ELEX 7620: Signal Processing and Filters

Lab 4

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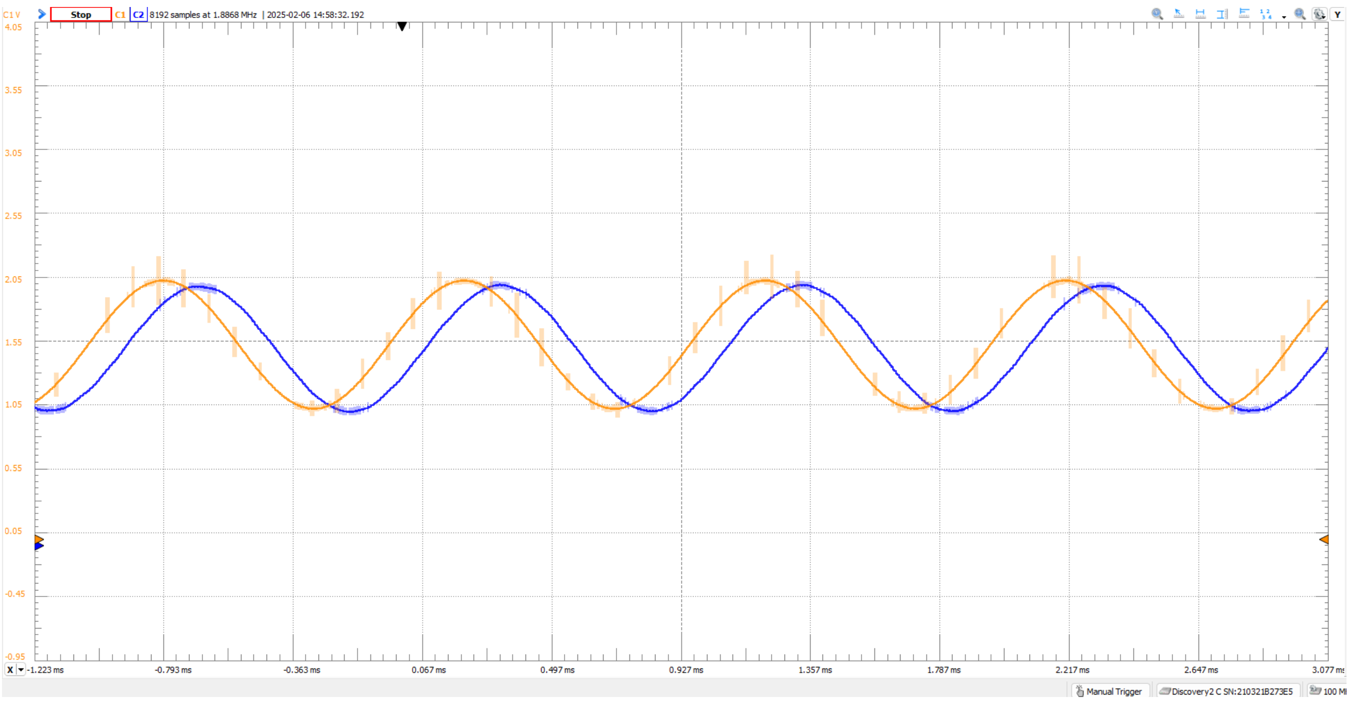
1 Basic verification

Q1. Using the AD2 or lab signal generator, create a 1kHz 1Vpp sine wave. Since the MSP432P401R microcontroller is running on a +3.3V supply, a DC offset must be applied to the input signal. Why is this?

A1. A DC offset is necessary to shift the entire sine wave into the valid input range of the MSP432P401R's ADC. Without an offset:

- The negative portion of the sine wave (below 0V) could damage the ADC or result in clipping or incorrect readings.
- The MSP432P401R's ADC operates between 0V and 3.3V, meaning it cannot interpret negative voltages.



2 Reading the Code

• What is the value of the ADC sampling frequency?

ADC sampling frequency is 12kHz

```
#define SR_12kHz     4096
#define FSAMP        SR_12kHz //sampling frequency
```

• What is the value of the PWM frequency?

The PWM frequency is 48 MHz/512 which results in 93.75kHz.

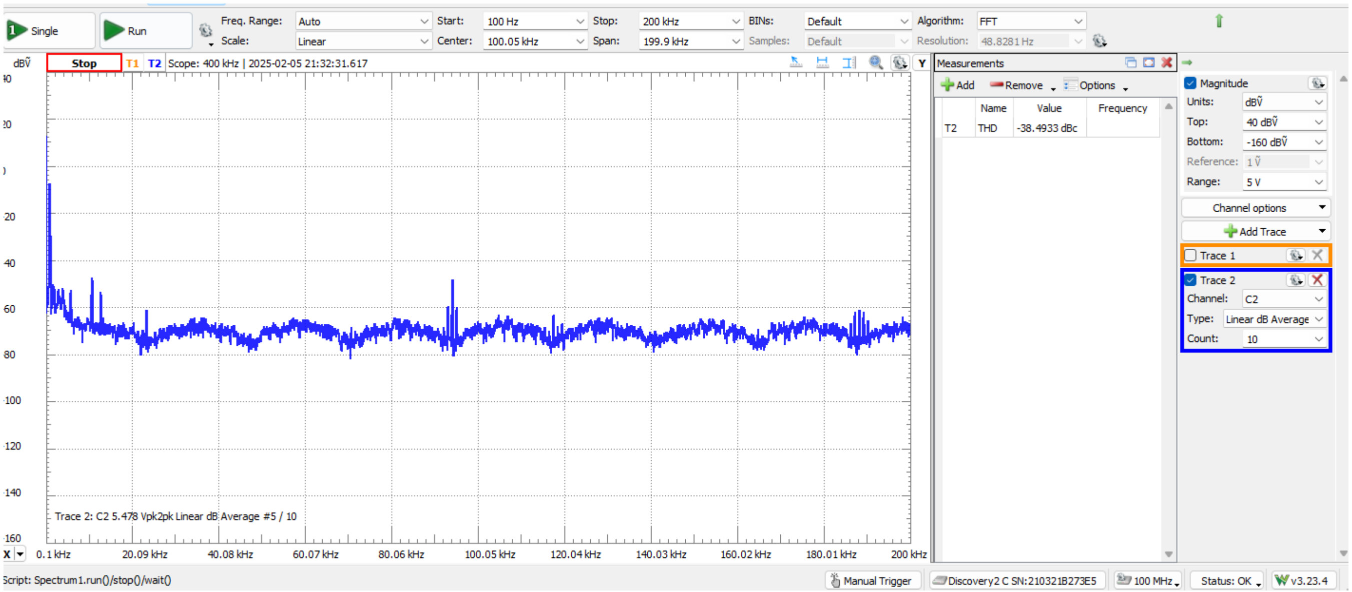
Refer to the below picture for details:

```
//assumes system clock is at 48 MHz
//input dividers on Timer A = div 1, input to Timer A = 48 MHz
//Divide by 512 -> PWM frequency = 93.75 kHz

#define SMCLK    BIT0        //port 7.0
#define A8_IN    BIT5        //port 4.5 ADC input channel 8

#define PWM_PERIOD  512      //9-bit DAC (2^9 = 512)
#define ADCSCALE    5        //14-bit ADC; reduce by 5 bits to match DAC
```

3 Measurements

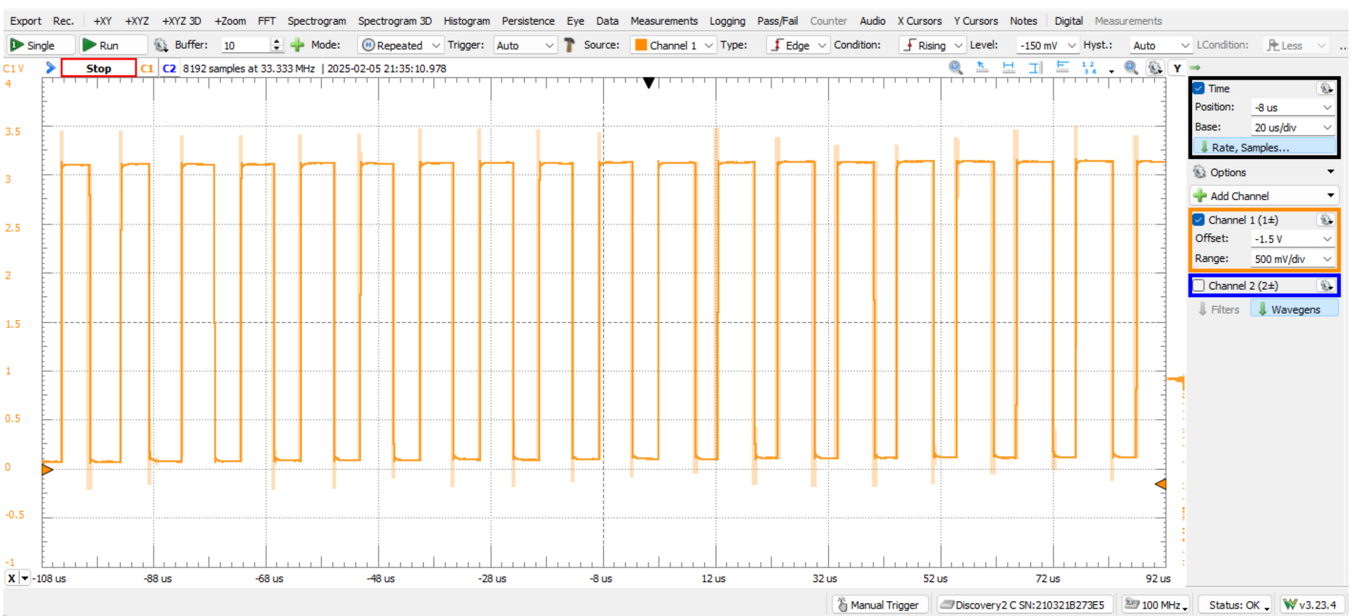
3.1 Total Harmonic Distortion

THD value is -38.4933 dBc.

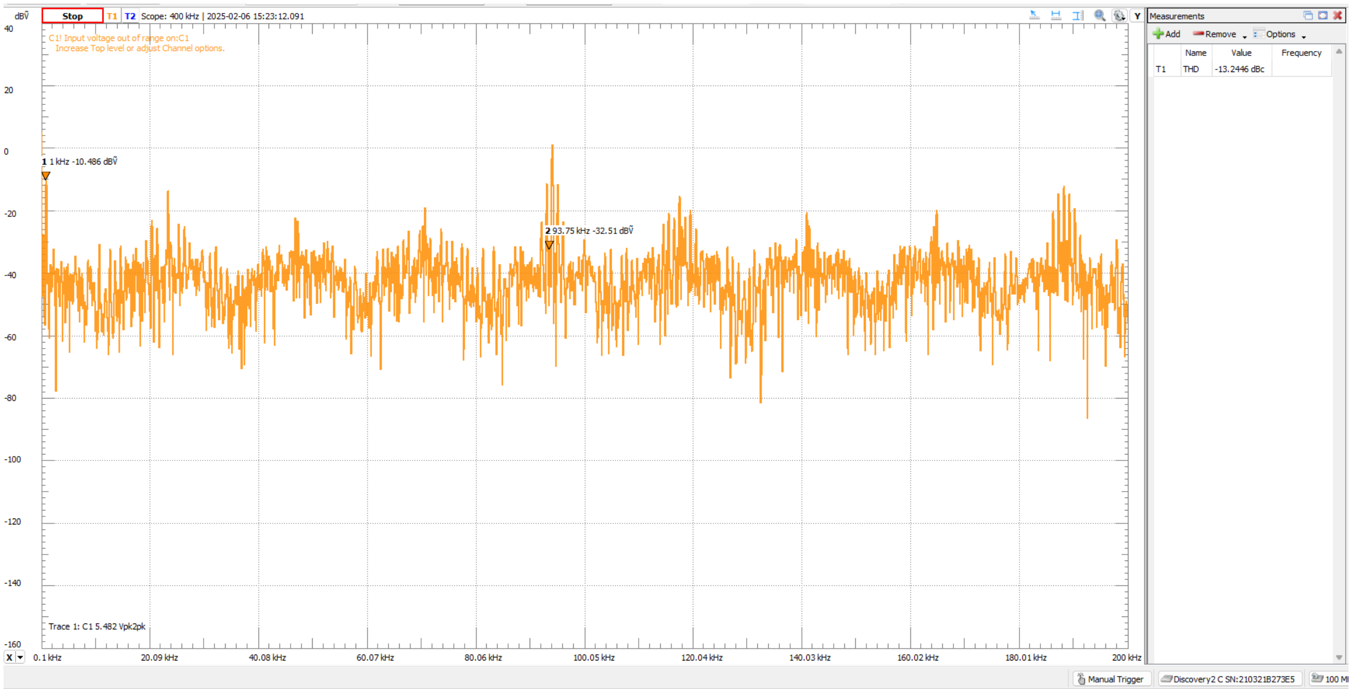


3.2 PWM Output

3.2.1 Time Domain



3.2.2 Frequency Domain



Q. How much is it above the desired signal at 1kHz in dB?

1kHz shows -10.486 dBV and at 93.75kHz shows -32.51dBV. The difference is 22.024dB.

Q. Find the THD of the PWM output and compare it to the filtered output's THD.

A. The difference of 23.66 dB (-14.83 dBc → -38.49 dBc) shows the significant improvement in signal quality after filtering. The low-pass filter successfully reduced harmonic distortion, improving the signal fidelity. The filtered output is much closer to the original sine wave, whereas the unfiltered PWM output contains excessive harmonics due to its high-frequency switching.

Q. Why is a lowpass filter used on the PWM output?

A. A low-pass filter is used on the PWM output to convert the digital PWM signal back into an analog waveform by removing high-frequency components. Since the original analog sine wave was sampled at 12kHz, the Nyquist frequency is 6kHz, and a 4kHz cutoff filter effectively preserves the signal while attenuating high-frequency PWM noise. PWM encodes amplitude using duty cycles but remains a high-frequency switching signal, so the low-pass filter smooths out rapid transitions, recovering the desired analog waveform. This is essential for Digital-to-Analog Conversion (DAC) using PWM.