

Finish cascade

- Example

- Ferris

Introduce Quantization

- Why

- Linear model

- Power

Spectrum Analyzer

Talking about noise

↳ looking at cascaded example

↳ Using two handy formulas to find noise temp

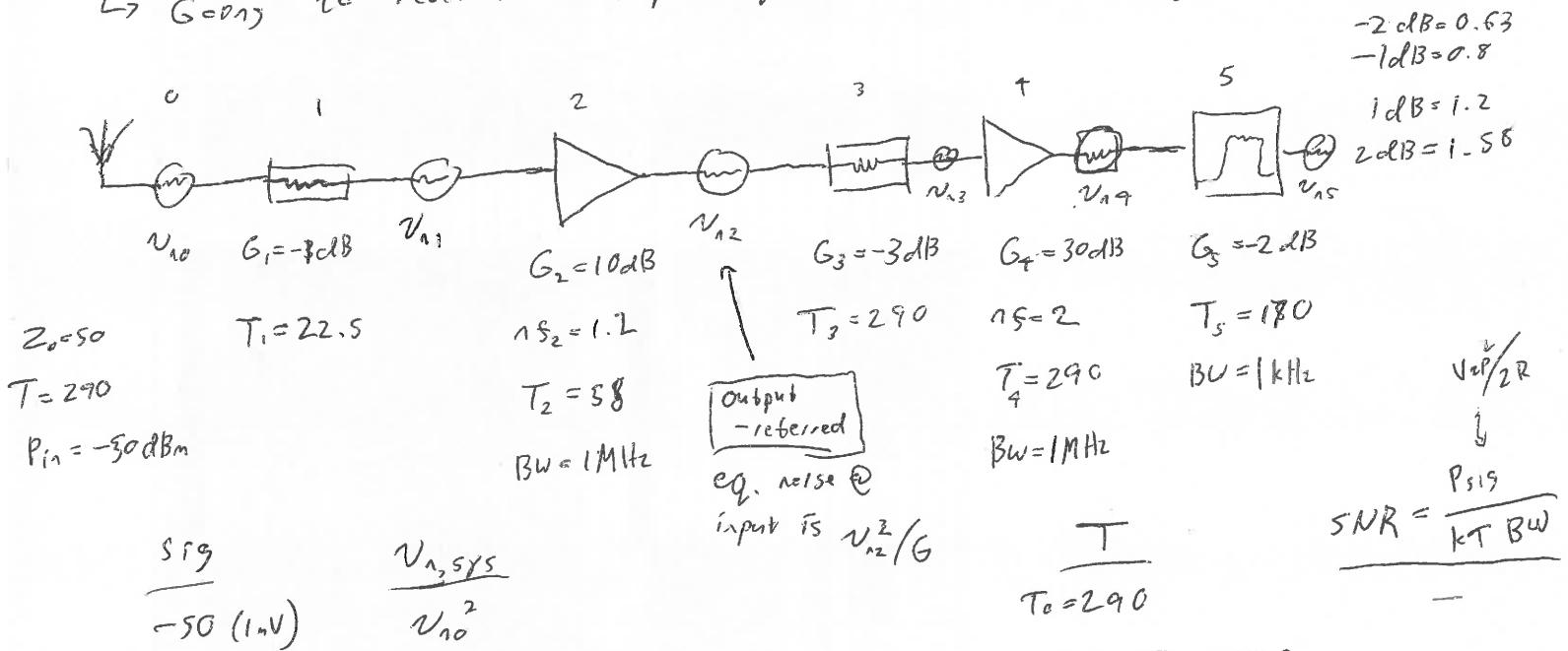
Lessy passive

$$T_N = \left(\frac{1}{G} - 1\right) T$$

Amplifier

$$T_N = (n_f - 1) T \quad \text{v} \quad n_f = \frac{\text{SNR}_i}{\text{SNR}_o} \quad \text{d} \text{SNR} = \frac{P_{S19}}{P_{noise}}$$

↳ Going to redraw & explicitly include noise voltage generators



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$$G_1 V_{n0}^2 + V_{n1}^2$$

$$G_2 (G_1 V_{n0}^2 + V_{n1}^2) + V_{n2}^2$$

$$= G_2 G_1 V_{n0}^2 + G_2 V_{n1}^2 + V_{n2}^2$$

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$$G_3 (G_2 G_1 V_{n0}^2 + G_2 V_{n1}^2 + V_{n2}^2) + V_{n3}^2$$

$$= G_3 G_2 G_1 V_{n0}^2 + G_3 G_2 V_{n1}^2 + G_3 V_{n2}^2 + V_{n3}^2$$

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; - Noise sees all gain after
etc. - Early noise really matters
- Don't control V_{n0} , so focus on
 V_{n1} or V_{n2}

- 16 (50 mV)

$$\begin{aligned} & G_2 (254.5) + T_2 \\ & = 254.5 + 58 \\ & = 260.3 \end{aligned}$$

$$\begin{aligned} & G_3 (260.3) + T_3 \\ & = 0.5 \cdot 260.3 + 58 \\ & = 159.15 \end{aligned}$$

$$\begin{aligned} & 1000(159.15) + 145 \\ & = 1.5 \text{e}6 \end{aligned}$$

$$1.5 \text{e}6 (0.63) + 170$$

$$\begin{aligned} & 2 \cdot 2 \times 10^6 \\ & \left. \begin{array}{l} \text{SNR} \\ \text{degraded} \\ \text{by gain} \end{array} \right\} \end{aligned}$$

$$\begin{aligned} & 1.8 \times 10^6 \\ & \left. \begin{array}{l} \text{effect} \\ \text{smaller} \\ \text{signal} \end{array} \right\} \end{aligned}$$

$$\begin{aligned} & 1.8 \times 10^6 \\ & \left. \begin{array}{l} \text{charge in} \\ \text{BW} \end{array} \right\} \\ & 1.8 \times 10^9 \\ & \left. \begin{array}{l} \text{1.8e-6} \end{array} \right\} \end{aligned}$$

Follow up questions

(1) - Can we capture this with one number?

↳ often we refer all noise to input to capture system temperature

↳ compare $k T_{sys} \text{ BW}$ ^{hardest in system, sometimes from DSP/FFT} vs. $P_{sys} \text{ w/ } T_{sys}$

↳ gives you SNR quickly

$$T_{sys} = \cancel{T_0} + \frac{T_{in}}{G_1} + \frac{T_{in}}{G_1 G_2} + \frac{T_{in}}{G_1 G_2 G_3} \dots \leftarrow \text{can see}$$

↳ in terms of noise factor, recall $T_n = (N_f - 1) T \rightarrow \frac{T_{sys}}{T_0} = (N_{F,sys} - 1)$

$$(N_{F,sys} - 1) = \cancel{N_{F,0} - 1} + N_{F,1} +$$

$$\begin{aligned} (N_{F,sys} - 1) &= (N_{F,0} - 1) + \frac{N_{F,1} - 1}{G_1} + \frac{N_{F,2} - 1}{G_2 G_1} \\ &= N_{F,0} + \frac{N_{F,1} - 1}{G_1} + \frac{N_{F,2} - 1}{G_2 G_1} + \dots \end{aligned}$$

(2) why use gain at all?

↳ SNR starts at 2.2×10^6 !

↳ but signal still very small @ $\sim 50 \text{ mV}$ ^{so} & need to go to ADC

↳ want to model that quantization problem

q_n = quantization noise



quantizer

quant noise

- ideal signal + stairstep

- if signal is near LSB & white
 $P(q=j)$ \rightarrow then q is uniform

- so quantization variance
is $\approx \bar{q}^2 = \frac{\text{LSB}^2}{12}$

- adds to total noise power

e.g.: end of our chain w/
10 bit ADC & 3.3 V supply

$$\bar{q}^2 = (3.2 \text{ mV})^2 / 12 = 0.865 \times 10^{-6} \text{ V}^2$$

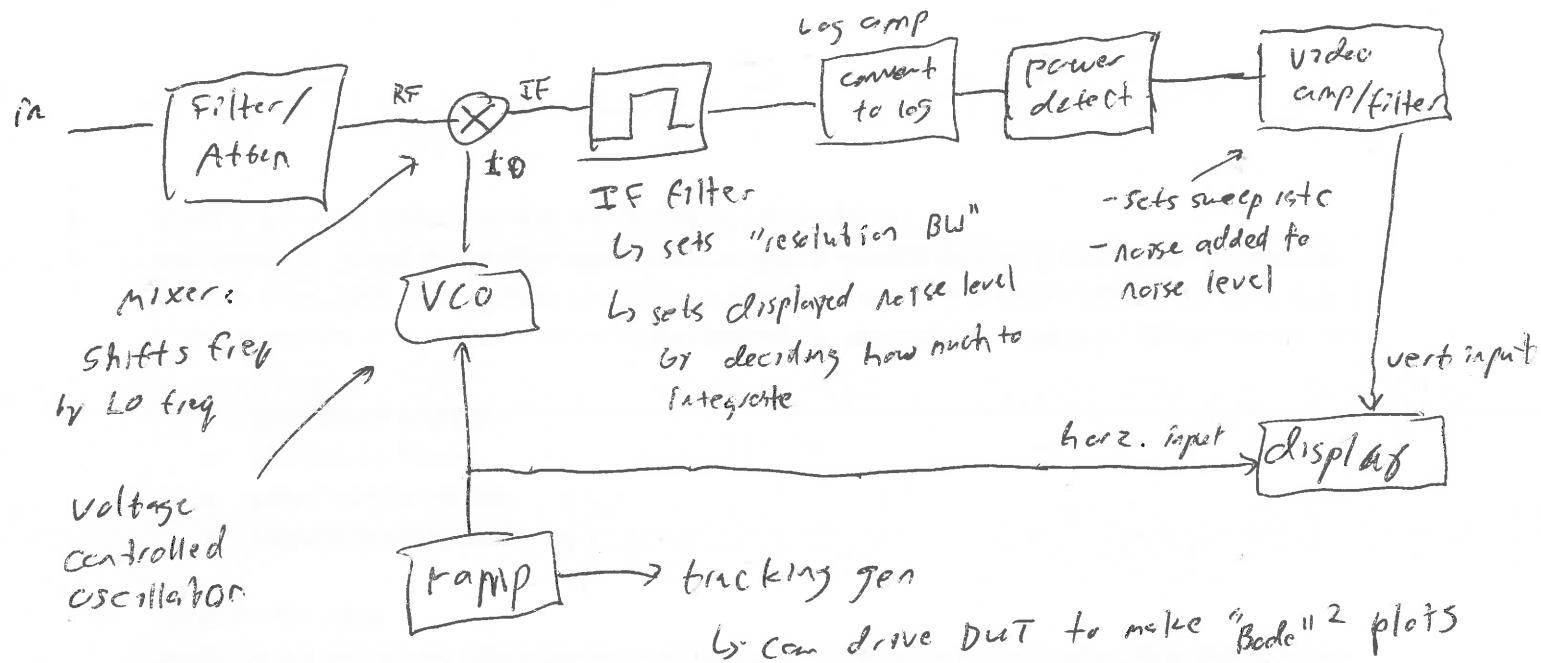


$$2R \cdot kT \text{ BW} = 1.38 \times 10^{-13} \text{ V}^2$$

- note aside: if Δ shrinks by $\frac{1}{2}$ then $\bar{q}^2 \rightarrow \frac{1}{4}$ so SQNR increases @ $\approx 6\text{dB}/6\text{Hz}$

Spectrum Analysers

- Good examples of noise & BW relation
- Also introduce some important tools: VCO & mixer



Take aways

- Displayed noise depends on size of freq. bin
- Determined for our spec on by width of screen
- $\bar{N}_n^2 = \text{BW} + (-114)\text{dB}$