Electronics 3 **Analog to Digital Converters** **Exercise 2**

Read application note AN-282 and the supplementary ADC notes to answer the following questions.

1. Explain what are aliases and how they are created in sampled data systems.
2. Explain what ENOB is.
3. Explain why aliases affect the effective ENOB of an ADC.
4. Explain what is quantizing error.
5. Explain what is differential non-linearity in ADC’s.
6. Explain what is integral non-linearity in ADC’s.
7. Explain what SINAD is.
8. Explain what SFDR is – use frequency spectrum to explain.
9. Explain what THD is and why it exists in ADC’s.
10. Explain what IMD is and why it exists in ADC’s.
11. Explain what is aperture time, aperture time jitter and why it degrades ENOB of an ADC.
12. Why is an equalizing filter used after a DAC when it is time to reconstruct the analog signal?
13. Calculate the dynamic range of a 16 bit ADC and explain what it is.

Use the XL anti-alias calculator provided on the website for the following problems.

14. GRAPH LIMITS		BUTTERWORTH ANTI-ALIASING LOW-PASS FILTER			SAMPLING SPEC'S			ADC SPEC'S		
					SAMPLING FREQUENCY	SAMPLE HOLD	NATURAL SAMPLING	NOISE LEVEL	ADC # BITS	APERTURE JITTER
Fmin	Fmax	Fc	ORDER	GAIN (V/V)	Fs	YES/NO	PW	dBrel (FS)	N	rms
100	70000	5000	8	1	20000	no	1.25E-05	-200	16	1.00E-10

Use the above settings and observe what happens to the frequency spectrum when the order of the filter is changed to 4. Also play with the sampling frequency and vary it from 10k to 20k and 30 kHz. What happens to the $ENOB_{eff}$? When is it better? Explain why.

15. GRAPH LIMITS		BUTTERWORTH ANTI-ALIASING LOW-PASS FILTER			SAMPLING SPEC'S			ADC SPEC'S		
					SAMPLING FREQUENCY	SAMPLE HOLD	NATURAL SAMPLING	NOISE LEVEL	ADC # BITS	APERTURE JITTER
Fmin	Fmax	Fc	ORDER	GAIN (V/V)	Fs	YES/NO	PW	dBrel (FS)	N	rms
100	70000	5000	8	1	20000	YES	1.25E-05	-200	16	1.00E-10

A) Use the above settings and observe what happens to the frequency spectrum when sample/hold is used instead of natural sampling. Describe what happens.

B) Now zoom in on the baseband by changing F_{max} to 7000 Hz. Read the the first alias level and the $ENOB_{eff}$ at 1000 Hz, 3000 Hz and 5000 Hz. Explain.

C) Increase F_s to 30 kHz and repeat step B – you may have to change the vertical scale to see the first alias, double click the scale an lower minimum value.

D) Repeat step B with –80 dB_{FS} of noise with settings as shown below.

GRAPH LIMITS		BUTTERWORTH ANTI-ALIASING LOW-PASS FILTER			SAMPLING SPEC'S			ADC SPEC'S		
					SAMPLING FREQUENCY	SAMPLE HOLD	NATURAL SAMPLING	NOISE LEVEL	ADC # BITS	APERTURE JITTER
Fmin	Fmax	Fc	ORDER	GAIN (V/V)	Fs	YES/NO	PW	dBrel (FS)	N	rms
100	7000	5000	8	1	30000	YES	1.25E-05	-80	16	1.00E-10

16. GRAPH LIMITS		BUTTERWORTH ANTI-ALIASING LOW-PASS FILTER			SAMPLING SPEC'S			ADC SPEC'S		
					SAMPLING FREQUENCY	SAMPLE HOLD	NATURAL SAMPLING	NOISE LEVEL	ADC # BITS	APERTURE JITTER
Fmin	Fmax	Fc	ORDER	GAIN (V/V)	Fs	YES/NO	PW	dBrel (FS)	N	rms
100	2.00E+06	1.00E+06	6	1	1.00E+07	YES	1.25E-05	-100	16	1.00E-11

A 0 to 1 MHz signal is sampled at 10 Msa/s and has a noise level of –100 dB_{FS}. Determine the maximum aperture jitter required to maintain a $ENOB_{eff}$ of at least 13 Over the bandwidth of the signal (0 to 1 MHz) with a 6^{th} order filter that has a cutoff frequency of 1 MHz. Repeat for a noise level of –90 dB_F. Explain the results.