E157 Lecture 22 Day Plan

Any questions before quiz

Quiz + Team Quiz + Talk through solution

Quantization noise

- Clarification on quantization noise stdev – it's also OK to say $\sigma_q = LSB/\sqrt{12}$
- What is the LSB size of an ADC with Nbits and Vfs?
    - LSB = Vfs / [ 2^(Nbits)-1 ], note you need a fencepost at VFS and at 0
- SQNR = 6.02dB/bit +1.76dB
    - Psig = (Vfs/2)^2/2R → "stdev sig" = Vfs/(2*sqrt(2))
    - "stdev quant" = LSB / sqrt(12)
    - Dynamic Range = stdev sig / stdev quant= sqrt(12)/(2*sqrt(2)) * (2^Nbits -1) =sqrt(3/2)…
    - SQNR = (Dynamic Range)^2
    - SQNR_dB = 2*10*[log(sqrt(3/2))+Nbits*log(2)] (ignoring the -1)

Processing Gain – a FFT sets the noise bandwidth

- In an FFT, each f0 captures frequencies from kf0-f0/2 to kf0+f0/2.
- Therefore, Pn=kTB will often have B set by the value of f0
- If f0 is narrower than the narrowest bandpass filter, fBP, then you have an apparent "gain" in SNR, because the noise floor is suppressed by the narrow FFT bandwidth

Are oscilloscopes limited by quantization or thermal noise?
https://www.keysight.com/en/pdx-x201837-pn-DSOX2024A?nid=-32542.1150190&cc=US&lc=eng
8 bits, 200MHz front-end BW into 1MHz termination, smallest V/div is 10mV on 10 divs

- Pn = kTB= (4.14x10^-21 J) * 200MHz = 8.28 x 10^-13W
- vn^2 = 4*R*Pn = 3.31e-6 V^2
- vn = 1.8mV
- vq^2 = LSB^2/12 = (100mV/(256-1))^2/12 = 1.28e-8 V^2 → vq=0.113mV @ tightest zoom
- Steeping out to wider gains increases vq, but also introduces more vertical gain to amplify vn

Noise spreadsheet

- Carrier frequency is 2.4GHz
- Chain goes: T/R switch – amp – filter – amp
- Amplifiers: https://www.minicircuits.com/pdfs/ZRL-3500+.pdf
- Filter: https://www.minicircuits.com/pdfs/VBF-2435+.pdf
- T/R Switch: https://www.minicircuits.com/pdfs/ZFSWA-2-46.pdf
- Fill in spreadsheet below, sketch the spectrum at the output of this system, and pick how many ADC bits and what ADC sample rate you want.

Noise spreadsheet:

https://docs.google.com/spreadsheets/d/1a8tp4q8aZqqk_zcnzNJ1Xu8owhBuvWTrAU_nkpJs9Y8/edit?usp=sharing