ECEN-361 Lab-08: DMAs with ADC/DAC

NAME: ____

Introduction and Objectives of the Lab

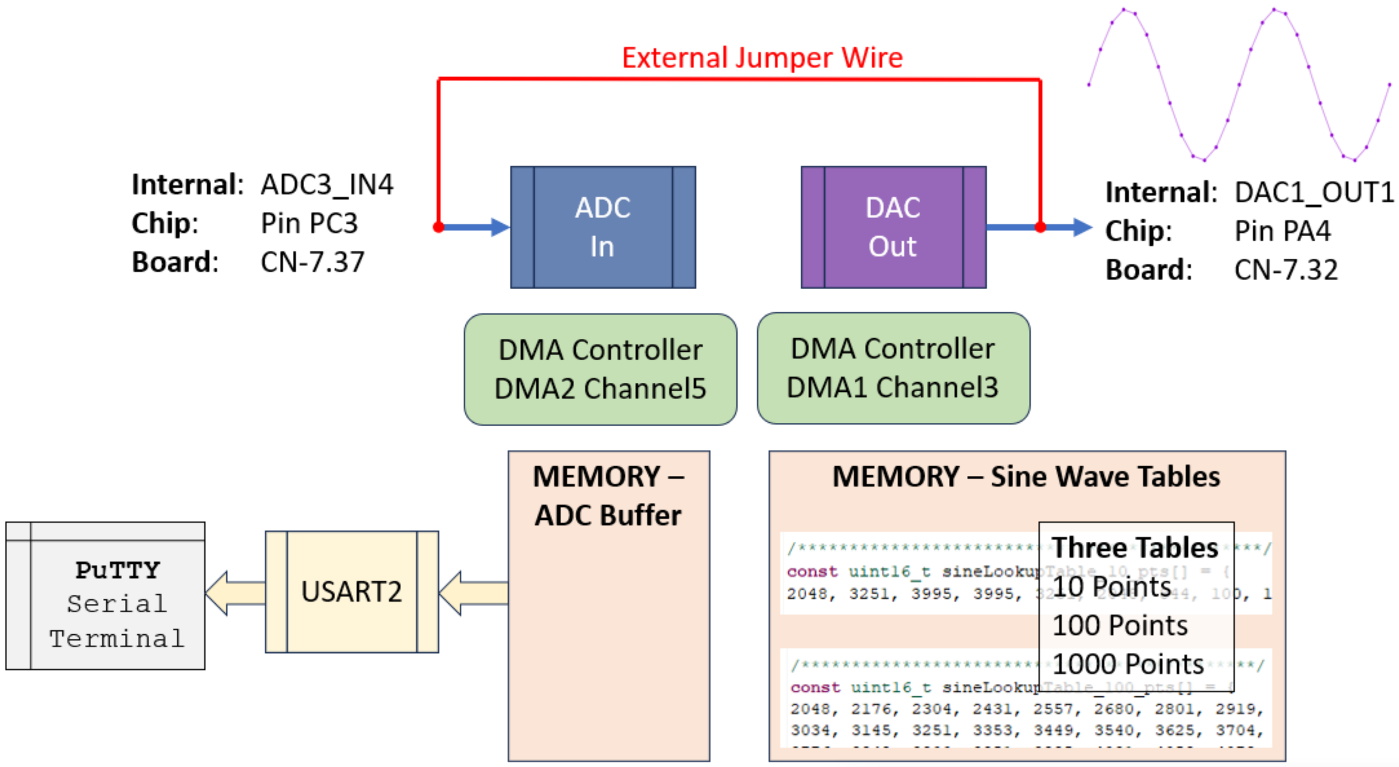
Part 1:	Learn how a Sine Wave can be created from a µController and investigate the characteristics and limitations of an ADC Controller (the one built into the STM32)
Part 2:	Exposure to and use of DMA channels in a µController.
Part 3:	*(**TBD** 2nd week: Use an external graphing tool to measure a signal on the STM32 Board.)*

For each of the parts, follow the instructions, then fill in answers to the questions. Expected answers are indicated in the boxes with red text/spaces to fill in answers.

Lab Instructions

Overview of System

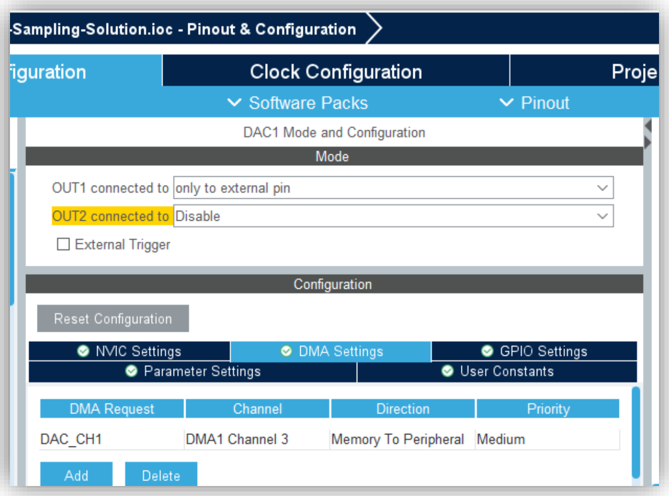
The project, as configured in the repo, is a bare-metal (no FreeRTOS) that is configured like this:



```
/*****************************************/
const uint16_t sineLookupTable_10_pts[] = {
2048, 3251, 3995, 3995, 3251, 2048, 844, 100, 1

/*****************************************/
const uint16_t sineLookupTable_100_pts[] = {
2048, 2176, 2304, 2431, 2557, 2680, 2801, 2919,
3034, 3145, 3251, 3353, 3449, 3540, 3625, 3704,
```

Explore the GUI by opening the
`ECEN-361-STM32-Lab-08-Sampling-Solution.ioc`
file to see the configurations.



DAC1 Mode and Configuration

Mode

OUT1 connected to: only to external pin

OUT2 connected to: Disable

☐ External Trigger

Configuration

DMA Request	Channel	Direction	Priority
DAC_CH1	DMA1 Channel 3	Memory To Peripheral	Medium

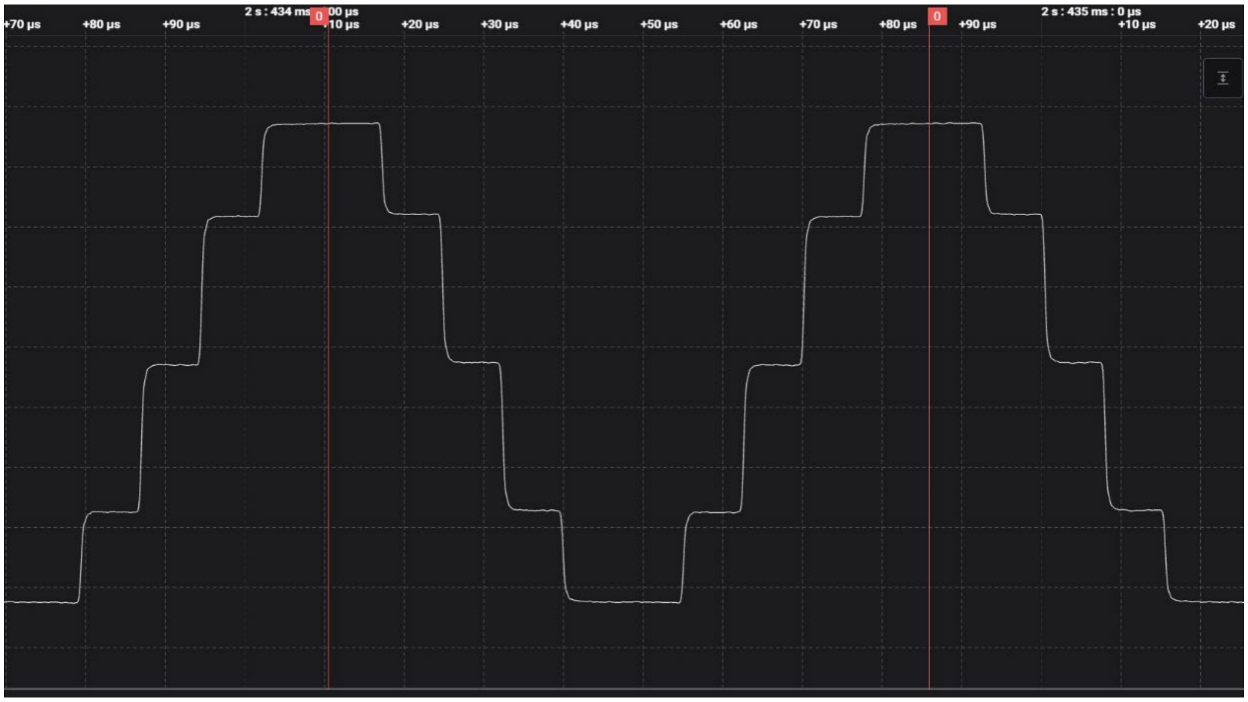
In this configuration, the DAC drives an analog sinewave ouput which is wired (external jumper wire) from its output pin, back to an ADC input pin. The transfers are set up to be done automatically, via DMA channels. Once these channels are configured, no uProcessor cycles are required to effect the transfer out (DAC) or the transfer in (ADC). The DMAs are configured to automatically:

- Read from a memory buffer (cyclically) and write to a fixed peripheral address (DAC).
- Read from a peripheral I/O address (ADC) and write to a memory buffer (cyclically).

Sine Wave Generation

Often, in embedded systems with limited compute power, an output waveform (like a Sine Wave) is created by calculating the points of the wave thru a cycle. Tools help generate these, depending on the number of points per cycle, the output voltage displacement, etc. In this approach, a memory value is read, its analog value put out to the pin in a periodic manner. For this lab, a simple web-based calculator (SEE HERE) created the integer values of the sine wave over time. If these are plotted over time, they look like this (depending on the number of points):

In this simplistic version, only 10 points / cycle are used, so the wave re-creation is crude:



The values to create the wave are put in an integer array, sequentially providing the points of the sine wave – See the '**`sinewavetable.h`**' include file in the project. For the lab, three different arrays have been populated with values of differing points per cycle to make up a single period:

- `const uint16_t sineLookupTable_10_pts[] = {`
  …
- `const uint16_t sineLookupTable_100_pts[] = {`
  …
- `const uint16_t sineLookupTable_1000_pts[] = {`
  …

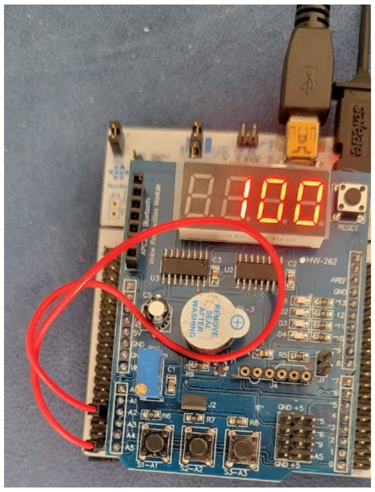
We'll compare the outputs of using different points/sample in this lab.

Part 1 2 Pts.

Q1 Look at the sine wave tables in the include file. What is the range of the values in the tables for each of the differing points/cycle?

Q2 If this is going to the DAC, explain the ranges stored in the table

Part 1: Looking at the Sine Wave Output



1. Connect the DAC out to the ADC in

You'll need a single jumper (from your ECEN-106 kits or available during lab time). Connect the DAC-out to the ADC-in (CN-7.32 → CN-7.37)

2. Accept the Assignment, Download the repo, Run the code.

Your board should show "1000" on the 7-seg display

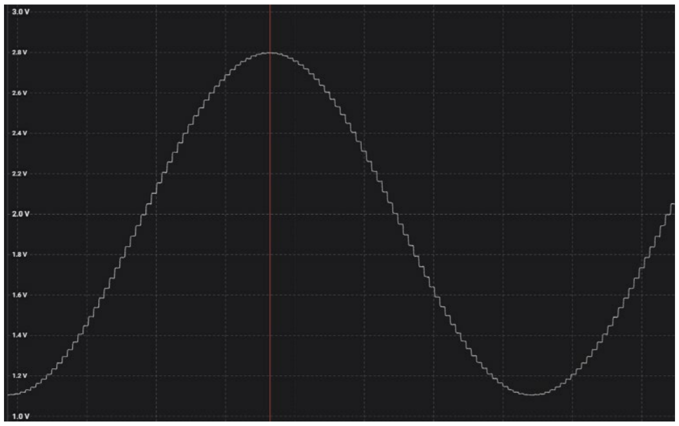
The 7-Seg LEDs indicate which of the points-per-cycle table is being used to output the DAC waveform.:10, 100, 1000. These values are cycled by pressing S1.

3. Look at the analog wave out with the Saleae Logic Analyzer.

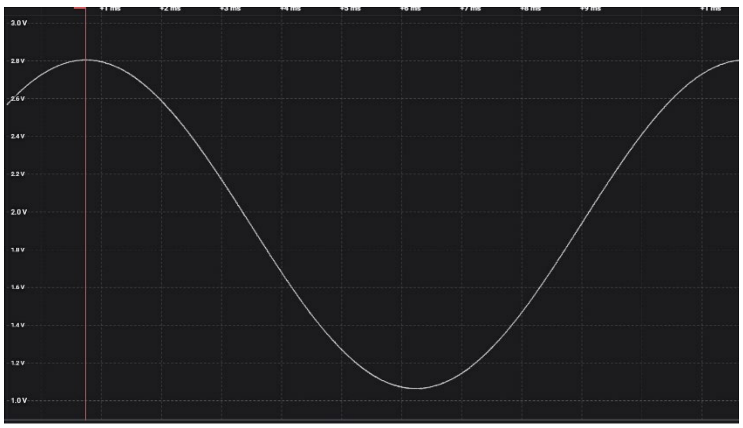
Connect / Configure the Logic Analyzer, same as previous labs, to use one of the inputs in analog mode. Connect the probe to the one of the red jumper wire endpoints, and connect a ground on the probe header.

Cycle through the different points/cycle option (Switch S1) – you should see something like this, with differing smoothness:

100 Points / Sample



1000 Points / Sample



Set the triggering to loop and adjust the sample rate and length of sample to get a good picture of each of the three different waveforms. Note that you can auto-adjust the vertical size of the analog wave to get a more readable picture. Use the ruler tool (shortcut: `<CTRL>-T`) to get accurate time differences.

Part 1.2 2 Pts.

Q3 Measure the three waveforms and fill out the following table:

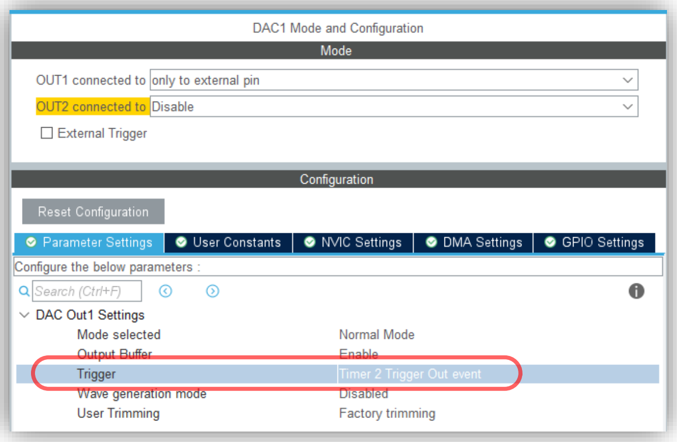
WaveformPoints / Cycle	10	100	1000
Period of Wave			
Time between each point			

Q4 Take/Paste a screenshot showing the measurements of each of the three samples/cycle, showing the frequency measurements.

The DMA controller has been configured to run cyclically – meaning after all the buffer entries are read, the DMA controller starts over again and reads sequentially thru the addresses. This continues as long as the DMA is enabled.

The timing of the DAC conversions can be free-running ("No trigger" = go as fast the conversion time allows) or based on a trigger. For this lab, the trigger has been configured to be one of the timers – Timer2.

See the .IOC GUI: →



DAC1 Mode and Configuration

Mode

OUT1 connected to: only to external pin

OUT2 connected to: Disable

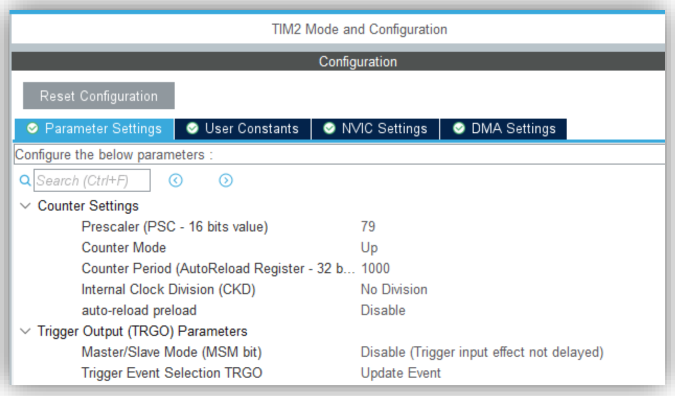
☐ External Trigger

Configuration

DAC Out1 Settings

Mode selected	Normal Mode
Output Buffer	Enable
Trigger	Timer 2 Trigger Out event
Wave generation mode	Disabled
User Trimming	Factory trimming

This means that the DAC conversion will start only as often as the Timer2 Trigger happens. **Timer2 is configured: →**



TIM2 Mode and Configuration

Configuration

Counter Settings

Prescaler (PSC - 16 bits value)	79
Counter Mode	Up
Counter Period (AutoReload Register - 32 b...	1000
Internal Clock Division (CKD)	No Division
auto-reload preload	Disable

Trigger Output (TRGO) Parameters

Master/Slave Mode (MSM bit)	Disable (Trigger input effect not delayed)
Trigger Event Selection TRGO	Update Event

As configured, the timer should call for a conversion

80 Mhz / 80 (pre-scaler) / 1000 == 1 KHz. Every mS.

By adjusting Timer2, you can change the frequency of the sinewave coming from the DAC.

Part 1.3 3 Pts.

Q5 Adjust Timer2, recompile each time, and measure to fill in the table. If the system 'breaks' put "breaks" in the box.

Timer2 Triggering			**Waveform Pts /Cycle:**	**10**	**100**	**1000**
	Prescaler	**Counter Period**				
Case "A"	**79**	**10000**	Period of Wave			
			Time between points			
Case "B"	**79**	**1**	Period of Wave			
			Time between points			
Case "C"	**7**	**100**	Period of Wave			
			Time between points			
Case "D"	**7**	**5**	Period of Wave			
			Time between points			

Q6 Are the results predictable and correlated with the timer? What would the FREQUENCY be with 1000 pts/cycle if the Timer2 had: Prescaler=799, Counter_Period=100?

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Part 1.3 3 Pts.

Q7 When the trigger for the DAC DMA (Timer2) was set to go too fast, what happened?

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Any ideas why?

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Q8 Sending out the DAC via the DMA, the point-to-point timing gets set by the trigger frequency. Could a polling-based approach be faster? (Supposing the DAC conversion time was zero) If so, why use DMA ?

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Extra Credit Ideas (5 pts.max for any of these completed)

1.) Note on the analog waveform from the DAC that the nadir (lowest point) of the waveform doesn't go all the way to 0.0Volts. It looks to be "clipped" at about 0.6 V. Explain why :

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2.) Doing a S/W-only solution to output the values to the DAC (Called: "Programmed I/O") requires a simple loop of :

a. Read the next digital out from the table
b. Output it to the DAC
c. Poll to see if the DAC conversion is done
d. Repeat

Write a procedure of the non-DMA version of the wave generator and see how fast you can make the frequency. Comments about it:

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3.) We used Timer2 as a trigger to define the timing between each waveform point. Can the DMA control be modified so that it runs continuously without a trigger? :

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