Coherent Sampling and Filtering to Improve SNR and THD

TIPL 4303

TI Precision Labs – ADCs

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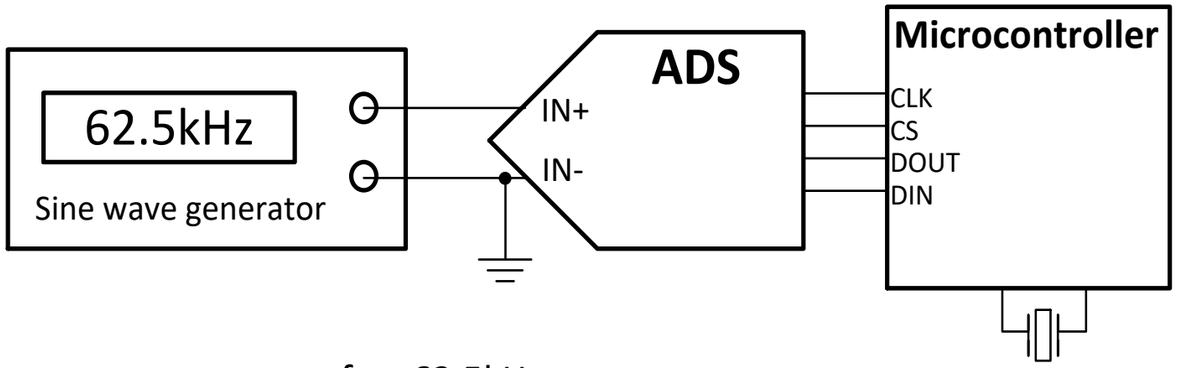
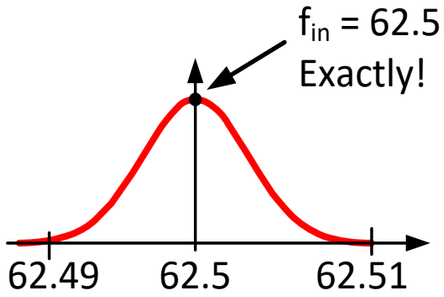
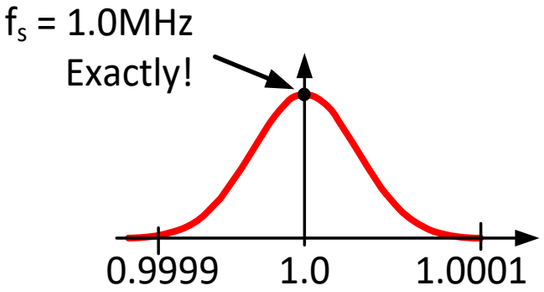
Presented by Peggy Liska

Ideal Situation: Coherent Sampling





Funct. Gen. Frequency Drift (kHz)



Sample Frequency Drift (MHz)
Based on Crystal Stability

Example FFT

$f_s = 1\text{Msps}$ — Sampling Rate

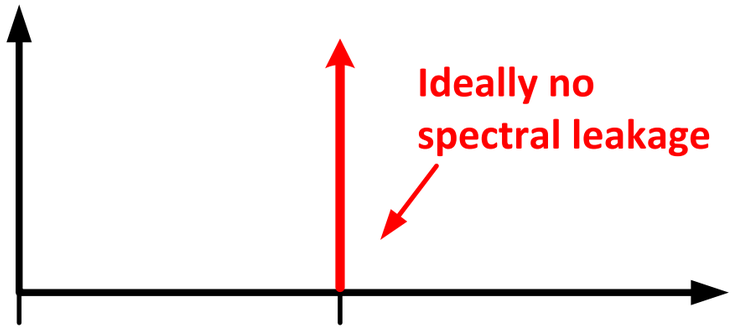
$N_{samp} = 256$ — Number of Samples

$\Delta f = \frac{f_s}{N_{samp}} = \frac{1\text{Msps}}{256} = 3.90625ksps$ — Frequency Resolution

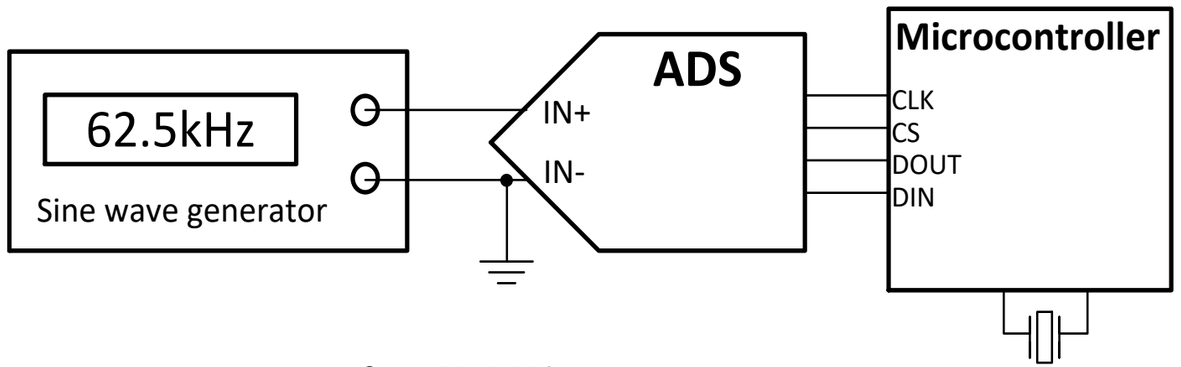
$f_{in} = 62.5kHz$ — Input signal

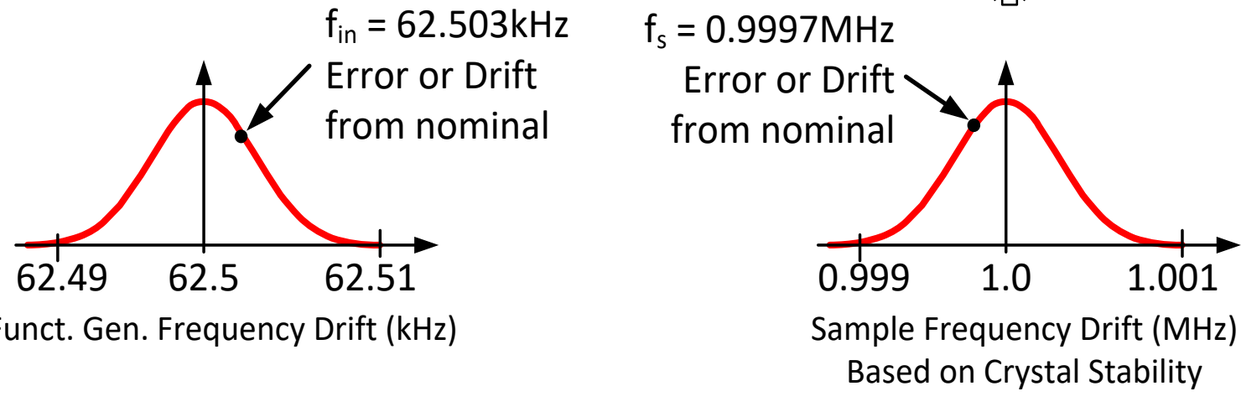
$k_f = \frac{f_{in}}{\Delta f} = \frac{62.5kHz}{3.90625ksps} = 16$ — Frequency Bin

Note: f_{in} is an exact integer multiple of Δf



Reality: Non-Coherent Sampling





Example FFT

$f_s = 1\text{Msps}$ — Sampling Rate

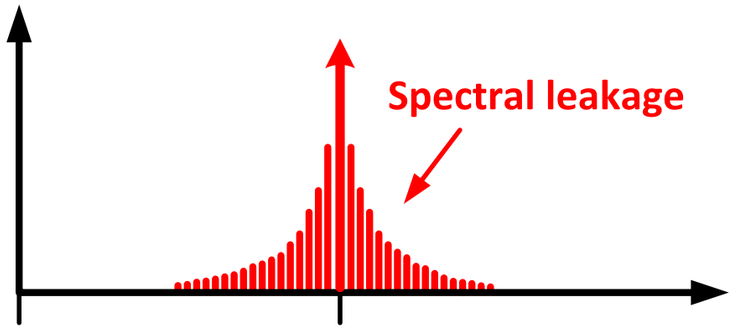
$N_{samp} = 256$ — Number of Samples

$\Delta f = \frac{f_s}{N_{samp}} = \frac{0.9997\text{Msps}}{256} = 3.905078ksps$ — Frequency Resolution

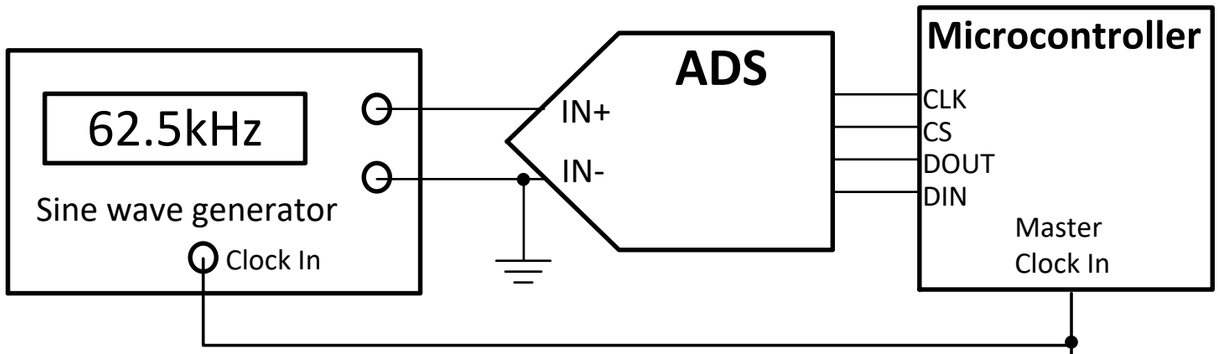
$f_{in} = 62.503kHz$ — Input signal

$k_f = \frac{f_{in}}{\Delta f} = \frac{62.503kHz}{3.905078ksps} = 16.006$ — Frequency Bin

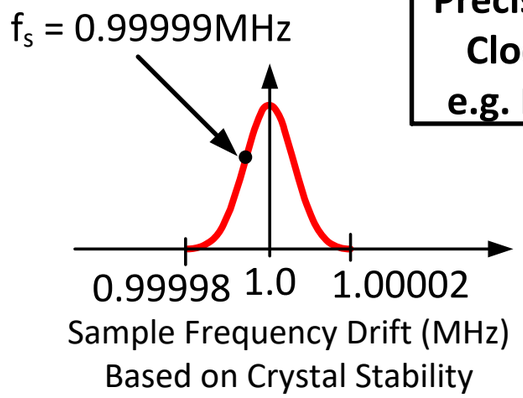
Note: f_{in} is NOT an exact integer multiple of Δf



Practical method for coherent sampling



Function generator divides clock by integer multiples of master clock



Example FFT

$f_s = 0.99999\text{Msps}$ — Sampling Rate

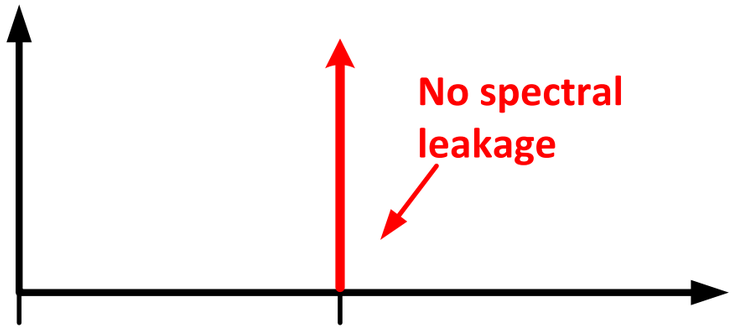
$N_{samp} = 256$ — Number of Samples

$\Delta f = \frac{f_s}{N_{samp}} = \frac{0.99999\text{Msps}}{256} = 3.90589ksps$ — Frequency Resolution

$f_{in} = 16 \cdot \Delta f = 62.499375kHz$ — Input signal Related to f_s

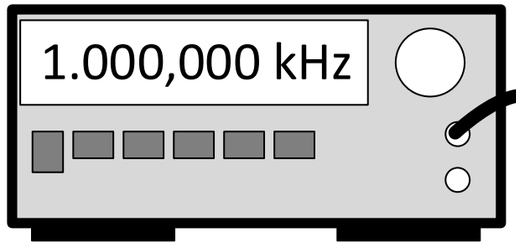
$k_f = \frac{f_{in}}{\Delta f} = \frac{62.499375kHz}{3.90625ksps} = 16$ — Frequency Bin

Note: f_{in} is an exact integer multiple of Δf



Using a filter to clean up signal source

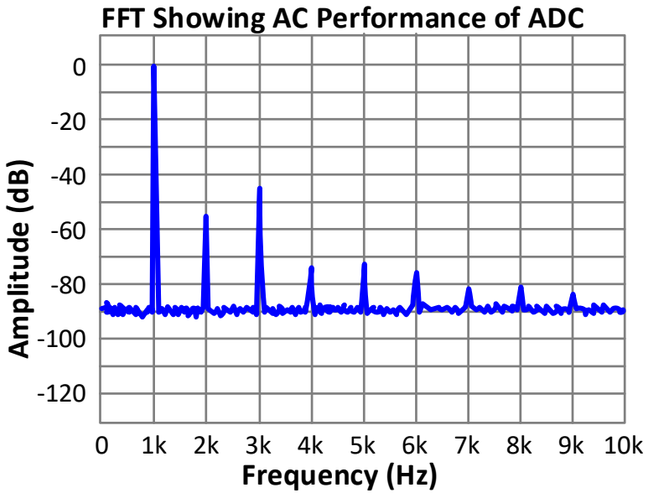
Typical Bench Signal Generator (12 bits)



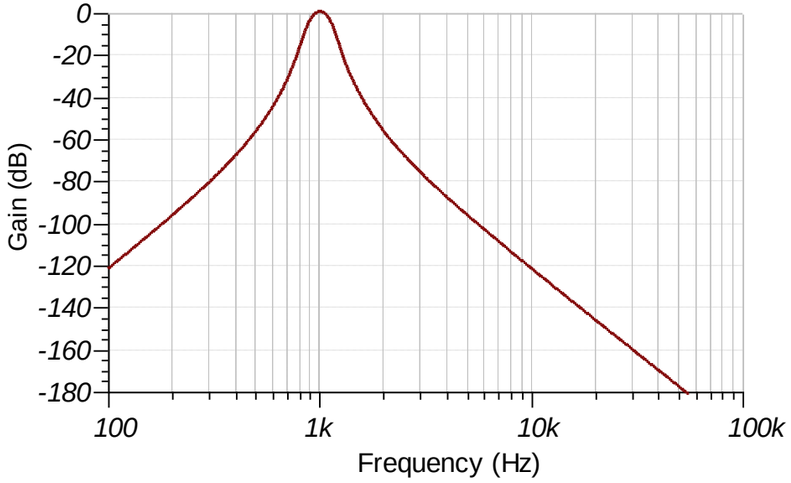
Band pass Filter

Precision ADC (20 bits)

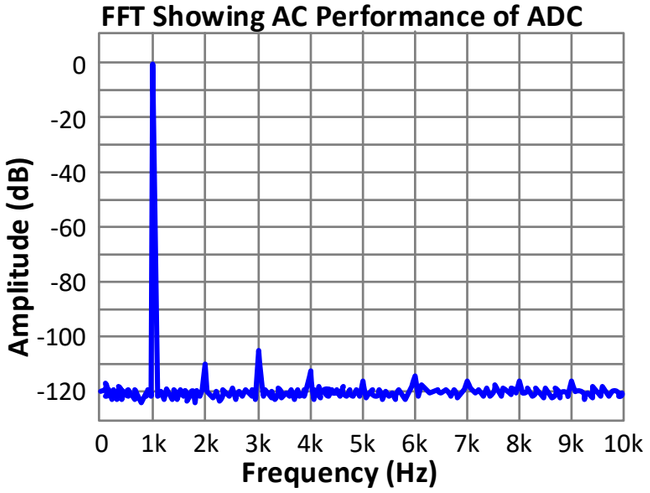
ADC Evaluation Module



12 bits resolution
THD = 79dB, SNR =50dB



8th order filter



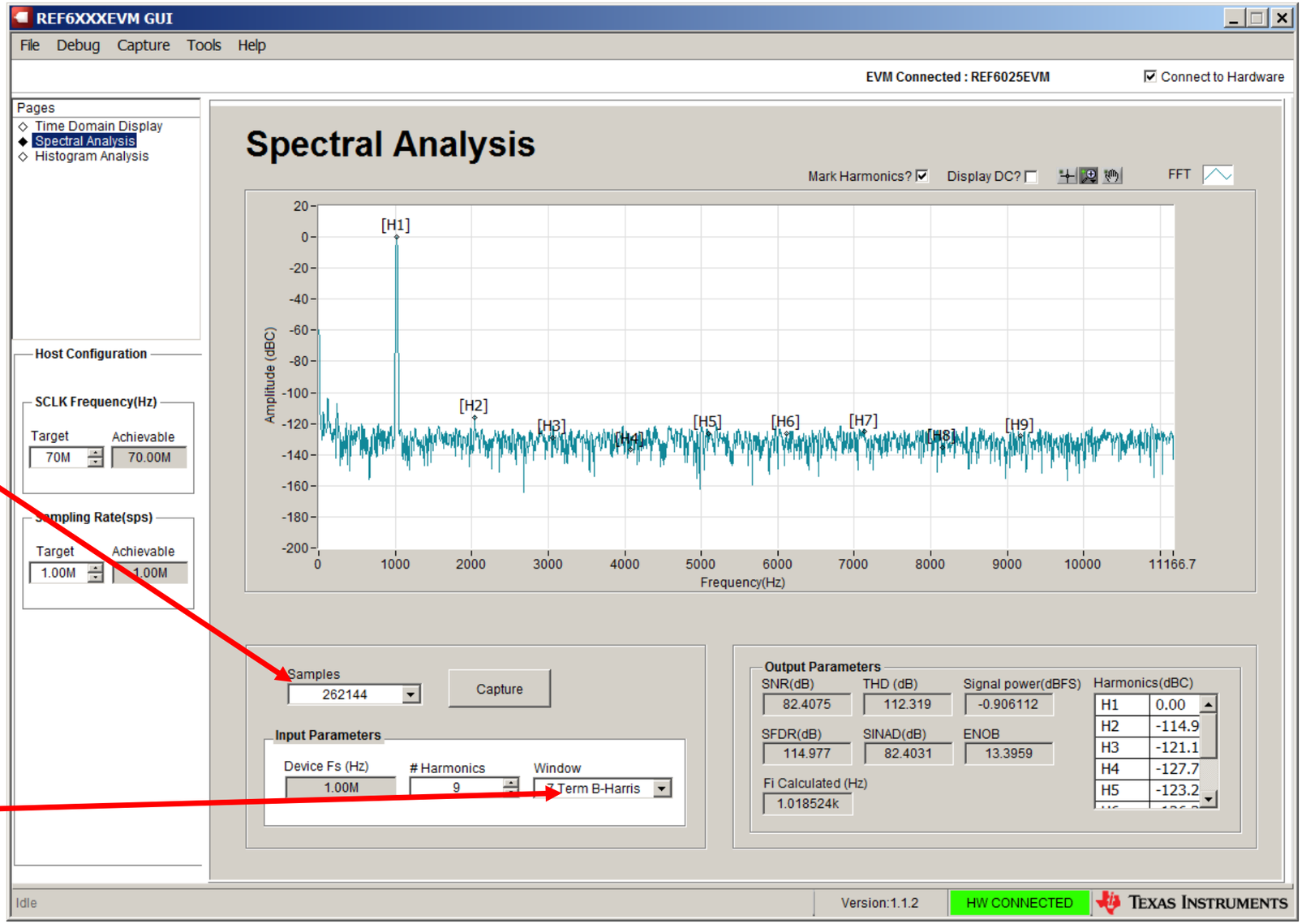
THD = 125dB, SNR =100dB

A practical example

Number of samples in FFT.
Increasing number of samples:

1. Increases frequency resolution
2. Minimizes impact of spectral leakage
3. Many samples increases measurement time and potential of frequency drift

Window type: 7 term Blackman-Harris works best for most ADC characterization.



Thanks for your time!
Please try the quiz.

Quiz: Coherent Sampling and Filtering to Improve SNR and THD

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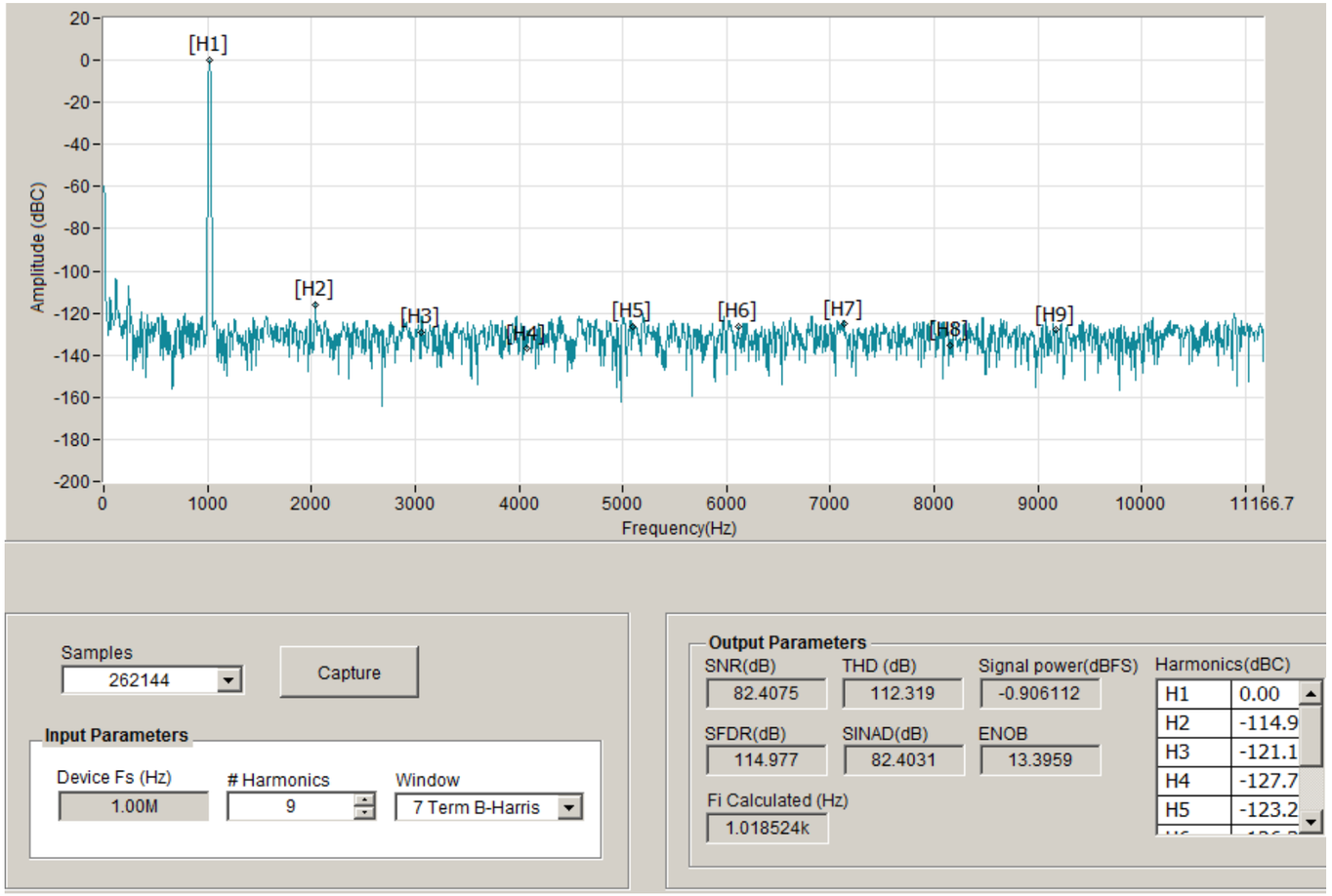
Quiz: Coherent Sampling and Filtering

1. (T/F) Coherent sampling will virtually eliminate spectral leakage?
   a) True.
   b) False.
2. Coherent sampling is _____.
   a) A technique that synchronizes the sampling rate to be a direct multiple of input signal generator frequency.
   b) Mathematical method using a time domain window to minimize spectral leakage and frequency drift.
   c) Samples multiple ADC inputs simultaneously to eliminate phase shift error.
   d) A band pass filter used to eliminate noise and harmonic distortion in the source signal.
3. For ADC characterization, a band pass filter is sometimes used _____.
   a) To eliminate spectral leakage.
   b) As an antialiasing filter.
   c) To drive the RC charge bucket circuit at the input of the switched capacitor ADC.
   d) To minimize the noise and distortion of the source signal.

Quiz: Coherent Sampling and Filtering

4. For the picture below:
   a) Identify the fundamental
   b) What is the amplitude of the second harmonic.
   c) How many samples in the time domain signal?
   d) What would be the advantage and disadvantage of increasing the number of samples.
   e) What type of window is used and why?



Solutions

Quiz: Coherent Sampling and Filtering

1. (T/F) Coherent sampling will virtually eliminate spectral leakage?
   a) **True.**
   b) False.
2. Coherent sampling is _____.
   a) **A technique that synchronizes the sampling rate to be a direct multiple of input signal generator frequency.**
   b) Mathematical method using a time domain window to minimize spectral leakage and frequency drift.
   c) Samples multiple ADC inputs simultaneously to eliminate phase shift error.
   d) A band pass filter used to eliminate noise and harmonic distortion in the source signal.
3. For ADC characterization, a band pass filter is sometimes used _____.
   a) To eliminate spectral leakage.
   b) As an antialiasing filter.
   c) To drive the RC charge bucket circuit at the input of the switched capacitor ADC.
   d) **To minimize the noise and distortion of the source signal.**

Quiz: Coherent Sampling and Filtering

4. For the picture below:
   a) Identify the fundamental. **H1**
   b) What is the amplitude of the second harmonic. **H2 = -114.9dB**

Quiz: Coherent Sampling and Filtering

4. For the picture below:
   d) How many samples in the time domain signal? **262144**
   e) What would be the advantage and disadvantage of increasing the number of samples. **More samples reduces spectral leakage. However, when more samples are used the total measurement time increases which may degrade performance for frequency drift.**
   f) What type of window is used and why? **Seven term Blackman Harris is used. This is generally the best window for ADC characterization. It has very deep attenuation (i.e. it minimizes spectral leakage).**