ECE 271 Microcomputer Architecture and Applications Lab 10: Digital to Analog Converter (DAC) Instructor: Prof. Yifeng Zhu Spring 2015

Goals

- 1. Understand basic concepts of DAC conversion
- 2. Configure DAC resolution and sampling rate
- 3. Perform fixed-point floating point operations by using only integer instructions
- 4. Find the result of an complex function via table lookup

Pre-Lab Assignment

- 1. Read Chapter 21 Digital to Analog Conversion
- 2. Complete the prelab assignment

Lab Demo

1. Generate a sinusoidal waveform with a frequency of 440Hz and use an oscilloscope to verify the frequency (80%).

Note: PA.5 and PA.4 are connected to the Channel 2 and Channel 1 of ADC2, respectively. However only PA.5 works since PA.4 is connected to the IDD measurement unit which measures the electrical current the processor take. A capacitor connects PA.4 and the ground.

2. Something cool (10%)

Post-lab Assignment

1. Write your answer in Readme.md and submit it to the gitlab server.

Introduction to Digital to Analog Converter (DAC)

In this lab, you are required to generate a 440Hz sine wave output signal either on PA.5 or PA4.

In this lab, we configure TIM4 as a master trigger to the DAC converter. When the MMS bits in the TIM4_CR2 register controls the trigger output (TIM4_TRGO). For example,

- When MMS bits are 010, the TRGO signal has a rising edge each time an update event occurs.
- When MMS bits are 100, 101, 110, and 111, the OC1REF, OC2REF, OC3REF and OC4REF is selected as the TRGO output, respectively.

The following gives an example C code of configuring the TIM4 that uses OC1REF as the TRGO output, and the default MSI clock is used. *Please note that you might need to change the parameters of this program. In addition, we will use the HSI clock (16MHz), instead of the default MSI (2MHz) as the processor clock.*

```
// Enable TIM4 clock
RCC->APB1ENR |= RCC APB1ENR TIM4EN;
// The counter clock frequency CK_CNT is equal to fCK_PSC / (PSC[15:0] + 1).
TIM4 - PSC = 2097000/1000 - 1;
// Auto reload value 1000
TIM4 \rightarrow ARR = 1000;
// Compare 500 with 1000
// TIM4->CCR1 = 500;
// Set OC1M of Channel 1 to 011: Toggle - OC1REF toggles
// when TIMx_CNT=TIMx_CCR1.
TIM4->CCMR1 = TIM CCMR1 OC1M 0 | TIM CCMR1 OC1M 1;
// Enable compare output 1
TIM4->CCER = TIM CCER CC1E ;
// Master Mode Selection
// 100: Compare - OC1REF signal is used as trigger output (TRGO)
TIM4->CR2 &= ~ TIM_CR2_MMS;
TIM4->CR2 |= TIM_CR2_MMS_2;
// Enable timer
TIM4->CR1 = TIM CR1 CEN;
```

ECE 271 Pre-lab Lab 10: Digital to Analog Conversion (DAC) Spring 2015

Submit your answer in *readme.md*.

In digital audio a common sampling frequency is 44,100Hz, i.e, 44.1kHz. That means an analog audio signal is recorded as 44100 digital values per second. Human ears can hear up to 20,000Hz. According to the Nyquist–Shannon sampling theorem, the sampling frequency must be at least twice of the maximum frequency of signals audible to human ears. Most Compact Discs (CD) are recorded with this rate.

(1) Assuming an audio is recorded at a rate of 44,100 Hz, and the DAC is driven by the Timer trigger output (TGRO). What is the time interval of between two consecutive triggers? If the timer is driven by the HSI clock (16MHz), how do you set up the values of TIM4->PSC and TIM4->ARR? Show your calculation.

TIM4->PSC = _____ TIM4->ARR = _____

$$\frac{f_{HSI}}{(1+PSC)(1+ARR)} = f_{sampling} = 44.1Khz$$

- (2) Assuming we are to generate a sinusoidal waveform of 440Hz (music tone A) and the DAC converter is triggered by TIM4 TRGO with a frequency of 44100Hz.
 - a. How many DAC outputs we should produce during one cycle of sinusoidal waveform?

- b. The angle of the sine function should increase from 0° to 360° to complete one cycle in the sinusoidal waveform. In order to achieve that, how many degrees the angle variable should be increased in *TIM4_IRQHandler* each time?
- c. The processor only supports integer arithmetic. If the degree to be increased is not an integer, what can you do to get around of this issue?

ECE 271 Post-lab Lab 10: Digital to Analog Conversion (DAC) Spring 2015

Submit your answer in *readme.md*.

- 1. Assume we are required to generate a sinusoidal waveform of 293.665 Hz (music tone D) and the DAC converter is triggered by TIM4 TRGO with a frequency of 44,100Hz.
 - a. How many DAC outputs should we produce during one cycle of sinusoidal waveform?
 - b. The angle of the sine function should increase from 0° to 360° in order to complete one cycle of the sinusoidal waveform. How many degrees should the angle variable be increased in timer interrupt handler each time?
 - c. The processor only supports integer arithmetic. If the angle degree to be increased is not an integer, what can you do to get around this issue?