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ECE2049-C24

21 February 2024

Lab4 – ADC & DAC Waveform Generator

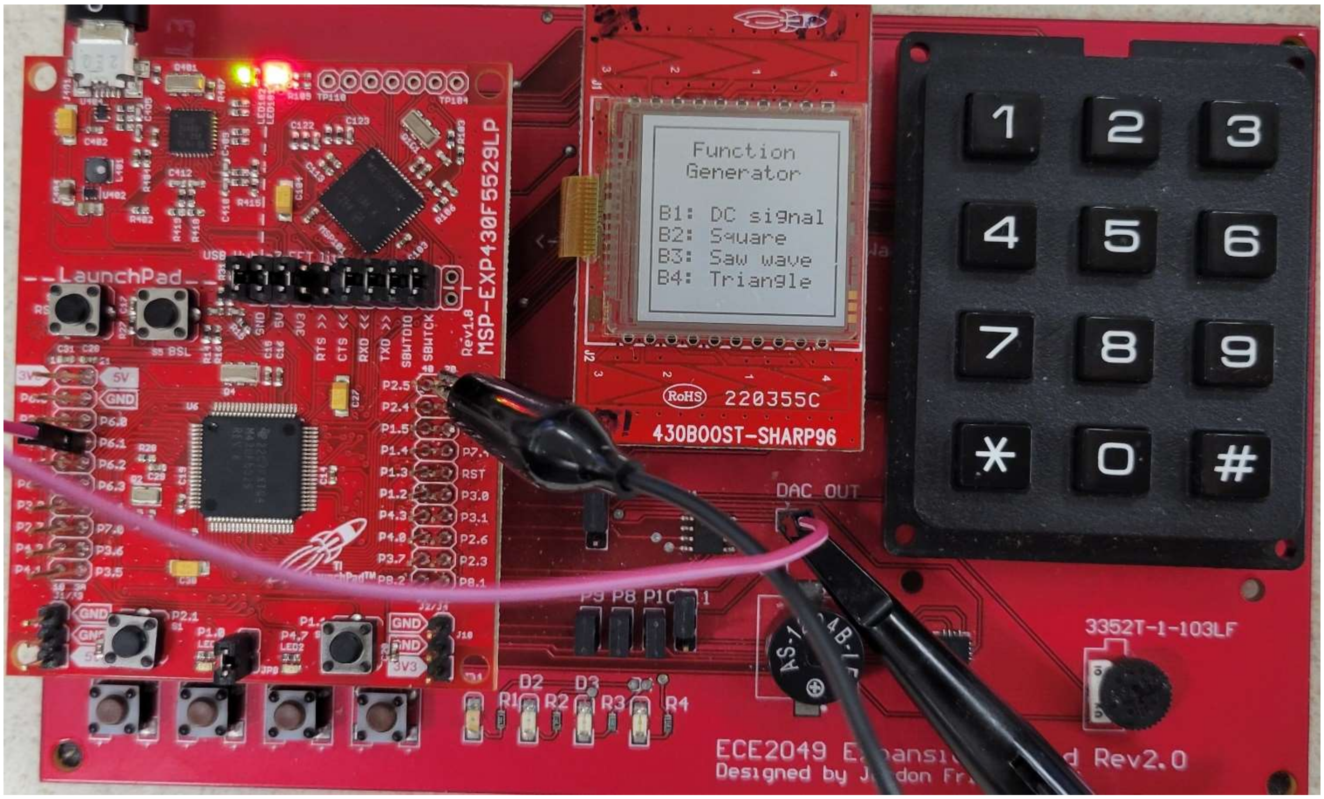

Figure 1 - MSP430F5529 Custom Lab Board displaying welcome screen for Function Generator Program. Oscilloscope is reading DAC OUT pin and jumper cable is connected to P6.1 from DAC OUT.

Introduction

The purpose of this lab was to create a waveform generator using the built-in ADC, timer A2, and LDAC. The program can produce a DC output wave, a square wave, a sawtooth wave, and a triangle wave. An oscilloscope was used on the DAC output to display the different waves. The scroll wheel was used to create a varying amplitude for each wave. Additionally, a jumper cable was used to read the DAC output and use it as an ADC input to read voltage values to determine linearity of both ADC and DAC.

This lab involved a variety of different modes that made various uses of both the ACLK and SMCLK. Careful consideration of configuring the SMCLK was especially important for the sawtooth and triangle waves which required a step increment structure. ADC interrupts were used to get values from the scroll wheel and timer interrupts contained the code that controlled the sawtooth and triangle functions.

Discussion and Results

Flow Diagram of Program

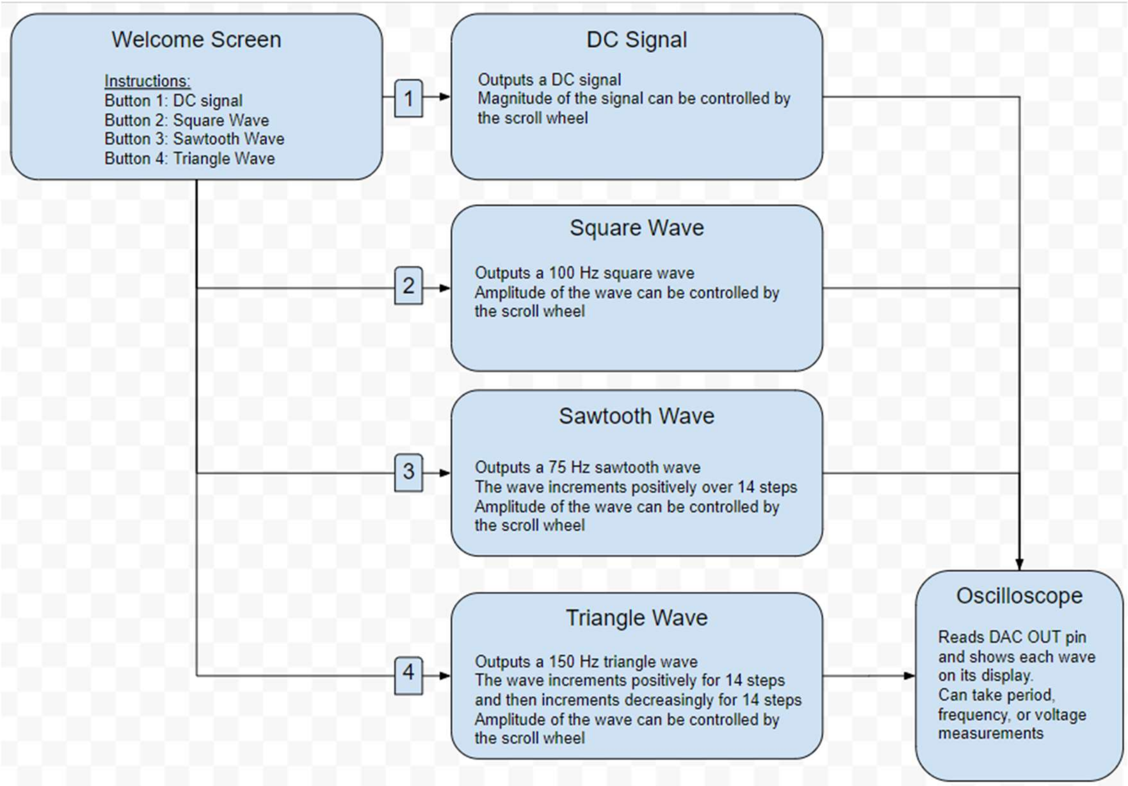

Figure 2 - Flow diagram for the program. Includes the welcome screen, all four different output modes, and the output reading performed by the oscilloscope.

Highlighted Questions

Do you have to repeatedly send the code to the DAC to maintain the voltage or do you only need to send the code once then give the LDAC?

Code only needs to be sent to the DAC once.

Screen shot of DC output on the oscilloscope.

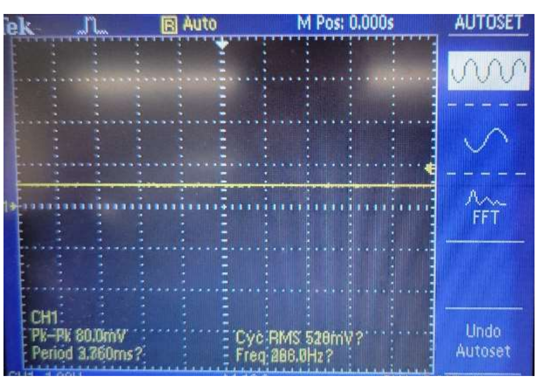

Figure 3 4 - DC signal output from DAC. Scroll wheel is currently set to show a "low" value.

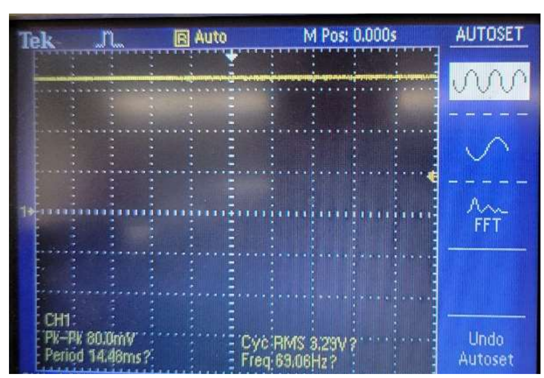

Figure 4 3 - DC signal output from DAC. Scroll wheel is currently set to show a "high" value.

What are the minimum and maximum DC voltages the MCP4921 DAC can actually generate when P7 is in the 3.3V position?

Measure the minimum and maximum DC voltages your DAC can actually generate when P7 is in the 5V position.

	P7 in 5V position	**P7 in 3.3V position**
Minimum DC voltage	695mV	597mV
Maximum DC voltage	5.08V	3.41V

Figure 5 5 - Tabulation of measured minimum and maximum DC voltage values for both the 5V and 3.3V P7 jumper positions.

Is it truly a “rail-to-rail” DAC?

No, the DAC is not truly “rail-to-rail” because the minimum and maximum DC voltages never truly reach the rails of 3.3V, 5V, and 0V, respectively.

Are there any offsets at either supply voltage setting?

Yes, there are offsets at both supply voltage settings. 5.08V – 5V = 80mV offset, 695mV – 0V = 695mV offset, 3.41V – 3.3V = 110mV offset, and 597mV – 0V = 597mV. The average offset from the maximum voltage is (110 + 80)/2 = 95mV and the average offset from the minimum voltage is (695 + 597)/2 = 646mV.

Take a screen shot of your square wave output on the oscilloscope showing the period.

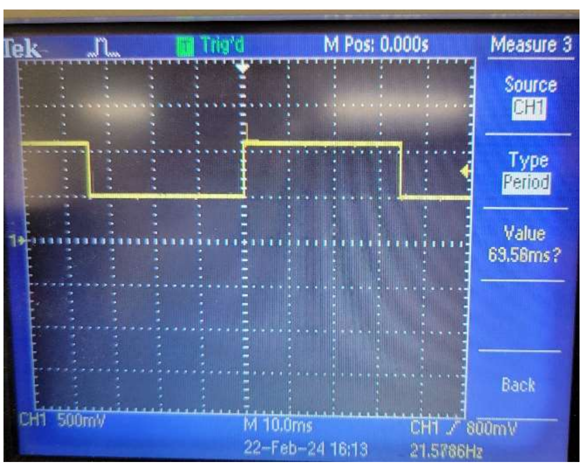

Figure 6 - Square wave output from DAC displayed on oscilloscope. Scroll wheel is set to show a "low" value.

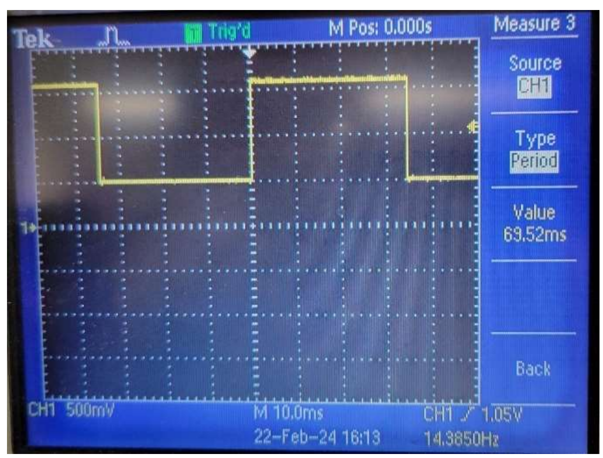

Figure 7 - Square wave output from DAC displayed on oscilloscope. Scroll wheel is set to show a "high" value.

What is the function of LDAC? How soon is the output voltage available after LDAC is applied? How fast can you effectively change the output voltage?

The function of the LDAC or Load Digital to Analog Converter is to convert digital values such as ADC bits to analog values that can be read by instruments such as an oscilloscope. The output voltage is available soon after the LDAC is applied with a slight delay. Changing the output voltage is dependent on how it is changed. In the case of this lab, the scroll wheel was used to change output voltage. There was a small amount of delay between changing the scroll wheel and viewing the oscilloscope, but it was a negligible factor.

For the Sawtooth Wave, what are your step size increment and step duration? Why? You must justify your step size!! Just choosing a number is not enough.

Because the frequency is 75Hz, the period of 1 tooth is about 1/75 = ~13.333ms. The sawtooth increments 14 steps with a duration of about 0.952ms per step. 14 steps allow each step to be just under 1ms. Also, the SMCLK was used which has a frequency of 1048576Hz Since 1/(75*14) = 1/1050, 1048576/1050 allows max_cnt to be 998, which is close to the pleasantly rounded value 1000. 14 steps allow for a well-defined wave shape while also having values that are close to well-rounded values.

Take a screen shot of your sawtooth wave output on the oscilloscope showing the period. Take a zoomed in screen shot, too, showing your staircase approximation.

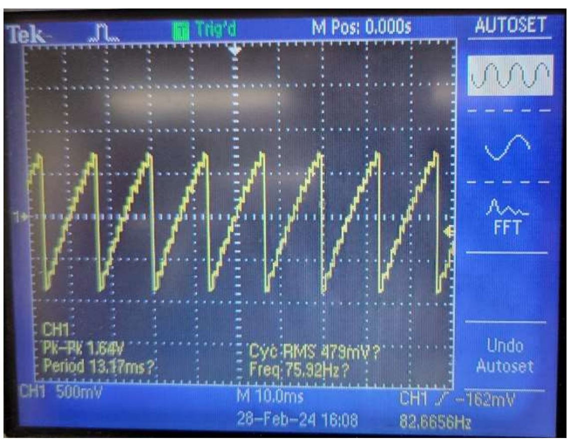

Figure 9 - Output of sawtooth wave from DAC displayed on oscilloscope. The wave roughly appears linear with some noise.

Figure 8 - Zoomed in image of sawtooth wave on oscilloscope showing the step increments of the wave. Period of 13.21ms and frequency of 75.70Hz are well within their expected values.

For the Triangle Wave, what are your step size increment and step duration? Why? Again, you must justify your choices.

For the triangle wave, the frequency is 150Hz or double the frequency of the sawtooth wave. Because of this, the SMCLK configuration for the sawtooth wave was repurposed for the triangle wave with it being multiplied into two reverse segments. The total number of increments is 28, and the length of each increment is once again 0.952ms for a total period of 0.0266s.

Take a screen shot of your triangle wave output on the oscilloscope. Take a zoomed in screen shot, too, showing your staircase approximation.

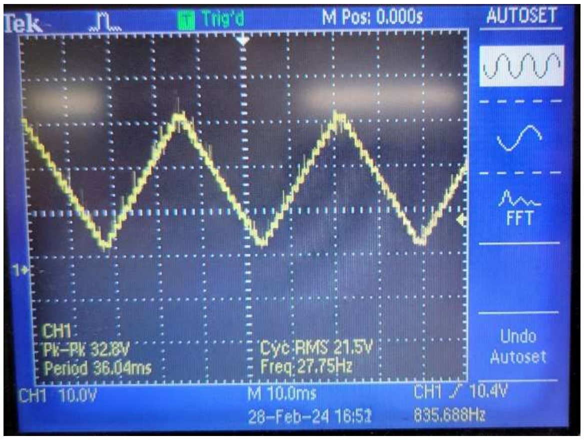

Figure 11 - Output for triangle wave. Appears linear with some noise.

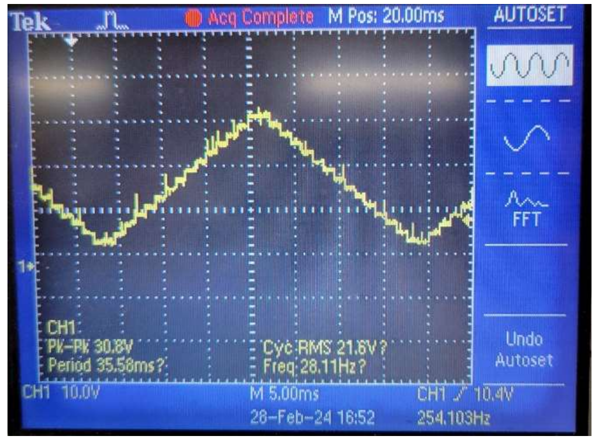

Figure 10 - Zoomed in triangle wave on oscilloscope, showing the step increments of an entire period.

Bonus: Take a screenshot of your triangle wave output on the oscilloscope at 3 different frequencies.

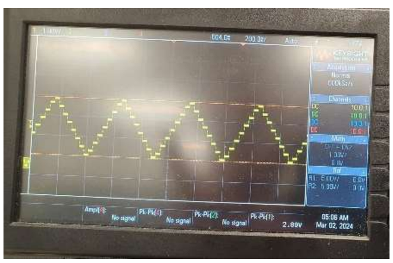
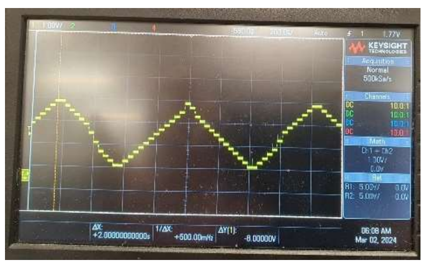
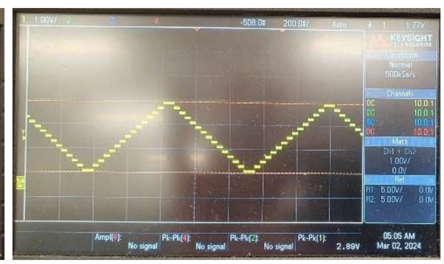

Figure 12-14: Output for triangle wave at different frequencies.

Set a break point after the call so that you can examine the voltage returned by the ADC function and measure the DAC output voltage on the oscilloscope. Take at least 5 measurements for DC values across the range from 0 to 3.3V. Tabulate the (1) codes sent to DAC, the (2) DAC output voltage from oscilloscope and (3) the voltage returned from your ADC function.

ADC Codes	DAC Voltage	ADC Voltage
0	0.585	0.000
682	1.100	0.550
1364	1.510	1.099
2046	2.010	1.649
2728	2.480	2.198
3410	2.980	2.748
4092	3.320	3.298

Figure 15 - Table of values from measurements taken by using ADC to read inputs from P6.1. ADC codes, DAC voltages, and ADC voltages were all included.

Is the MSP430 ADC12 actually linear? What about the MCP4921DAC?

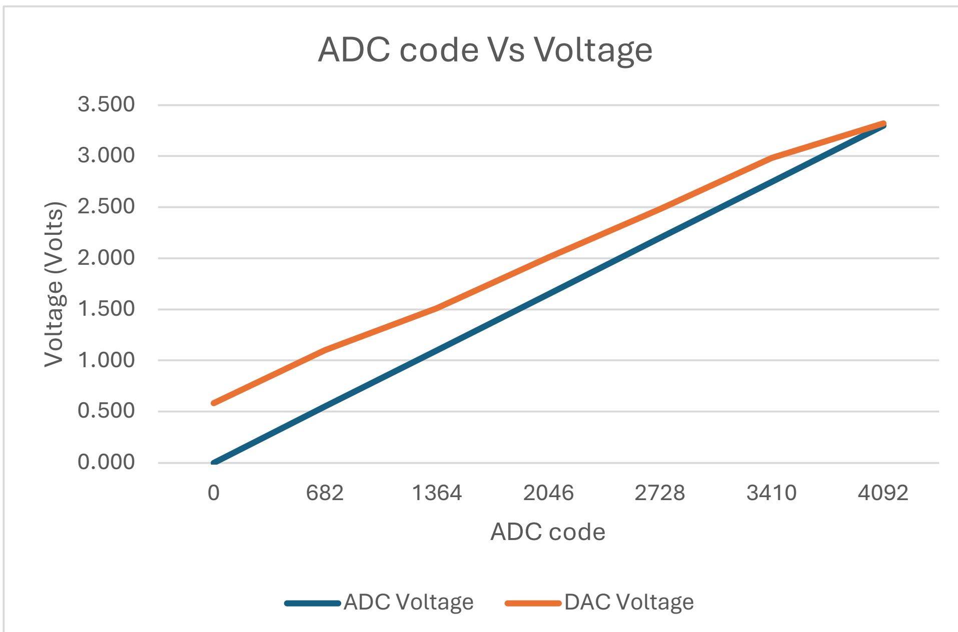

Figure 16 - Graph showing the linearity of both the ADC and DAC. ADC is certainly linear while the DAC appears linear but is less consistent than the ADC.

MSP430 ADC12 is linear while MCP4921DAC appears to be relatively linear.

What impact do your findings have for a measurement system that relies on either or both of these devices?

Devices that use ADC would be very accurate for a measurement system while DAC would be less accurate for a measurement system. Hence, it wouldn't be great for rockets or systems that rely on very precise measurements. This may also be a matter of quality, with better DACs having a stronger linearity and lower quality DACs having more error.

Summary and Conclusion

In this lab, we successfully designed and implemented a waveform generator using the MSP430F5529's built-in ADC, timer A2, and LDAC. Through careful configuration and programming, we were able to generate four different types of waveforms: DC, square, sawtooth, and triangle waves. The use of ADC interrupts for obtaining values from the scroll wheel and timer interrupts for controlling the sawtooth and triangle functions, allowed for precise waveform generation.

Additionally, we analyzed the performance of the MCP4921 DAC and the MSP430 ADC12. We found that while the MSP430 ADC12 exhibited linearity, the MCP4921 DAC showed relatively good linearity but with some deviations from ideal behavior. These findings suggest that the MSP430 ADC12 can provide accurate measurements, while the MCP4921 DAC may introduce some level of error.

Overall, this lab provided valuable hands-on experience in working with ADCs, DACs, timers, and interrupts. The understanding gained from this lab will be instrumental in developing more complex systems and applications in the future.

Appendices

Timer Calculations

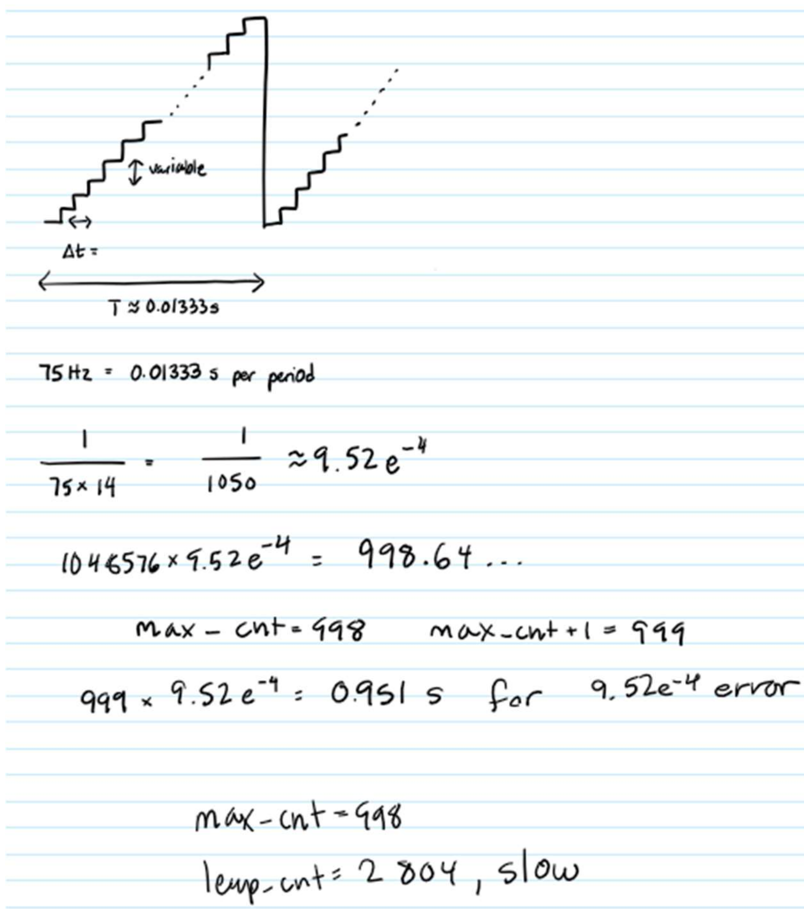

Figure 13 - Calculations done to determine SMCLK configuration for both the sawtooth wave and triangle wave.