



# **ADSP-21990: Utilization of the Analog to Digital Converter (ADC)**

AN21990-05

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## Summary

This application note demonstrates the usage of the pipeline flash Analog to Digital Converter (ADC) system<sup>1</sup> on the ADSP-21990. Section one will discuss the ADC library routines. In section two, an example will be used to demonstrate the usage of these routines. The last section shows some experimental results.

## 1 Implementation of the ADC library routine

### 1.1 Usage of ADC routine

In this library, two routines are defined for initialising the ADC block and reading the ADC channel values. It is developed as an easy-to-use library, which has to be linked to the user's application. The library consists of two files. The file "adc.dsp" contains the assembly code of the subroutines. The block has to be compiled and then linked to an application. The user has to include the header file "adc.h", which provides the function-like call to the subroutine. The following table shows the macro that is defined in this library.

<i>Operation</i>	<i>Usage</i>	<i>Explanation</i>
Initialisation	<b>ADC_Init(ADC_Number_of_samples, ADC_EOC_interrupt_label)</b>	<b>Initialise the ADC block, including configuring the ADC end of conversion interrupt</b>
Read ADC	<b>ADC_Read(ADC_DATAx, Offset_0to3 or Offset_4to7)</b>	<b>Reading the ADC channel values, with the offset values being taken into account</b>

**Table 1 Implementation Routine**

This routine requires a configuration constant from the main include-file "main.h" that comes with every application note. Section 2 shows an example of usage of this library. For more information regarding this routine, see the comments in the "adc.h" and the "adc.dsp" files.

### 1.2 Usage of DSP registers

The macro listed in the Table 1 is based on the subroutine listed in Table 2. This subroutine will be discussed in the following section. The following table gives an overview of what DSP registers are used in this macro:

<i>Subroutine</i>	<i>Inputs</i>	<i>Outputs</i>	<i>Modified registers</i>
ADC_Init_	<b>ADC_Number_of_samples: the number of samples to be taken for calculating the offset</b>	mr1 = Offset_0to3 sr1 = Offset_4to7	ar, ay0, ay1, mr, mx0, my0, sr,
ADC_Scale_	None	ar = ADC channel value after offset	ar, ay0

**Table 2 Input and output format, modified registers in the ADC library routines**

<sup>1</sup> Please refer to the ADSP-21990 hardware reference manual for information on the ADC block

## 1.3 Configuring the ADC block

### 1.3.1 *adc.h*

The library may be accessed by including the header file “*adc.h*” into the application code. Two macros, the `ADC_Init` and the `ADC_Read` are defined in this file. The `ADC_Init` loads the value of the number of samples used for calculating the ADC initial offsets and also sets the interrupt vector for the ADC end of conversion (EOC) interrupt. (Another macro called the `Set_InterruptVector` is used; which is defined in the general-purpose file “*macro.h*”). It then provides a call to the `ADC_Init_` routine, which is defined in the *adc.dsp* file. In the `ADC_Read` macro, the value of the required ADC channel is loaded into the DSP, and then a call is made to the `ADC_Scale_` routine for calculating the actual ADC channel value. For more information on the “*adc.h*” file, please refer to the comments in the file.

### 1.3.2 *adc.dsp*

In this file, the `ADC_Init_` and the `ADC_Scale` routines are defined. It obtains the system parameters and the ADC configuration value, which is the `ADC_Number_of_samples`, defined in “*main.h*”(refer to Section 2.2). The user can define this value to specify the number of samples to be taken from each channel for calculating the offset values for the ADC. Then the `ADC_Init_` initialises the ADC block. In the ADSP-21990, there are 12 user-defined interrupt lines, from `USR0` (highest priority) to `USR11` (lowest priority). In this routine, the ADC EOC interrupt is assigned to `USR2`. Then the ADC is set to the offset calibration mode, with software conversion start. Then the routine enters a loop such that it will calculate the average values of `VIN0` to `VIN3` and `VIN4` to `VIN7`, which are the `Offset_0to3` and `Offset_4to7` respectively. When the offsets are ready, the routine configures the ADC to simultaneous sampling mode with `PWMSync` conversion start.

In the `ADC_Scale_` routine, the actual value of the ADC channel is calculated by subtracting the offset from the value read in the ADC channel. For more information on the “*adc.dsp*” program, please refer to the comments in the file.

## 2 Software Example: Utilization of the ADC block to generate Three-Phase Sine-Wave PWM

This example is based on another application note<sup>2</sup>. The user can specify the fundamental frequency of the waveform in the “*main.dsp*” program. The only difference is that the amplitude of the waveform is controlled by the ADC channel value.

### 2.1 *Main.dsp*

It contains the initialisation and ADC end of conversion and `PWMTRIP` interrupt service routines. Besides the “*adc.h*”, the “*pwm.h*” and “*main.h*”, since sinusoidal calculation is also required, the “*trigono.dsp*” file is also included. Some constants and variables (including the amplitude factor, which will be obtained from the ADC channel) are defined. In this example, the fundamental frequency is 60Hz.

At the start of the program, initialisations such as setting the data memory page registers to accessing the internal memory, PWM initialisation (see the “*pwm.h*” and “*pwm.dsp*” files for details) and the ADC initialisation (see the “*adc.h*” and “*adc.dsp*” files for details) are accomplished. Then only the `PWMTRIP` and the `ADC_EOC` interrupts are enabled while the `PWMSync` interrupt is disabled. (User can enable this by enabling `USR1` interrupt).

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<sup>2</sup> Please refer to the application note “Generation of Three-Phase Sinewave PWM patterns” for details.

The implementation of this example is performed in the ADC\_EOC interrupt service routine. Since the ADC sampling is set to be PWMSync triggered, that means the ADC\_EOC is executed at the rate same as the PWM switching rate (20kHz here). This interrupt service routine is used such that the most up-to-date data obtained from the ADC channel is used<sup>3</sup>. In this routine, firstly, the ADC interrupt status in the ADC status register is cleared. Then the ADC VIN0 value is read with the offset value (Offset\_0to3 in this case) being taken into account to obtain the actual ADC VIN0 value. This value is the amplitude factor that is used to adjust the amplitude of the PWM waveform. The phase angle Theta is incremented and stored for the next interrupt. Sin(Theta) is computed for each phase such that phase A, B and C are 120° apart. The duty cycle for each phase is computed, and then written to the duty cycle registers.

In the PWMTRIP interrupt service routine, the users can define what to implement in case of a PWM fault. In this example, the status bit of the PWMTRIP interrupt in the PWM status register is cleared.

For more details on the “main.dsp”, please refer to the comments in the file.

## 2.2 Main.h

As discussed before, the configuration of the ADC block requires a constant, which is defined in the “main.h” file. The use of this file is to define general system parameters and constants, such as the crystal clock [kHz], core clock [kHz] and the peripheral clock [kHz] (also denoted as  $H_{clk}$ ). Besides, any constants required by the library files will be defined here. In this case, the ADC\_Number\_of\_samples<sup>4</sup> (30 samples are used from each channel for calculating the offset values) and the constants needed by the PWM library, such as the PWM switching frequency [Hz], the dead time [nsec] and the PWM sync pulse time [nsec] will be included in this file. Two files, the “ADSP-21990.h” and the “macro.h” are also included in the “main.h” file. The “ADSP-21990.h” defines the peripheral registers of the ADSP-21990 while the “macro.h” defines the most commonly used macro.

## 3 Experimental Results

The results below show the waveforms on the PWM channels while running this example with the ADC VIN0 input changing. Here, the crystal clock is 25MHz, the peripheral clock ( $H_{clk}$ ) is 12.5MHz. PWM switching frequency = 20kHz, PWM dead time = 2 $\mu$ s and PWM sync pulse width = 440ns. The fundamental frequency of the sine wave is 60Hz. In this example, internal reference voltage is used (which is 1V) and the input voltage range into the ADC through the EZ board is from -Vref to +Vref, hence voltage input range from -1V to +1V correspond to -1 to +1 in 1.15 value. In Figure 1, one can see the PWM waveforms of channel A when the PWM amplitude factor is 100% (achieved by applying +1V into the ADC VIN0). Figure 2 shows the PWM patterns when the amplitude factor is -50%. From Figure 3, an amplitude factor of 50% is applied and it shows that the three phases are 120° apart.

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<sup>3</sup> If the PWMSync interrupt service routine is used instead, the user has to make sure all the ADC samples from the previous cycle are saved into memory before the new samples are converted.

<sup>4</sup> Note that this number can be any positive integer value and does not have to be a power to two.

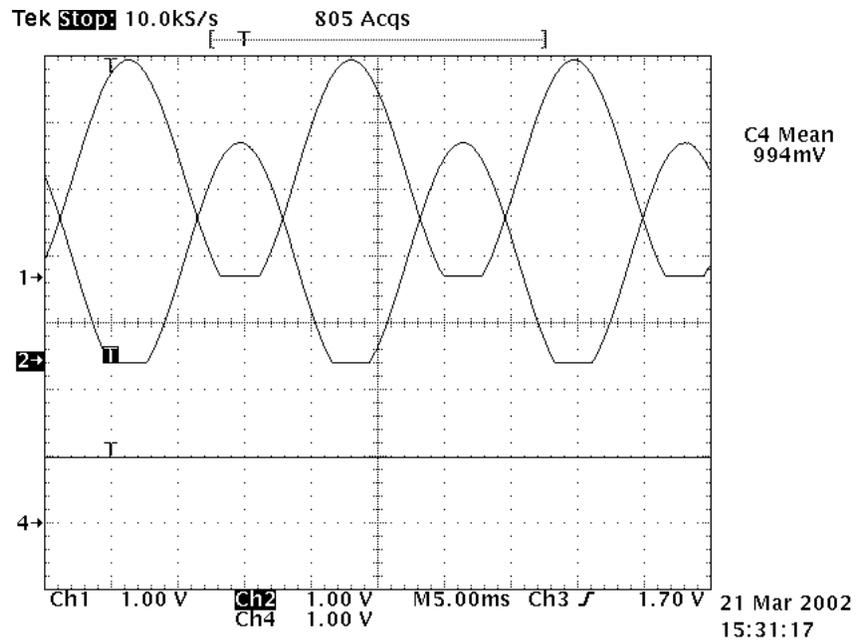


Figure 1 Filtered sine PWM outputs Ch1: AH, Ch2:AL CH4: ADC VIN0 input = amplitude factor (100%)

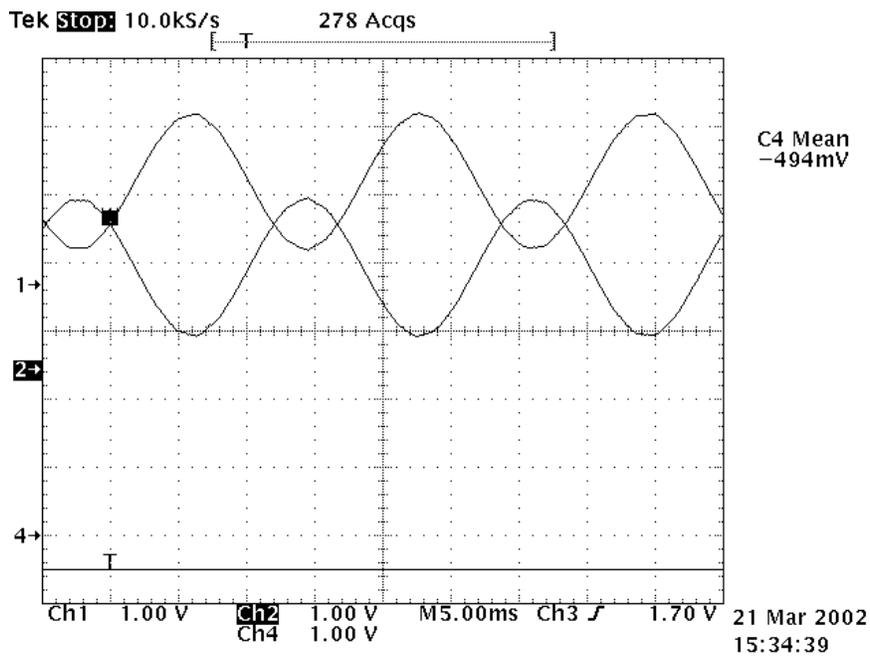


Figure 2 Filtered PWM outputs, Ch1: AH, Ch2: AL, Ch4: ADC VIN0 input = amplitude factor (-50%)

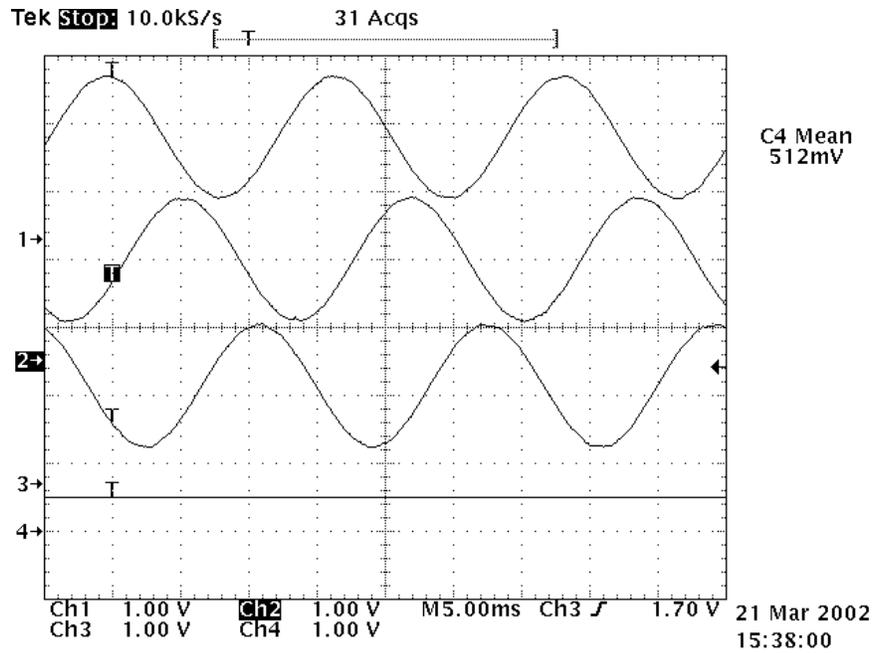


Figure 3 PWM outputs, Ch1: AH, Ch2: BH, CH3: CH, CH4: ADC VIN0 input = amplitude factor (50%)