1. **Abstract**

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

2. **Introduction**

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

   - MCU: M16C/63 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 Repeat Mode

This section describes operation when using the A/D converter in repeat 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.
(2) After completing A/D conversion, the value in the successive conversion register (conversion result) is transferred to the ADi register (i = 0 to 7). The IR bit in the ADIC register does not become 1 (interrupt requested).
(3) A/D conversion continues until the ADST bit in the ADCON0 register is set to 0 by a program. The conversion result is transferred to the ADi register every time A/D conversion is completed.

Figure 3.1 shows Operation Timing in Repeat Mode.

![Figure 3.1 Operation Timing in Repeat Mode](image-url)
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 repeat mode, inter-execution processing time is inserted between A/D conversions.

- Repeat mode:
  
  Start processing time + (A/D conversion execution time + inter-execution processing time + A/D conversion execution time + inter-execution 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 **A/D Operation Clock Frequencies**

Table 4.2 lists the A/D Operation Clock Frequencies.

Table 4.2 **A/D Operation Clock Frequencies (1)**

| Symbol | Parameter                  | Measuring Condition     | Standard Unit |
|--------|----------------------------|-------------------------|---------------|
| φAD    | A/D operating clock frequency | 4.0 V ≤ VREF ≤ AVCC ≤ 5.5 V | 2   | 20 MHz |
|        |                            | 3.2 V ≤ VREF ≤ AVCC ≤ 5.5 V | 2   | 16 MHz |
|        |                            | 3.0 V ≤ VREF ≤ AVCC ≤ 5.5 V | 2   | 10 MHz |
|        |                            | 1.8 V ≤ VREF ≤ AVCC ≤ 5.5 V | 2   | 5 MHz  |

Note:

1. Use when AVCC = VCC1 = VCC2.
5. Settings

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

![Diagram showing the setting procedure for repeat mode](image)

- **Setting for repeat mode**
  - Set a pin to be used for analog input to input mode, and set the PCR register for the pin.

- **Set an analog input pin**
  - Select A/D converter functions
    - b2, b1: Select A/D input group
    - b4: Select an operation clock frequency

- **Set the ADCON2 register**
  - Select A/D converter functions
    - b2-b0: Select an analog input pin
    - b4, b3: Set to 01b when using repeat mode
    - b5: Select an A/D conversion start trigger
    - b6: A/D conversion start flag
    - b7: Select an operation clock frequency

- **Set the ADCON0 register**
  - Select A/D converter functions
    - b2: Set to 0 when using repeat mode
    - b4: Select an operation clock frequency
    - b5: Set to 1 when enabling A/D conversion
    - b7, b6: Select a setting for extended pins

- **Wait for one or more cycles of φAD**
  - Wait time until the A/D converter is ready for a conversion when changing the ADSTBY bit from 0 to 1.

- **Start A/D conversion**
  - Generate the A/D conversion start trigger.

**Figure 5.1 Setting Procedure When Using Repeat 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 repeat 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 repeat mode. Refer to 6.2 Function Tables for details on functions.

| 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 ADTRG                      |
| Analog input pins  | ✓ 1 pin from AN0 to AN7               |
|                    | ✓ 1 pin from AN0_0 to AN0_7           |
|                    | ✓ 1 pin from AN2_0 to AN2_7           |
| Extended analog pins | ✓ Not used                         |
|                    | ANEX0 pin                             |
|                    | ANEX1 pin                             |
| A/D open-circuit detection assist function | ✓ Not used                           |
### 6.2 Function Tables

**Function Tables for This Document**

| Declaration          | void ad_repeat(void) |
|----------------------|----------------------|
| Outline              | A/D conversion in repeat mode |
| Argument             | None                 |
| Variable             | None                 |
| Returned value       | None                 |
| Function             | Set the A/D converter to repeat mode and set the functions as marked in Table 6.1. Set an analog input pin to AN0, and set P10 to input mode. Generate a software trigger and start A/D conversion of the input voltage at the AN0 pin. |

| 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             | None                                             |
| Returned value       | unsigned short read_ad_data  Value read from the A/D register |
| Function             | Read the A/D register selected with the unsigned char ch argument. 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/63 Group User’s Manual: Hardware Rev.1.00
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.

Website and Support
Renesas Electronics website
http://www.renesas.com/

Inquiries
http://www.renesas.com/inquiry
| Rev. | Date       | Description              |
|------|------------|--------------------------|
| 1.00 | 2011.03.15 | First edition issued     |

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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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