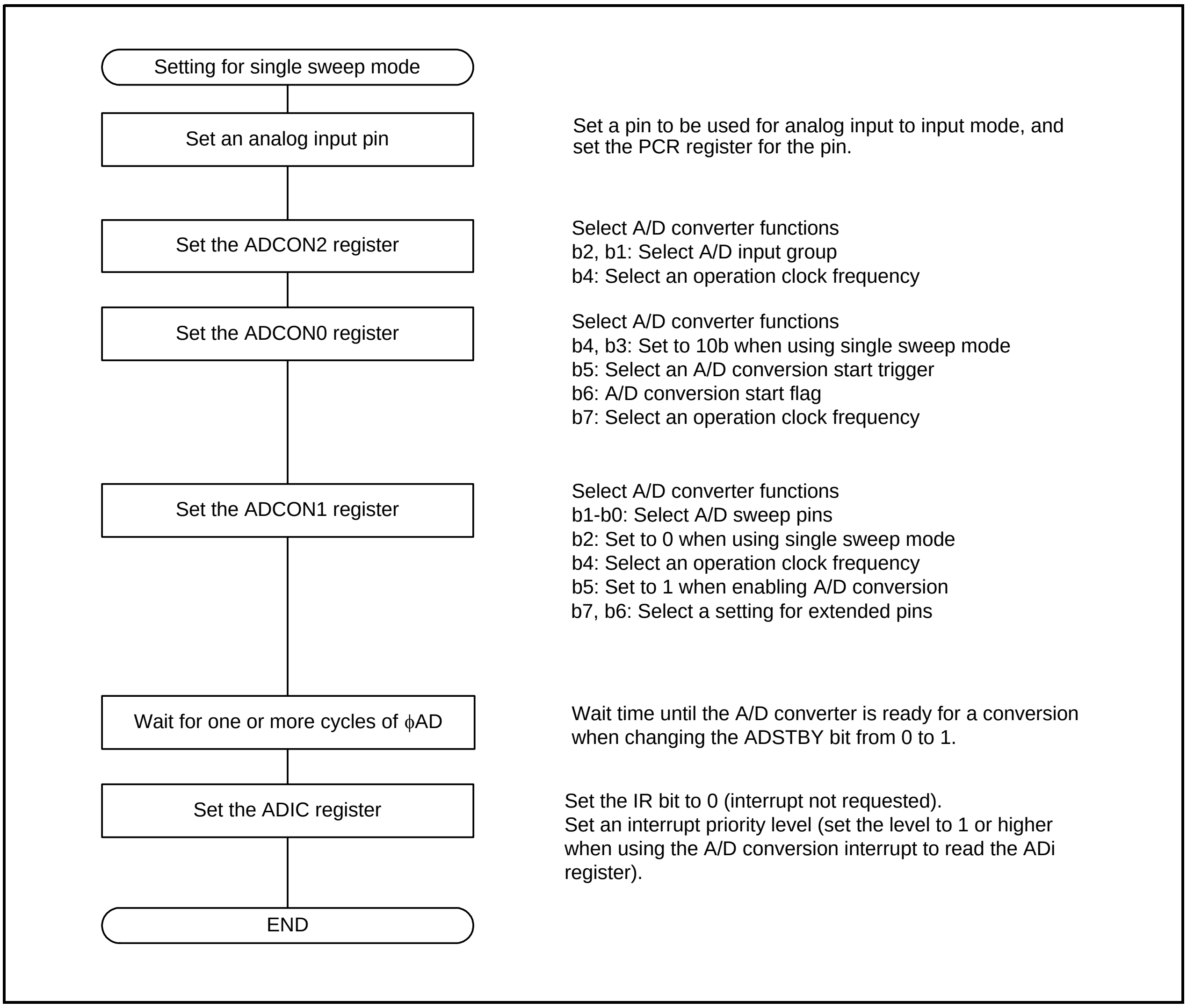

Figure 5.1 Setting Procedure When Using Single Sweep Mode

6. Sample Code

A sample code can be downloaded from the Renesas Electronics website.
To download, click "Application Notes" in the left-hand side menu of the M16C Family page.

6.1 Sample Code Operation

In single sweep mode, functions listed in Table 6.1 can be selected. The settings used in the sample code are marked with "✓" in the table. The sample code operation is as follows; set the CPU clock as the main clock with no division by executing functions for CPU initialization, transition from 125 kHz on-chip oscillator mode to high-speed mode, then execute the function for A/D conversion in single sweep mode. Refer to 6.2 Function Tables for details on functions.

Table 6.1 Sample Code Settings

Functions	Settings	
Operating clock ϕAD	✓	f1
		f1 divided by 2
		f1 divided by 3
		f1 divided by 4
		f1 divided by 6
		f1 divided by 12
		fOCO40M divided by 2
		fOCO40M divided by 3
		fOCO40M divided by 4
		fOCO40M divided by 6
		fOCO40M divided by 12
A/D conversion start conditions	✓	Software trigger
		Trigger by $\overline{\text{ADTRG}}$
Analog input group	✓	AN0 to AN7
		AN0_0 to AN0_7
		AN2_0 to AN2_7
A/D sweep pin		AN0 to AN1 (2 pins)
		AN0 to AN3 (4 pins)
		AN0 to AN5 (6 pins)
	✓	AN0 to AN7 (8 pins)
A/D open-circuit detection assist function	✓	Not used

6.2 Function Tables

Function Tables for This Document

Declaration	void ad_singlesweep(void)
Outline	A/D conversion in single sweep mode
Argument	None
Variable	None
Returned value	None
Function	Set the A/D converter to single sweep mode and set the functions as marked in Table 6.1. Set analog input pins AN0 to AN7 to input mode, and the interrupt priority level of the A/D conversion interrupt to 1.

Declaration	void _ad_converter(void)
Outline	A/D converter interrupt
Argument	None
Variable	None
Returned value	None
Function	Executed when an A/D conversion interrupt occurs. Execute read_ad_register().

Declaration	unsigned short *read_ad_register(unsigned char ch)	
Outline	Read A/D register	
Argument	unsigned char ch	Select the A/D register to be read
Variable	static unsigned short read_ad_data[8]	Array for storing A/D conversion result
Returned value	unsigned short *read_ad_data	The beginning address of the array for storing the A/D conversion result
Function	Read the A/D register selected with the argument, unsigned char ch. Then return the read value as a returned value.	

Other Function Tables

Declaration	void mcu_init(void)
Outline	CPU initialization
Argument	None
Variable	None
Returned value	None
Function	Set to single-chip mode. Switch the CPU clock from 125 kHz on-chip oscillator mode divided-by-8 to 125 kHz on-chip oscillator mode divided-by-1.

Declaration	void highspeed_from_foco125k(void)
Outline	Transition from 125 kHz on-chip oscillator mode to high-speed mode
Argument	None
Variable	None
Returned value	None
Function	Switch the CPU clock from 125 kHz on-chip oscillator mode (fOCO-S divided by 1) to high-speed mode.

7. Reference Documents

M16C/65 Group User's Manual: Hardware Rev.1.10
The latest version can be downloaded from the Renesas Electronics website.

Technical Update/Technical News
The latest information can be downloaded from the Renesas Electronics website.

M16C Series/R8C Family C Compiler Package V.5.45 C Compiler User's Manual Rev.3.00
The latest version can be downloaded from the Renesas Electronics website.

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Revision History	M16C/65 Group Using Single Sweep Mode

Rev.	Date	Description	
		Page	Summary
1.00	2011.03.15	—	First edition issued

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 an 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.

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