Chapter 28

Problem 28.1

The quantization levels needed is

$$M = \frac{150°C - (-50°C)}{0.1°C} = 2000$$

Assume the resolution of ADC is N.

$$2^N = 2000 \Rightarrow N = 10.9$$

∴ A 11-bit ADC is required.

Problem 28.2

The frequency of $15° \sin(0.01 \times 2\pi t)$ is 0.01 Hz.
According to Nyquist criterion, the minimum sampling frequency is $F_{sampling} = 2F_{max} = 0.02$ Hz, that is, the sampling rate required is 0.02 sample/sec.

Problem 28.3

For a 16-bit ADC, $1\ LSB = \frac{V_{ref}}{2^N} = \frac{5V}{2^{16}} \approx 76.3\ \mu V$.

∴ The maximum droop allowed is $\frac{1}{2} LSB \approx 38.1\ \mu V$.

Problem 28.4

Assume ADC is ideal, the maximum speed is

$$\frac{1}{5\mu s} = 0.2 \times 10^6 = 200\ kHz$$

Problem 28.4 (cont.)

Since the resolution of the S/H circuit is 1%, the maximum resolution of the ADC, N, is given by

$$\frac{1}{2^N} = 1\% \Rightarrow N = 6.64 \approx \underline{\underline{7}}.$$

Problem 28.5

The smallest incremental change at output is

$$1\,LSB = \frac{V_{REF}}{2^N} = \frac{10V}{2^{14}} \approx \underline{\underline{0.61\,mV}}$$

The DAC's full-scale value is

$$V_{FS} = \frac{2^N - 1}{2^N} V_{REF} = \frac{2^{14} - 1}{2^{14}} \times 10\,V \approx \underline{\underline{9.9994\ V}}$$

The accuracy is

$$\frac{1}{2^N} = \frac{1}{2^{14}} = \underline{\underline{6.1 \times 10^{-5}}}$$

28.6

Digital Input	Voltage Output(V)	Actual Step height(V)	Ideal Step height(V)	DN
000	0			
001	0.625	0.625	0.625	0
010	1.5625	0.9375	"	0.31
011	2.0	0.4375	"	-0.1
100	2.5	0.5	"	-0.1
101	3.125	0.625	"	0
110	3.4375	0.3125	"	-0.3
111	4.375	0.9375	"	0.3

$|DNL|_{max} = 0.3125(V) = \boxed{0.5\ LSB} \leftarrow 1\ LSB = \frac{5}{2^3} = 0.625$

28.7

Digital Input	Actual Voltage Output (V)	Ideal Voltage Output(V)	INL(V)
000	0	0	0
001	0.625	0.625	0
010	1.5625	1.25	0.3125
011	2.0	1.875	0.125
100	2.5	2.5	0
101	3.125	3.125	0
110	3.4375	3.75	-0.3125
111	4.375	4.375	0

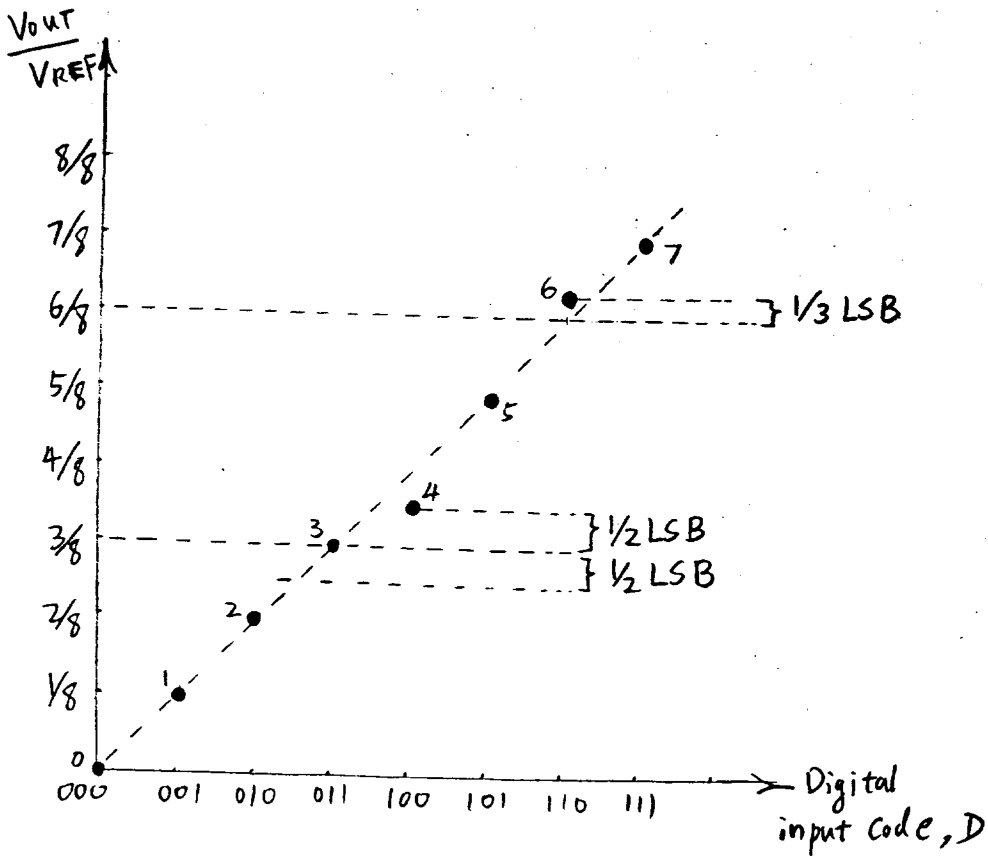
$|INL|_{max} = 0.3125\ (V) = \boxed{0.5LSB}$

28.8

$$0.5\ LSB = \frac{V_{REF}}{2^{N+1}} = \frac{1000\,V}{2^{N+1}} = 2.5 \times 10^{-3}\ V$$

$$2^{N+1} = \frac{1000\,V}{2.5 \times 10^{-3}} = 400{,}000 \Rightarrow N = 18.$$

Problem 28.9



INL :

$INL0 = INL1 = INL2 = INL3 = INL5 = INL7 = 0$

$INL4 = -0.5LSB$, $INL6 = +\frac{1}{3}LSB$

DNL:

$DNL1 = DNL2 = DNL3 = 0$

$DNL4 = \frac{1}{2}LSB - 1LSB = -\frac{1}{2}LSB$

$DNL5 = 1\frac{1}{2}LSB - 1LSB = +\frac{1}{2}LSB$

$DNL6 = 1\frac{1}{3}LSB - 1LSB = +\frac{1}{3}LSB$

$DNL7 = \frac{2}{3}LSB - 1LSB = -\frac{1}{3}LSB$

Problem 28.10

$$V_{FS} = \frac{2^N - 1}{2^N} V_{REF} \quad (\text{where } V_{REF} = 5V, \ V_{FS} = 4.97V)$$

$$\Longrightarrow N \approx 7.38$$

∴ The resolution of the DAC is 7. The dynamic range of the converter is:

$$DR = 20 \log\left(\frac{2^N - 1}{1}\right) dB = 20 \log\left(\frac{2^7 - 1}{1}\right) dB$$

$$\simeq 42 dB.$$

28.11

$$V_{FS} = \frac{2^N - 1}{2^N} V_{REF} = \left(1 - \frac{1}{2^N}\right) V_{REF}$$

$$N = -\frac{\ln\left(1 - \frac{V_{FS}}{V_{REF}}\right)}{\ln 2} = -\frac{\ln(1 - 4.97/5)}{\ln 2}$$

$$= 7.3808$$

The converter resolution is $N = 7$

The converter dynamic range is

$$DR = 20 \operatorname{Log}\left(\frac{2^N - 1}{1}\right) dB$$

$$\doteq 42.08 \ dB$$

Problem 28.12

The SNR of an ADC is given by

$$SNR = 6.02N + 1.76 = 94 \text{ (dB)}$$

$$\Longrightarrow N = 15.3$$

$\therefore$ The effective number of bits of resolution of the converter is 15.

Problem 28.13

There are two ways to eliminate aliasing: sampling at higher frequencies or filtering the analog signal before sampling. From theory, sampling at the frequency at least two times the highest frequency contained in signal will essencially eliminate the aliasing. The problem is that in practice some noise signals are wide-band, which makes this method practical impossible and costly. It is good practice to filter the analog signal to eliminate any unknown higher order harmonics or noise before sampling. However, simply filtering the input signal and the sampled signal will add delays to the overall conversion and increase the expense of the circuit. The best way is to use a combination of the two methods.