**TI Precision Labs – ADCs** 

Created by Art Kay

**Presented by Peggy Liska** 





## **Aliasing: Time Domain vs. Frequency Domain**



**Nyquist frequency** = fs/2, the maximum input signal without aliasing.







## **Nyquist Theorem, Sampling Frequency = 1Msps**





The maximum frequency that system without aliasing is half the sampling frequency. This maximum frequency is called



## Eliminate redundant information



## Continues infinitely

![](_page_3_Picture_4.jpeg)

## Anti-aliasing filter (f<sub>s</sub> = 1Msps)

![](_page_4_Figure_1.jpeg)

![](_page_4_Figure_2.jpeg)

Sampling frequency = fs = 1Msps

![](_page_4_Figure_4.jpeg)

![](_page_4_Figure_5.jpeg)

![](_page_4_Picture_6.jpeg)

## **SAR Anti-aliasing Filter Design**

![](_page_5_Figure_1.jpeg)

![](_page_5_Picture_3.jpeg)

## What's the "Charge Bucket" for?

![](_page_6_Figure_1.jpeg)

![](_page_6_Picture_2.jpeg)

# Thanks for your time! Please try the quiz.

![](_page_7_Picture_1.jpeg)

TIPL 4304 TI Precision Labs – ADCs

**Created by Art Kay** 

![](_page_8_Picture_3.jpeg)

![](_page_8_Picture_4.jpeg)

- 1. How do you determine Nyquist frequency?
  - a) It is equal to the sampling rate of the data converter.
  - b) It is equal to twice the sampling rate of the converter.
  - c) It is equal to half the sampling rate of the converter.
  - d) It depends on the anti-aliasing filter.
- 2. Applying an input signal that exceeds the Nyquist frequency will \_\_\_\_\_
  - a) Cause an erroneous "alias" signal to be measured by the ADC.
  - b) Cause damage to the ADC.
  - c) Introduce significant distortion in the signal.
  - d) Cause a dramatic reduction in SNR.

![](_page_9_Picture_11.jpeg)

- 3. A data converter has a sampling rate of 1MHz. The input amplifier has a second order low pass filter with a cutoff frequency of 1MHz. What is a potential issue?
  - No problem, this configuration will work well for antialiasing. a)
  - Any input form 500kHz to 1MHz will not be attenuated at all and will produce aliases. b)
  - A second order filter will not work for antialiasing. C)
  - A band pass filter is required for antialiasing. d)
- A data converter has a sampling rate of 1MHz. A 900kHz input signal is applied. What frequency 4. will show up in the FFT?
  - 100kHz. a)
  - 400kHz. b)
  - 500kHz C)
  - d) No result will be displayed as this exceeds the Nyquist frequency.

![](_page_10_Picture_14.jpeg)

4. Design an anti aliasing filter for a data converter with a 1Msps sampling rate. The desired input signal range is 0 to 100kHz. The filter must attenuate all alias input signals by at least 40dB. Use FilterPro or Filter Designer to design the circuit.

Below is a link to FilterPro. This is a downloadable active filter design tool that helps design op amp active filters.

https://e2e.ti.com/support/amplifiers/precision\_amplifiers/w/design\_notes/3076.filterpro-v3-1

Below is a link to Filter Designer. This is an on-line active filter design tool that helps design op amp active filters

http://www.ti.com/design-tools/signal-chain-design/webenchfilters.html?keyMatch=filter%2520designer&tisearch=Search-EN-Everything

![](_page_11_Picture_10.jpeg)

## **Solutions**

![](_page_12_Picture_1.jpeg)

- 1. How do you determine Nyquist frequency?
  - a) It is equal to the sampling rate of the data converter.
  - b) It is equal to twice the sampling rate of the converter.
  - c) It is equal to half the sampling rate of the converter.
  - d) It depends on the anti-aliasing filter.
- 2. Applying an input signal that exceeds the Nyquist frequency will \_\_\_\_\_\_.
  - a) Cause an erroneous "alias" signal to be measured by the ADC.
  - b) Cause damage to the ADC.
  - c) Introduce significant distortion in the signal.
  - d) Cause a dramatic reduction in SNR.

![](_page_13_Picture_11.jpeg)

- 3. A data converter has a sampling rate of 1MHz. The input amplifier has a second order low pass filter with a cutoff frequency of 1MHz. What is a potential issue?
  - No problem, this configuration will work well for antialiasing. a)
  - Any input form 500kHz to 1MHz will not be attenuated at all and will produce aliases. b)
  - A second order filter will not work for antialiasing. C)
  - A band pass filter is required for antialiasing. d)
- 4. A data converter has a sampling rate of 1MHz. A 900kHz input signal is applied. What frequency will show up in the FFT?
  - 100kHz. a)
  - 400kHz. b)
  - 500kHz C)
  - d) No result will be displayed as this exceeds the Nyquist frequency.

![](_page_14_Picture_14.jpeg)

4. Design an anti aliasing filter for a data converter with a 1Msps sampling rate. The desired input signal range is 0 to 100kHz. The filter must attenuate all alias input signals by at least 40dB. Use FilterPro or Filter Designer to design the circuit.

A simple graphical method can be used to estimate the filter order if you don't use a filter design package. You will see in the next few slides that FilterPro will give more accurate and detailed results.

![](_page_15_Figure_3.jpeg)

## -40dB at 500kHz

-60dB after one decade

![](_page_15_Picture_8.jpeg)

Design an anti aliasing filter for a data converter with a 1Msps sampling rate. The desired 4. input signal range is 0 to 100kHz. The filter must attenuate all alias input signals by at least 40dB. Use FilterPro or Filter Designer to design the circuit.

![](_page_16_Figure_2.jpeg)

## Step 2: Filter Specifications

Please enter filter specifications:

Gain ( <i>Ao</i> ):	1
Passband Frequency ( <i>fc</i> ):	100k
Allowable Passband Ripple ( <i>Rp</i> ):	1
Stopband Frequency ( <i>fs</i> ):	500k
Stopband Attenuation (Asb):	-40

2. Using FilterPro we can enter the passband frequency, stopband frequency and stopband attenuation.

![](_page_16_Figure_8.jpeg)

![](_page_16_Picture_10.jpeg)

## 4 (continued) Using filter Pro.

![](_page_17_Figure_2.jpeg)

## Step 4: Filter Topology

Please select a filter topology:

![](_page_17_Figure_5.jpeg)

![](_page_17_Picture_6.jpeg)

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Name: Lowpass, Salen Key, Besel Part: Ideal Opump Order: 4 Number Of Stages: 2 Gain: 1 V/V (0.68) Allowable PassBand Ripple: 1.69 Passband Frequency: 100 kHz Corner Frequency Attenuation: -3.68 Stopband Attenuation: -0.68 Stopband Frequency: 500 kHz	»	Schematic Data BOM Comments Design Report	
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Stopband Attenuation: 40 dB Stopband Frequency: 500 kHz Rest Component Tolerance - Resistors E192: 0.5% or lower - Capacitors E44: 5% File: Stope: 1 File: Stope: 1 File: Stope: 2 Restand Cain(Ao): 1 File: Stope: 2 Restand Cain(Ao): 1 File: Stope: 2 Restand Cain(Ao): 3 Rest Component Tolerance - Resistors E192: 0.5% or lower - Capacitors E44: 5% 4 A. Finally active fills will meeter 4 A. Finally active fills will meeter 4 Restand Cain(Ao): 1 File: Stope: 1 Restand Cain(Ao): <td></td> <td>Gain: 1 V/V (0 dB) Allowable PassBand Ripple: 1 dB Passband Frequency: 100 kHz Corner Frequency Attenuation: -3 dB</td> <td></td>		Gain: 1 V/V (0 dB) Allowable PassBand Ripple: 1 dB Passband Frequency: 100 kHz Corner Frequency Attenuation: -3 dB	
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Will meet		9.65KΩ 11.8KΩ 4.99KΩ 7.41KΩ	
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riequency (nz)	•	Frequency (Hz) Frequency (Hz)	
v: 3.1.0.23446 Texas Instruments	v: 3.1.	0.23446 Qin Texas Instruments	

y, FilterPro provides the your requirements.

# ter component selection that

![](_page_18_Picture_4.jpeg)

![](_page_19_Figure_1.jpeg)

![](_page_19_Picture_2.jpeg)