TB3319

How to Perform ADC Conversions with DMA Data Transfers on PIC32MK Devices Using MPLAB Harmony v3

Introduction

When performing a large number of ADC conversions on many channels, transferring the resulting data from the peripheral registers to a user buffer using interrupts can result in a high CPU load.

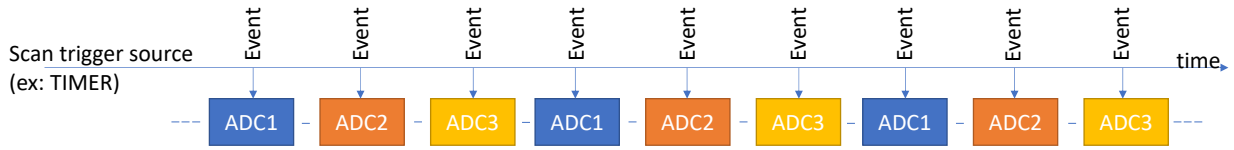
The data can be transferred using the DMA to avoid this increased CPU load. On the PIC32MK microcontrollers, the general-purpose DMA cannot be used with the ADC as the ADC modules on this family of devices have their own dedicated DMA data transfer mechanism.

This document describes how to configure and use the ADC peripheral library in MPLAB® Harmony v3 with the DMA data transfer feature.

1. The Operation of the ADC in Scanning Mode with DMA Transfer Mode

Automatic conversions using hardware triggering can be performed using the scan mode feature. The scanning feature allows the ADC converters to be triggered sequentially for each scan source event, for example, the match event of a timer.

Figure 1-1. ADC Scan

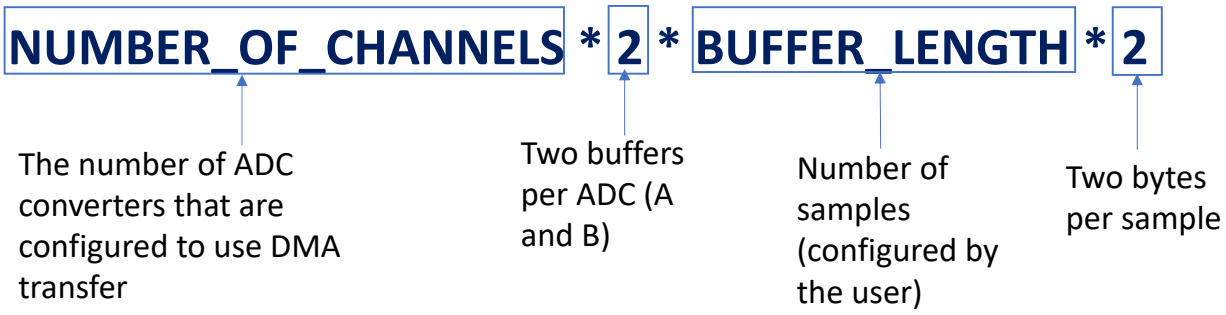


When using the DMA feature of the ADC module, the internal DMA of the module will automatically transfer the data from the result registers to a buffer in the RAM. The memory layout of the destination buffer is determined by the number of ADC converters and the configured buffer length. The user must configure the start address of the destination buffer.

Each ADC channel will have two buffers: Buffer A and Buffer B. The Buffer A and Buffer B are separate buffers in the RAM, which allows one buffer to be processed by the application, while the other buffer is being filled by the DMA. The length of each buffer is configured by the user and is represented by the number of samples that must be stored in each buffer.

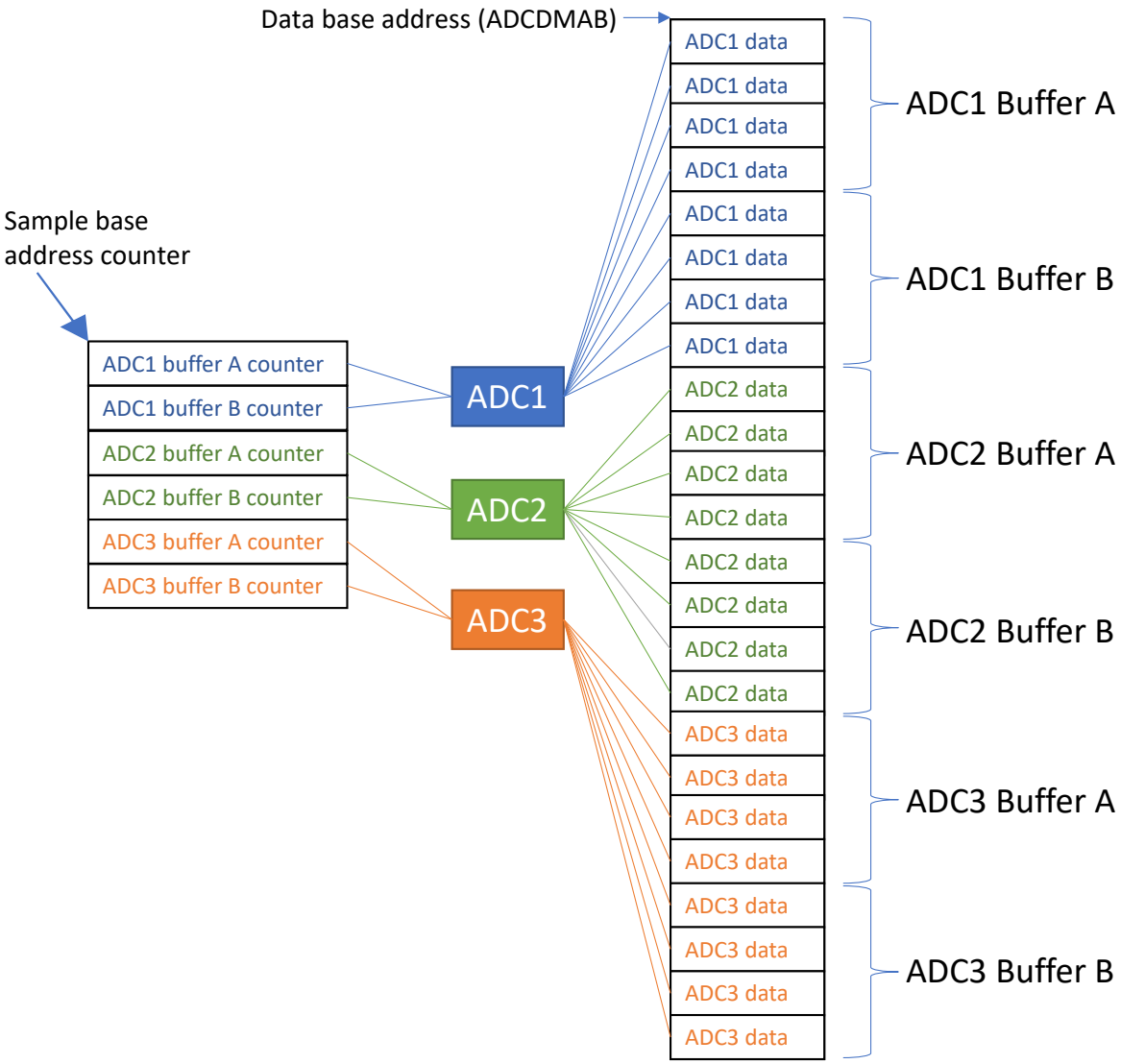
In addition to the data, the ADC DMA can also transfer the sample counter for each buffer in a separate area of the RAM, which starts at an address specified by the user. The sample counter value can be used to determine the index of the recent sample in each buffer. The size of the destination buffer, in bytes, can be determined using the following formula:

Figure 1-2. Buffer Size Formula



The following figure illustrates how the destination buffer will look when using three ADCs with a buffer length of four samples:

Figure 1-3. DMA Buffer



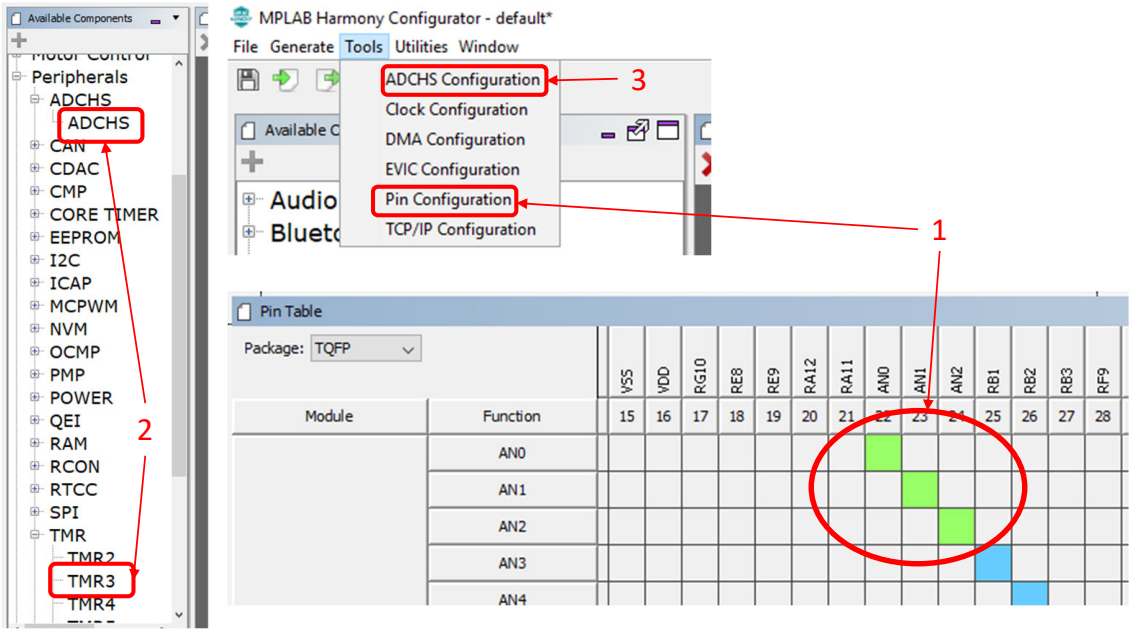
2. Implementation Example Using MPLAB Harmony v3

This example uses the MPLAB Harmony v3 PLIB drivers. To use the DMA feature of the ADC in MPLAB Harmony v3, CSP version 3.10 or later is required. For additional information on downloading MPLAB Harmony v3 and creating a MPLAB Harmony v3 project, refer to the "MPLAB® Harmony v3 Configurator Overview" which is available for download at: https://microchipdeveloper.com/harmony3:mhc-overview.

The following example will use Timer3 to trigger the ADC0, ADC1, and ADC2 in scanning mode. The DMA is configured for all the three ADCs with the buffer length equal to four.

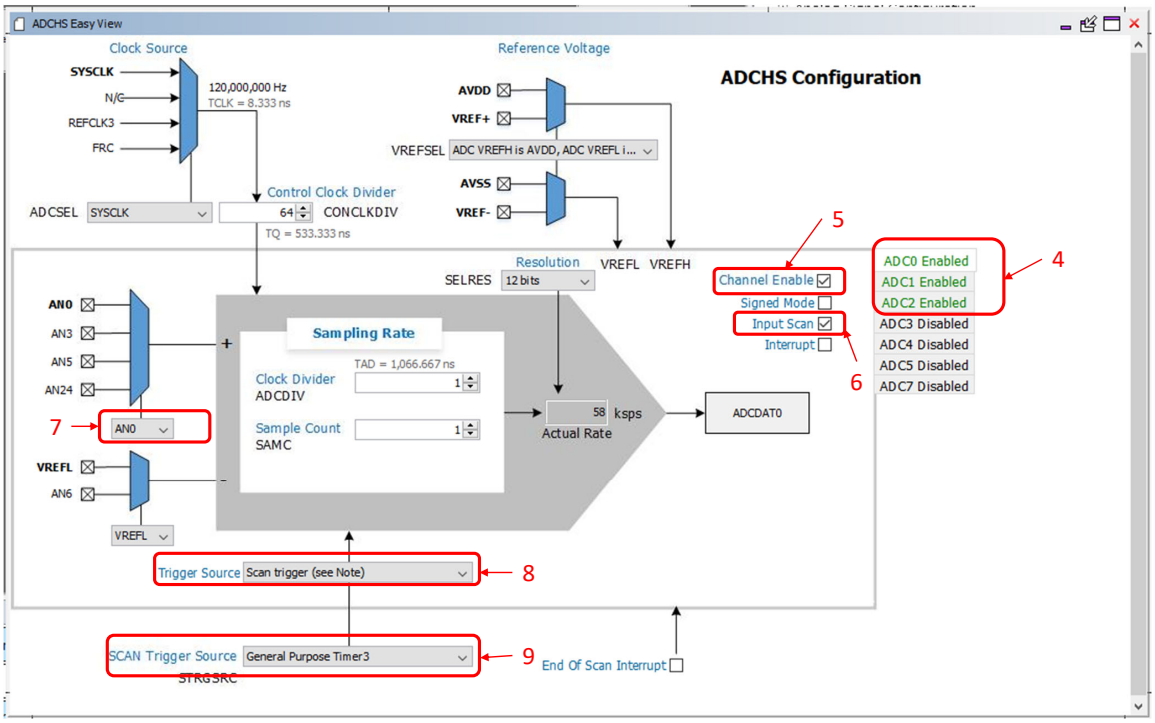
1. In the MPLAB Harmony Configurator, select *Tools* > *Pin Configuration*. The Pin Table Window will be displayed. Configure the required ADC pins.
2. After choosing the ADC pins to be used, in the Available Components list, double-click and add ADCHS and TIMER3 modules to the MPLAB Harmony v3 configurator.
3. To configure the main characteristics of the ADC module, from the Tools menu, select ADCHS Configuration.

Figure 2-1. ADC Pins Configuration and Adding ADCHS and TIMER



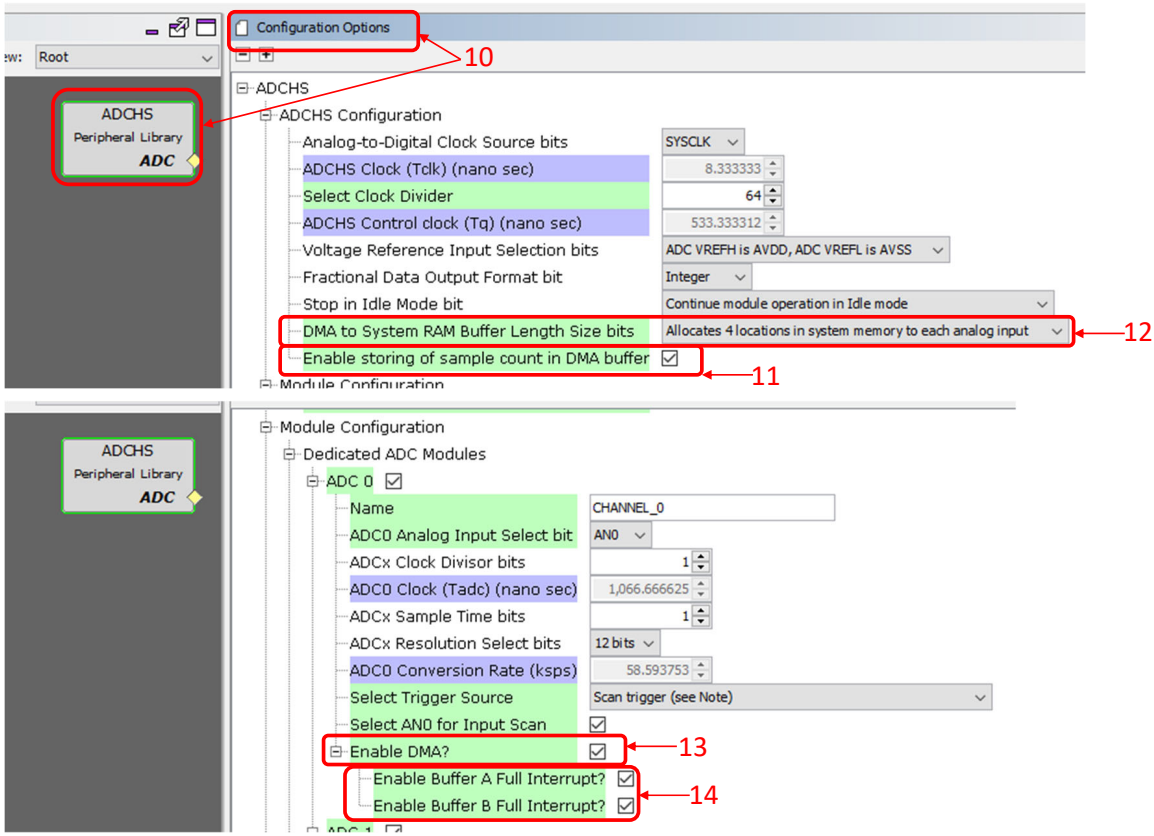
4. In the ADCHS Easy View, each ADC can be configured by selecting its respective tabs.
5. For each ADC, select Channel Enable.
6. For each ADC, select Input Scan.
7. Choose and select the channel.
8. To trigger the ADC in scanning mode, for the Trigger Source, choose Scan trigger.
9. The scanning operation also needs a trigger source to be selected.
10. For the SCAN Trigger Source, choose General Purpose Timer3.

Figure 2-2. ADCHS Configuration



11. After the main parameters of the ADCs have been configured, the DMA parameters for the ADCHS can be configured from the Configurations Options section by selecting the ADCHS module.
    Note: All the parameters that can be configured in the ADCHS Easy View can also be accessed from the Configurations Options section.
12. Expand ADCHS > ADCHS Configuration, and then select Enable Storing of Sample Count in DMA buffer.
13. For DMA to System RAM Buffer Length Size bit, choose Allocate 4 locations in system memory to each analog input.
14. Expand Module Configuration > Dedicated ADC modules > ADC 0 (For each ADC, perform these actions), select Enable DMA.
15. For each ADC, select Enable Buffer A Full Interrupt and Enable Buffer B Full Interrupt.

Figure 2-3. ADC DMA Configuration



After generating the code, the project will contain the generated peripheral libraries and a main function that calls the `SYS_Initialize` function for initializing the peripherals.

The user must perform these actions:

16. Define the variables which will store the result and counter data.
17. Call additional APIs for configuring the address of the data buffer.
18. Call additional APIs for configuring the address of the counter buffer.
19. Call additional APIs for starting Timer3.
20. Optionally, if the DMA buffer full interrupts are enabled, a callback function can be configured to be called by the buffer full notification.

Note: The buffers must be defined as non-cacheable memory for the DMA data to be valid, this can be done using the `__COHERENT` macro or using the `__attribute__((coherent))` attribute in front of the variable definition.

Figure 2-4. ADC DMA Declarations and API Calls

```
#define ADC_CHANNEL_COUNT    3
#define ADC_NUMBER_OF_BUFFERS    2
#define ADC_CHANNEL_BUFFER_LENGTH    4
#define ADC_DMA_BUFFER_A     0
#define ADC_DMA_BUFFER_B     1

/*destination buffer for result Data*/
__COHERENT uint16_t adcResultBuffer[ADC_CHANNEL_COUNT][ADC_NUMBER_OF_BUFFERS][ADC_CHANNEL_BUFFER_LENGTH];

/*destination buffer for result counters*/
__COHERENT uint8_t adcSampleCntBuffer[ADC_CHANNEL_COUNT][ADC_NUMBER_OF_BUFFERS];
```

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```
int main ( void )
{
    /* Initialize all modules */
    SYS_Initialize ( NULL );

    ADCHS_DMACallbackRegister(ADC_ResultHandler, (uintptr_t)NULL);
    ADCHS_DMASampleCountBaseAddrSet((uint32_t)KVA_TO_PA(adcSampleCntBuffer));
    ADCHS_DMAResultBaseAddrSet((uint32_t)KVA_TO_PA(adcResultBuffer));
    TMR3_Start();
```

19
16
17
18

For a better understanding of how the data is organized in the result and counter buffers, the `adcResultBuffer` and `adcSampleCntBuffer` arrays can be viewed in the Watches window while debugging.

Figure 2-5. ADC Sample Buffer

Figure 2-6. ADC Result Buffer

3. References

The following documents are used as reference. For additional information, visit the Microchip Website, or contact a local Microchip sales Representative.

- The MPLAB Harmony v3 Quick Docs repository provides standalone help pages for users to get started developing applications on Microchip's 32-bit SAM and PIC32 MCUs. Start from the `index.html` file present in the docs folder.
  The online version is available at microchip-mplab-harmony.github.io/quick_docs/.
- MPLAB Harmony Landing page:
  www.microchip.com/harmony
- How to Build an Application by Adding a New PLIB, Driver, or Middleware to an Existing MPLAB Harmony v3 Project:
  www.microchip.com/DS90003253
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  microchipdeveloper.com/harmony3:start

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