

CHEMISTRY 133
Spring, 2017 Homework 1.2 Solutions
Non-Collected Problems (R&R problems + 1.2.6 and 1.2.7)

R&R Problems: 17.2, 17.3, 17.4

17.2. It is estimated that the S/N of a particular experiment is 1:10. How many times must the data be averaged to obtain a S/N of 10:1? of 20:1?

$$S/N = kn^{0.5} \quad (n = \text{number of trials}) \text{ or } (S/N)_{n=1}/(S/N)_n = 0.1/10 = 0.01 = (1/n)^{0.5}$$

$$\text{or } n^{0.5} = 100 \text{ or } n = \mathbf{10,000}$$

To get a S/N of 20:1, $n^{0.5} = 200$ or $n = \mathbf{40,000}$

17.3. An ADC has 16 bits of resolution.

a) How many different levels can it register?

16 bits means 2^{16} levels = $\mathbf{6.55 \times 10^4}$ levels

b) If the output is in absorbance, at $A = 0.6$ what is the minimum difference in absorbance that can be discerned?

Not enough information is given to answer this. First of all, it is not clear if the ADC is reading A , T (transmittance) or light intensity. Second, the minimum and maximum values are not given.

If the signal is absorbance (the log of the transmittance can be created using analog electronics), the minimum normally would be close to zero with a maximum of 1 or 2 typical (but could be as high as 5). It is more likely that the ADC is reading transmittance (the ratio of sample light intensity to blank intensity – also possible to calculate through analog electronics). Transmittance varies from 0 to 1. In this case, 1 bit corresponds to $\Delta T = 1/2^{16} = 1.53 \times 10^{-5}$.

$$A = -\log T = -(1/2.303)\ln T \text{ or } dA/dT = -(1/2.303)/T \sim \Delta A/\Delta T \text{ so } \Delta A = -(1/2.303)\Delta T/T$$

$$\Delta A = (0.4342)(1.53 \times 10^{-5})/10^{-A} = (0.4342)(1.53 \times 10^{-5})/10^{-0.6} = 6.64 \times 10^{-6}/2.51 \times 10^{-1} = \mathbf{2.6 \times 10^{-5}}$$

[the text solution is in error]

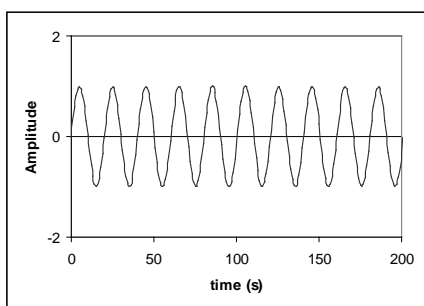
17.4. The ratio of the maximum signal to the rms noise level is often called the **dynamic range**.

For proper translation of the data it is necessary to have at least 1 bit to record the presence of noise (rms) [rms stands for root mean square]. Can the 16-bit ADC properly translate to a signal with a dynamic range of 20,000? With a dynamic range of 100,000?

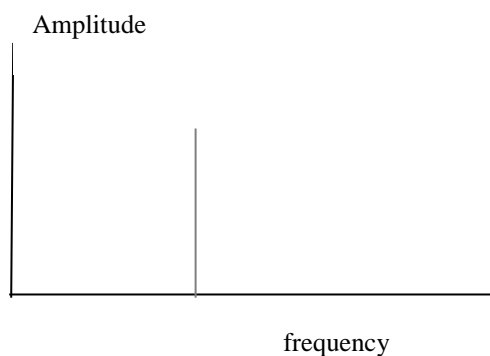
If one bit is to record the noise, then the other 15 bits can detect the signal. This allows a signal to noise of $2^{15}/1$ or = 32,770. So, this allows a dynamic range of more than 20,000 but not 100,000.

1.2.3. Sketch waveforms or Fourier transforms of waveforms

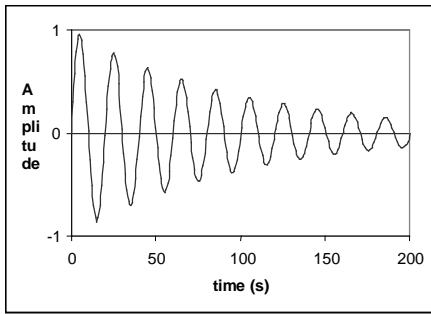
a) assume infinite waveform



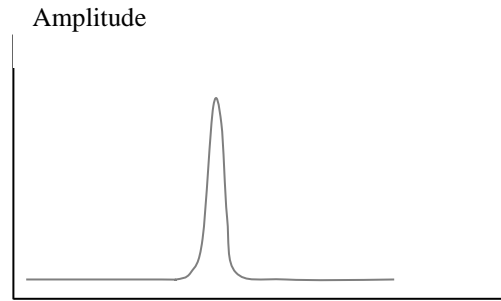
F.T.
→



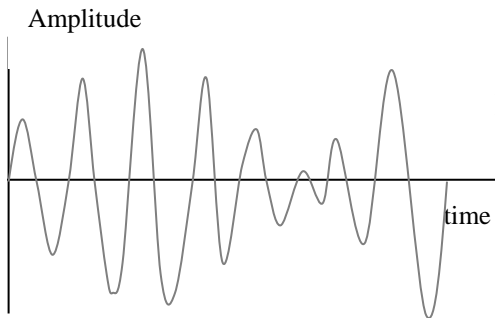
b)



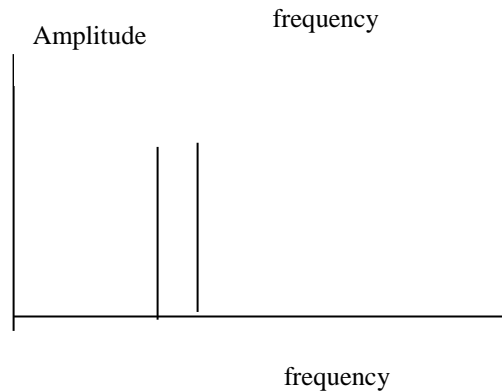
F.T.
→



c)



F.T.
→



1.2.7. A CO monitor with an analog signal of 0.050 V/ppm put is placed in a parking garage. It is desired to be able to record "normal" garage air (concentration ranging between 1 and 10 ppm) as well as to measure high concentration periods when cars drive by (up to 100 ppm). An analog to digital converter with 10 bits with an input range of 0 to 10V is used (0 corresponding to 10 0's and 10 corresponding to 10 1's).

a) Calculate the **voltage** from the monitor and corresponding **decimal** and **binary** numbers from the digitizer given a CO concentration of 8.20 ppm.

$$V = (8.20 \text{ ppm})(0.050 \text{ V/ppm}) = 0.41 \text{ V.}$$

$$\text{Decimal \#} = (V_{\text{meas}} - V_{\text{min}}) \cdot 2^n / (V_{\text{max}} - V_{\text{min}}) = (0.41 \text{ V} - 0) \cdot 2^{10} / (10 \text{ V}) = 41.98 = \mathbf{42} \text{ (could also be 41 depending how rounded)}$$

the **binary number is 101010**

b) What is the maximum CO concentration that can be recorded (without exceeding the A/D board's limit)?

$$10 \text{ V corresponds to } 10 \text{ V} / (0.050 \text{ V/ppm}) = \mathbf{200 \text{ ppm}}$$

c) It is desired to be able to record concentrations as low as 1 ppm with a relative uncertainty of 5% or less. What is the minimum number of bits needed to accomplish this?

*uncertainty = 1/2(smallest bit). This would correspond to 0.05 ppm (5% of 1 ppm). Converting this to V, (0.05 ppm)(0.050 V/ppm) = 2.5 x 10⁻³ V or the smallest bit corresponding to 5 x 10⁻³ V / 10 V = 1/2ⁿ bits. Taking the log of each side: log(5 x 10⁻⁴) = -n log 2 or n = -log(5 x 10⁻⁴) / log 2 = 10.97, so **11 bits would be needed.***