ELEN0037
Microelectronics
Tutorials

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Tutorial 6: Data Converters (fundamentals, D/A)

Exercise 1 (1st, P11.2/2nd, P15.2)

What is the SQNR for an ideal 12-bit unipolar A/D converter with $V_{ref} = 3\,V$, when a sinusoid input of $1\,V_{pp}$ is applied?[1] What signal size input would result in an SQNR of $0\,dB$?[2]

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[1] $SQNR = 64.5\,dB$
[2] $V_{pp,input} = 0.6\,mV$

Exercise 2 (1st, P11.7,8/2nd, P15.11,12)

The following measurements are found from a 3-bit unipolar D/A converter with $V_{ref} = 8\,V$:

$$\{-0.01,\ 1.03,\ 2.02,\ 2.96,\ 3.95,\ 5.02,\ 6.00,\ 7.08\}\,.$$

1. In units of LSBs, find the offset error, gain error, maximum DNL, and maximum INL.[3]
2. How many bits of absolute accuracy does the converter have?[4]
3. How many bits of relative accuracy does it have?[5]
4. Based on the previous results, and assuming the same process technology (or components accuracy) is used, what would be the maximum number of bits of such a converter?[6]

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[3] $O_{err} = -0.01\,LSB,\ G_{err} = 0.09\,LSB,\ DNL_{max} = -0.073,\ INL_{max} = -0.091$

[4] $N_{eff,abs} = 6.64\ bits$

[5] $N_{eff,rel} = 6.46\ bits$

[6] $N_{max} = 6\ bits$

Exercise 2 (continued)

The following table lists the different words, with the corresponding ideal values, actual measurements, compensated values, INL, and DNL:

word	$V_{ideal}\,(V)$	$V_{actual}\,(V)$	$V_{compensated}\,(V)$	INL	DNL
000	0	-0.01	0	0	$+0.027$
001	1	1.03	1.027	-0.027	-0.023
010	2	2.02	2.004	0.004	-0.073
011	3	2.96	2.931	0.069	-0.022
100	4	3.95	3.909	0.091	-0.057
101	5	5.02	4.966	0.034	-0.033
110	6	6.00	5.933	0.067	$+0.067$
111	7	7.08	7	0	

Exercise 3 (1st, P11.9/2nd, P15.13)

A 10-bit A/D converter has a reference voltage $V_{ref} = 10.24\,V$, calibrated at $T = 25\,°\mathrm{C}$. Find the maximum allowable temperature coefficient in terms of $\mu V/°\mathrm{C}$ for the reference voltage if the reference voltage is allowed to cause a maximum error of $\pm 1/2\,LSB$ over the temperature range of 0 to $50\,°\mathrm{C}$.[7]

[7] $Coeff_{temp} = 200.2\,\mu V/°C$

Exercise 4 (1st, P11.10/2nd, P15.14)

Consider the following measured voltages for a 2-bit D/A converter with $V_{ref} = 4\,V$:

$$\{00 \leftrightarrow 0.01V,\, 01 \leftrightarrow 1.02V,\, 10 \leftrightarrow 1.97V,\, 11 \leftrightarrow 3.02V\}\,.$$

1. In units of LSBs, find the offset error, gain error, maximum DNL, and maximum INL.[8]
2. How many bits of absolute accuracy does the converter have?[9]
3. How many bits of relative accuracy does it have?[10]
4. Based on the previous results, and assuming the same process technology (or components accuracy) is used, what would be the maximum number of bits of such a converter?[11]

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[8] $O_{err} = 0.01\,LSB$, $G_{err} = 0.01\,LSB$, $DNL_{max} = 0.05$, $INL_{max} = -0.047$

[9] $N_{eff,abs} = 7.06\,bits$

[10] $N_{eff,rel} = 6.4\,bits$

[11] $N_{max} = 6\,bits$

Exercise 5 (1st, P11.11/2nd, P15.15)

Find the maximum magnitude of quantization error for a 12-bit A/D converter having $V_{ref} = 5\,V$ and $1/2\,LSB$ additional absolute accuracy.[12]

[12] $E_{max} = 1.22\,mV$

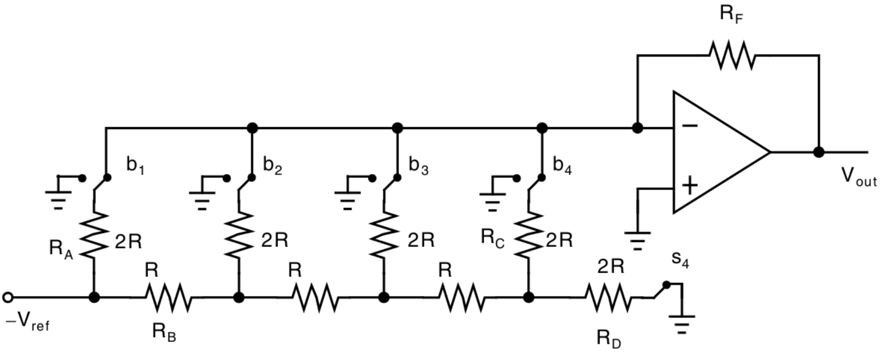
Exercise 6 (1st, P11.12/2nd, P15.16)

What sampling-time uncertainty can be tolerated for a 16-bit A/D converter operating on an input signal from $0 - 20\,kHz$?[13] (We assume a full scale input sine wave, and we allow an absolute error $\Delta V = V_{LSB}$.)

[13] $\Delta t < 0.24\,ns$

Exercise 7 (1st, P12.11/2nd, P16.11)

For the 4-bit R-2R-ladder D/A converter shown hereafter, what is the output error (in LSBs) when $R_A = 2.01R_B$?[14] What is the output error (in LSBs) when $R_C = 2.01R$?[15]



[14] *Output error* $= 0.04$ *LSB*

[15] *Output error* $= 0.005$ *LSB*