ECE615 Mixed-Signal IC Design

Lecture 4 Slides: Quantization

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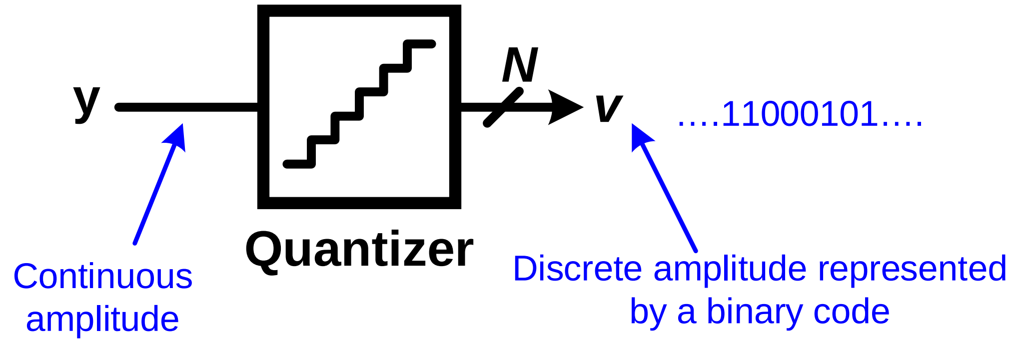
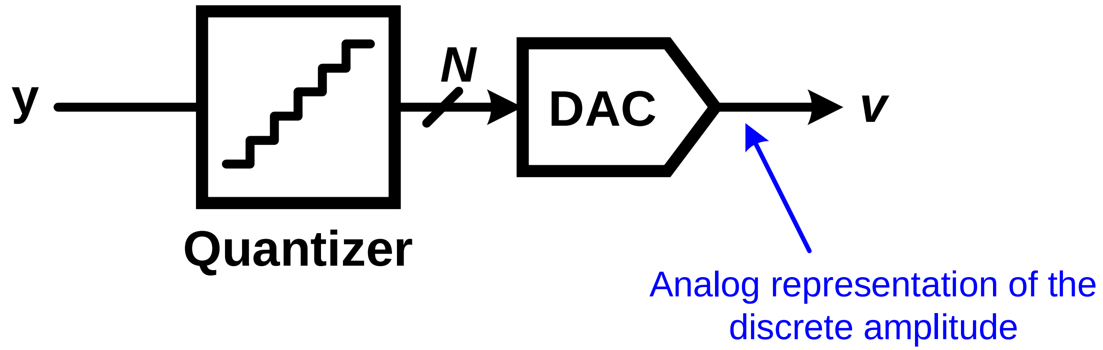
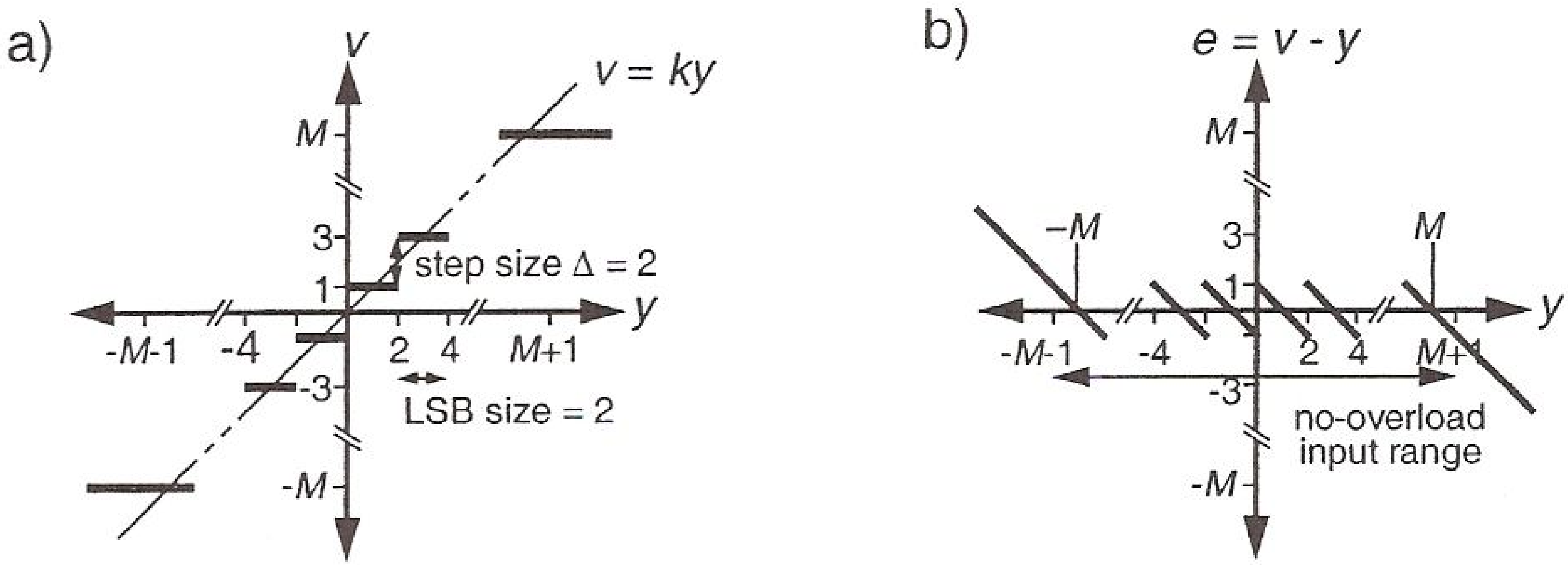
Quantizer



Modeling

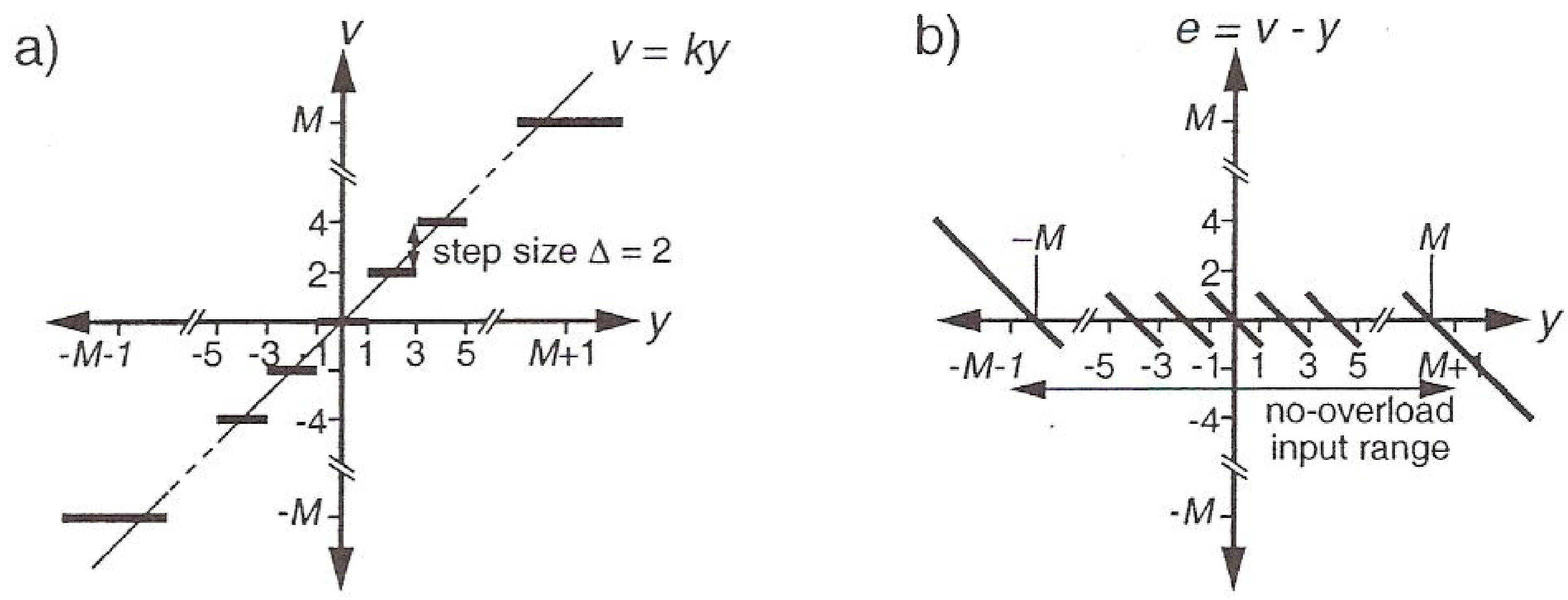


Mid-Rise Quantizer (even number of levels)



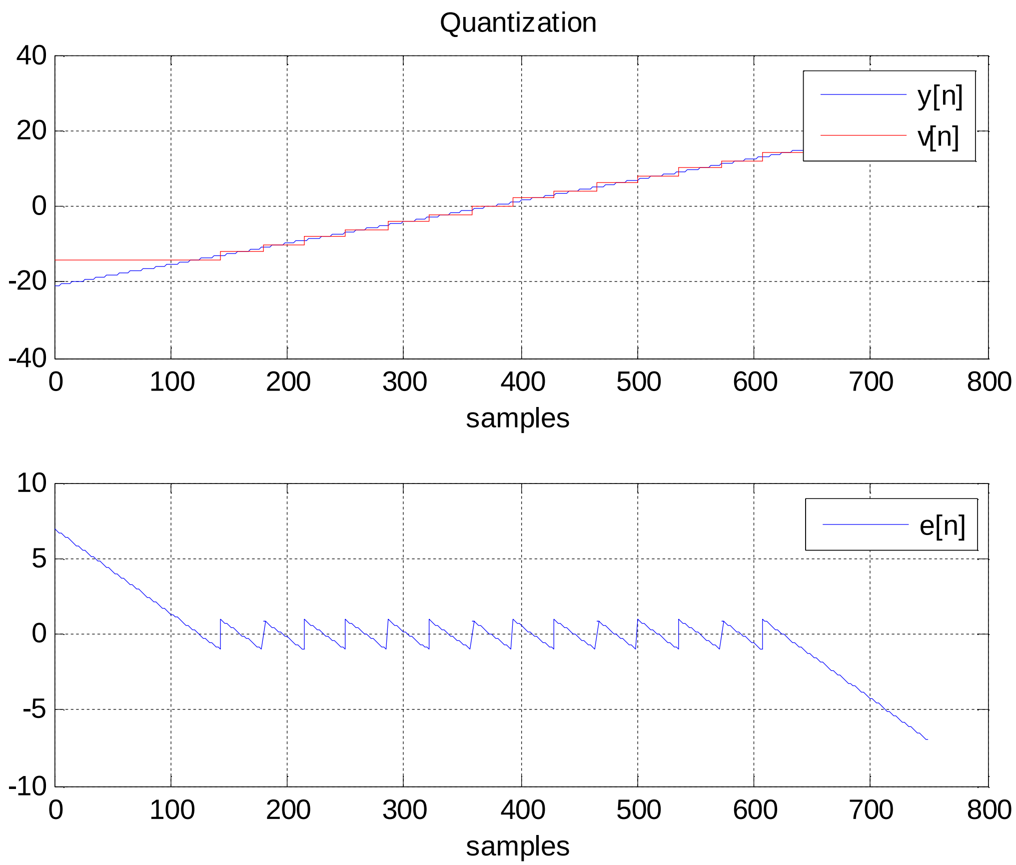
- Step rising at y=0 (mid-rise).
- In this figure (DSM toolbox model), LSB= Δ= 2
- M = Number of steps, (M is odd here)
  - Number of levels (nLev) = M+1, (even)
- Input thresholds: 0, ±2, ……, ±(M–1).
- Output levels: ±1, ±3, ……, ±M.

Mid-Tread Quantizer (odd number of levels)



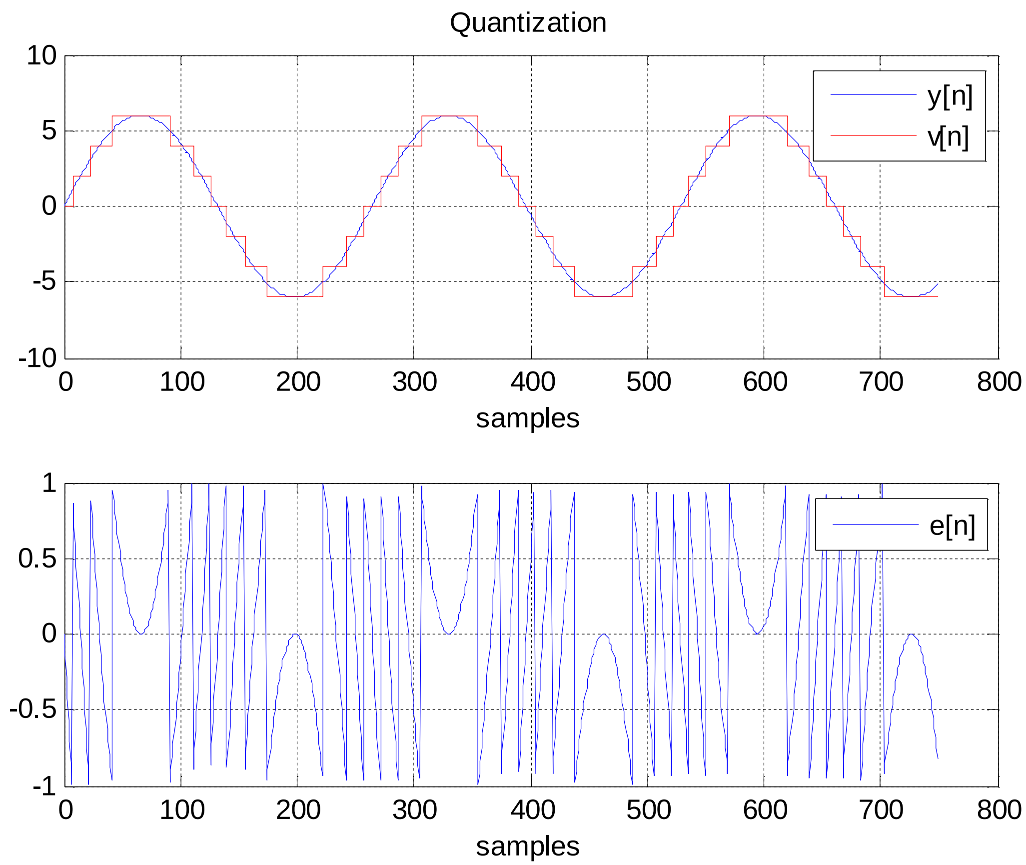
- Flat part of the step at y=0 (mid-tread).
- Here, LSB= Δ= 2
- M = Number of steps, (M is even here)
  - ✓ Number of levels (nLev) = M+1, (odd)
- Input thresholds: 0, ±2, ……, ±(M–1).
- Output levels: 0, ±2, ±4, ……, ±M.

Quantizer characteristics : Slow ramp input



File: Quantizer_ramp_input.m

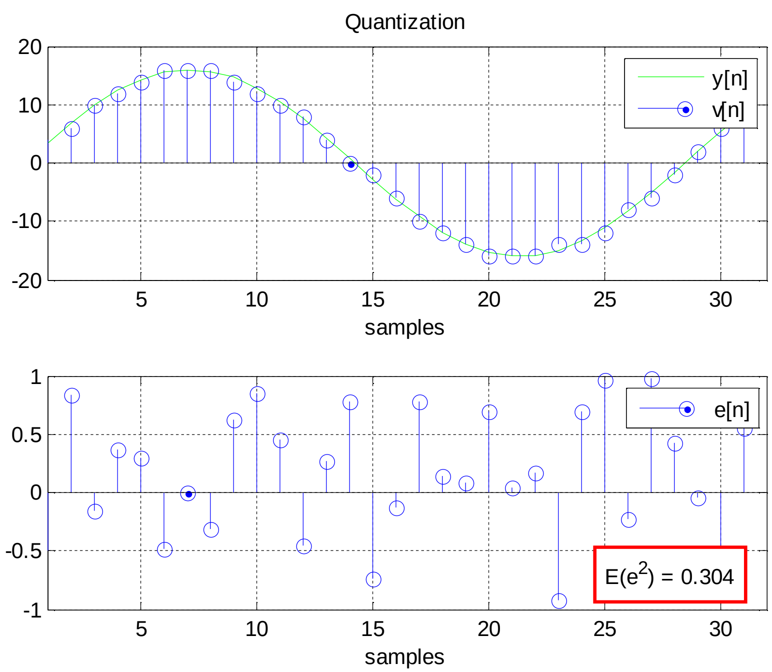
Quantizer characteristics : Sine input

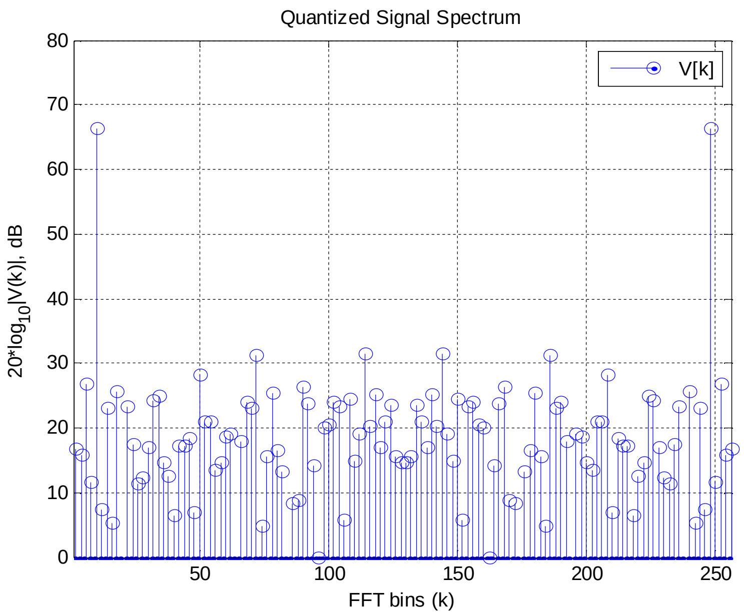


File: Quantizer_sine_input.m

Quantization Noise Spectrum

Quantization Noise : Example 1



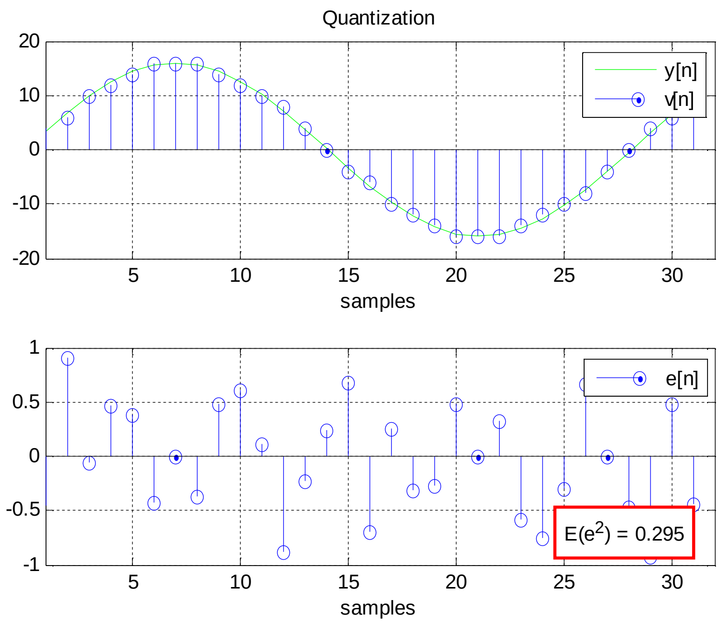


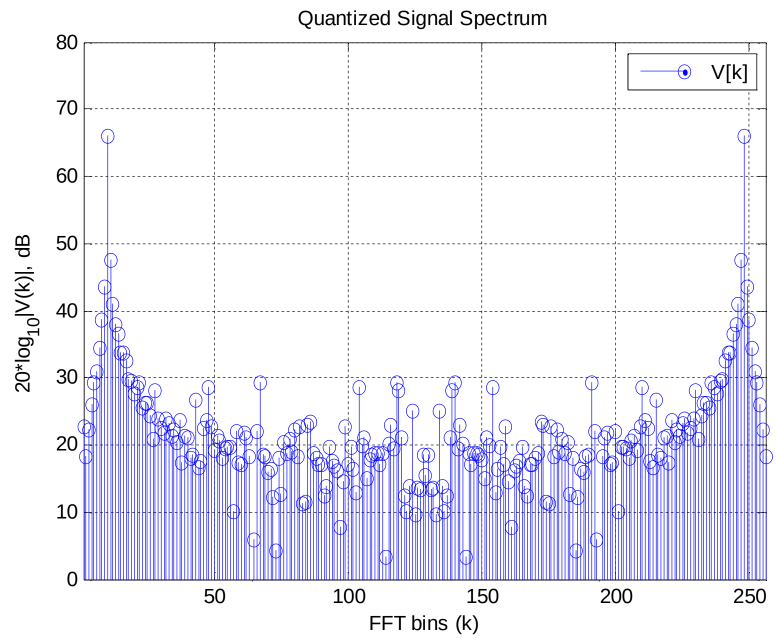
nLev=17, Δ=2, $f_{in}/f_s = 9/256$:

•$E(e^2) = 0.304 \approx \Delta^2/12$

file:Quantization_Noise1.m

Quantization Noise : Example 1 contd.



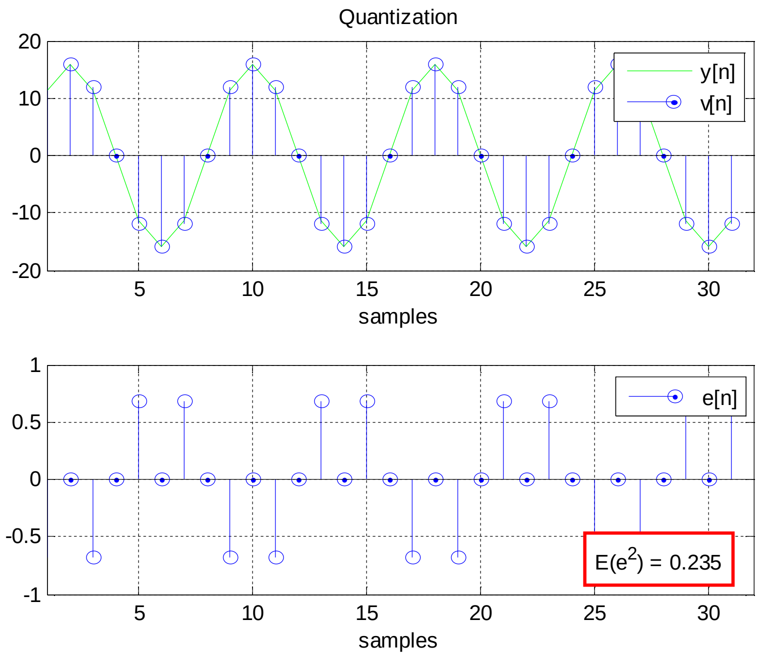


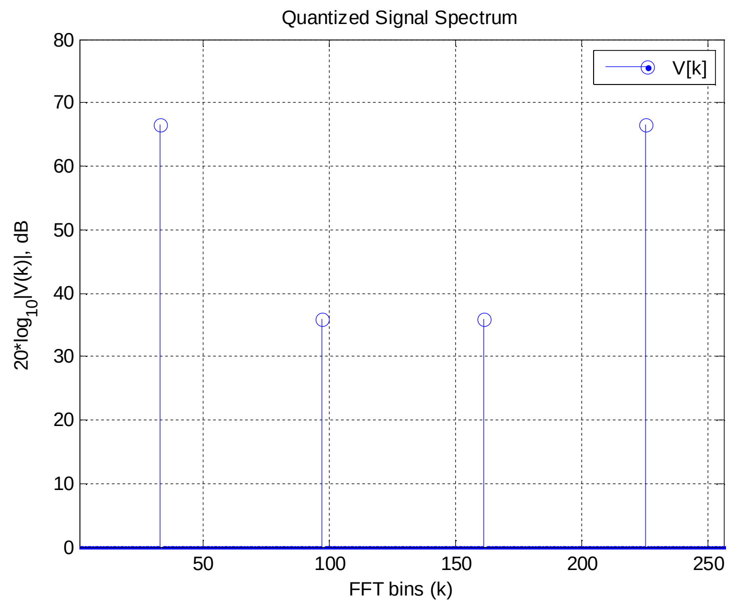
nLev=17, Δ=2, $f_{in}/f_s = 9.1/256$:

- $E(e^2) = 0.295 \approx \Delta^2/12$
- Notice the FFT leakage.

file:Quantization_Noise1.m

Quantization Noise : Example 1 contd.



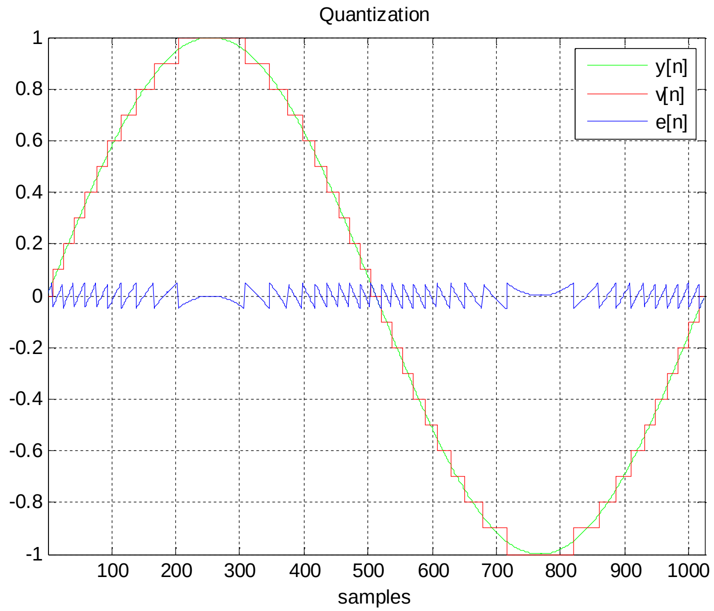


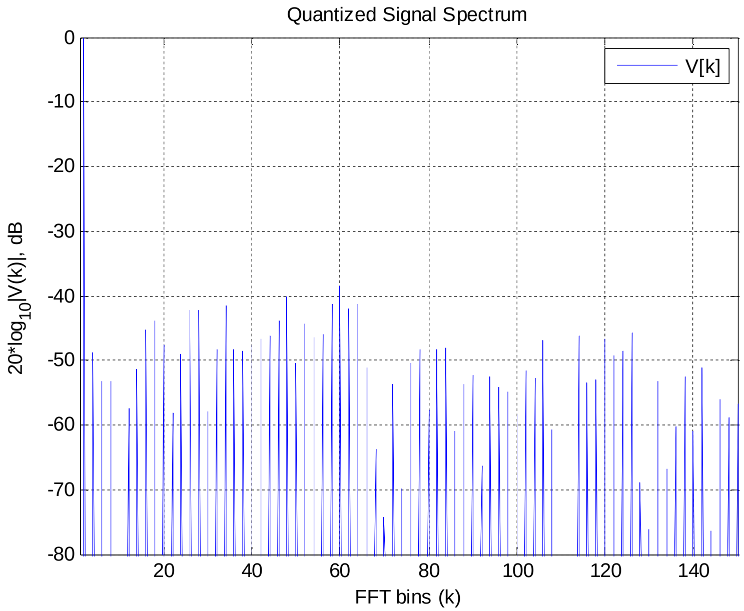
nLev=17, Δ=2, $f_{in}/f_s = 32/256 = 1/8$:

- $E(e^2) = 0.235 < \Delta^2/12$
  - Quantization *noise* approximation not valid

file:Quantization_Noise1.m

Quantization Noise : Example 2



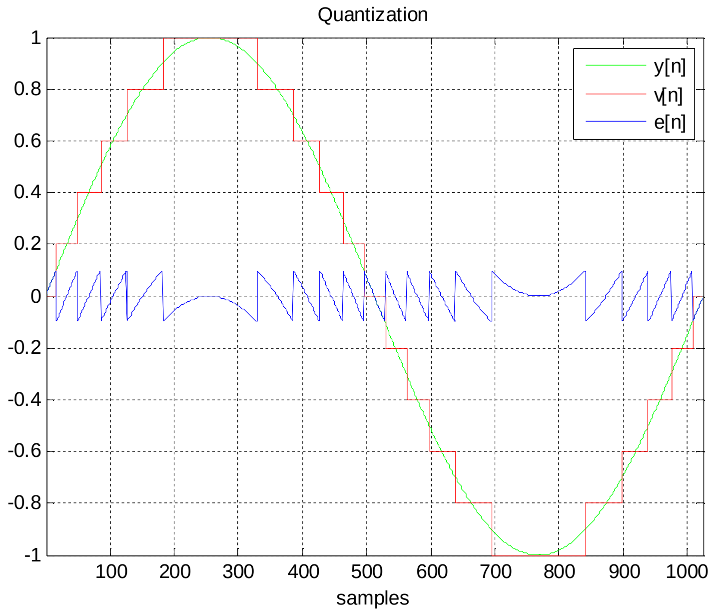


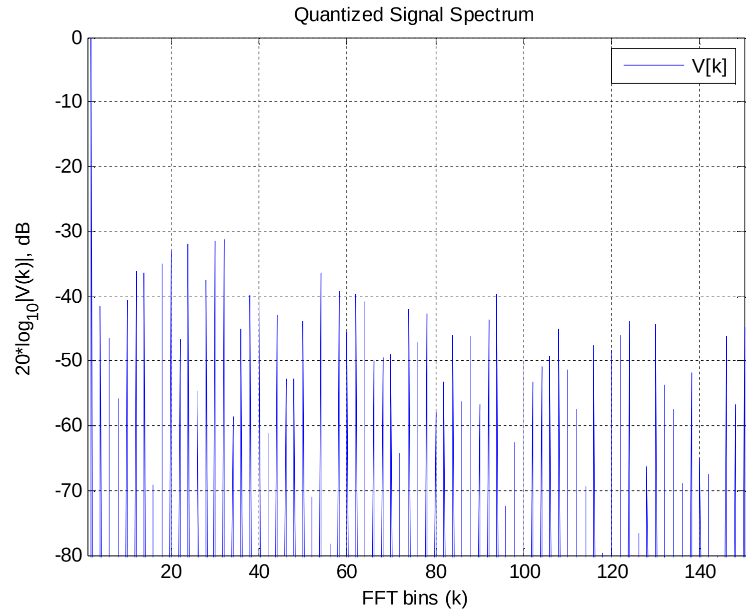
A=1, Δ=0.1, f_{in}/f_s = 1/1024 :

- Most of the tones around the 44th bin
- Average quantization noise floor lowers by 6 dB
- SFDR = -39 dB (SFDR increases by 9 dB if LSB size is halved)

file:Quantization_Noise2a.m

Quantization Noise : Example 2 contd.



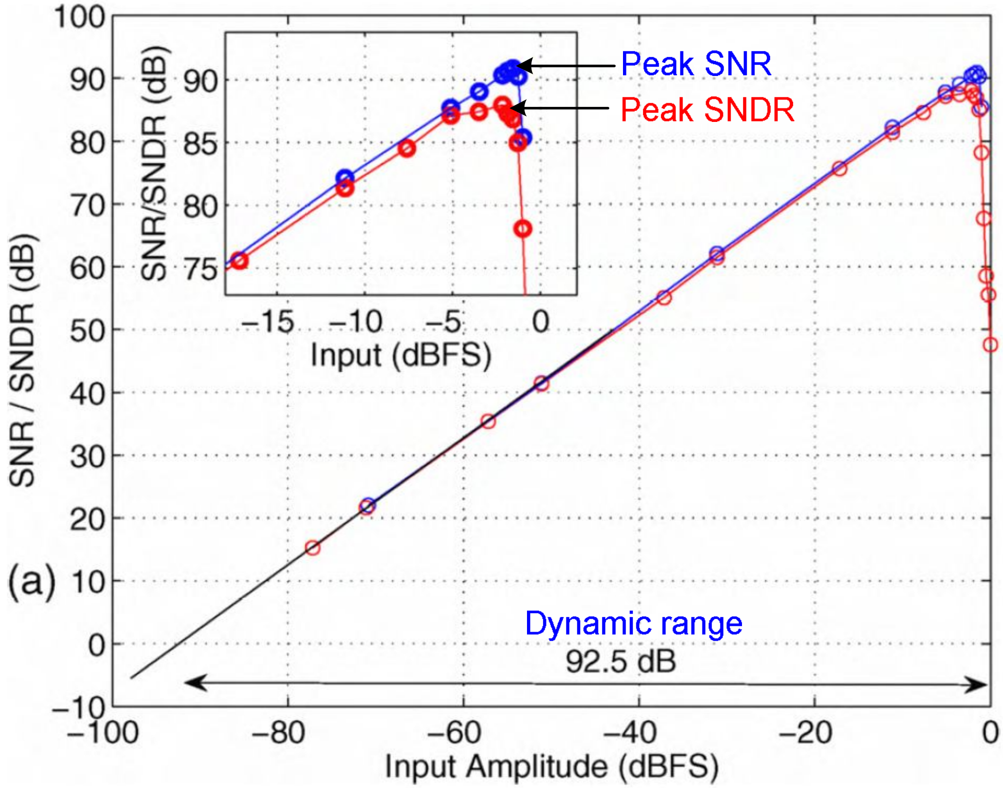


A=1, Δ=0.2, $f_{in}/f_s = 1/1024$:

- Most of the tones around the 20th bin
- SFDR = -30 dB
- Quantizer spectrum not white and the error (e) is correlated with the input (y).

file:Quantization_Noise2b.m

Frequency Domain Measurements

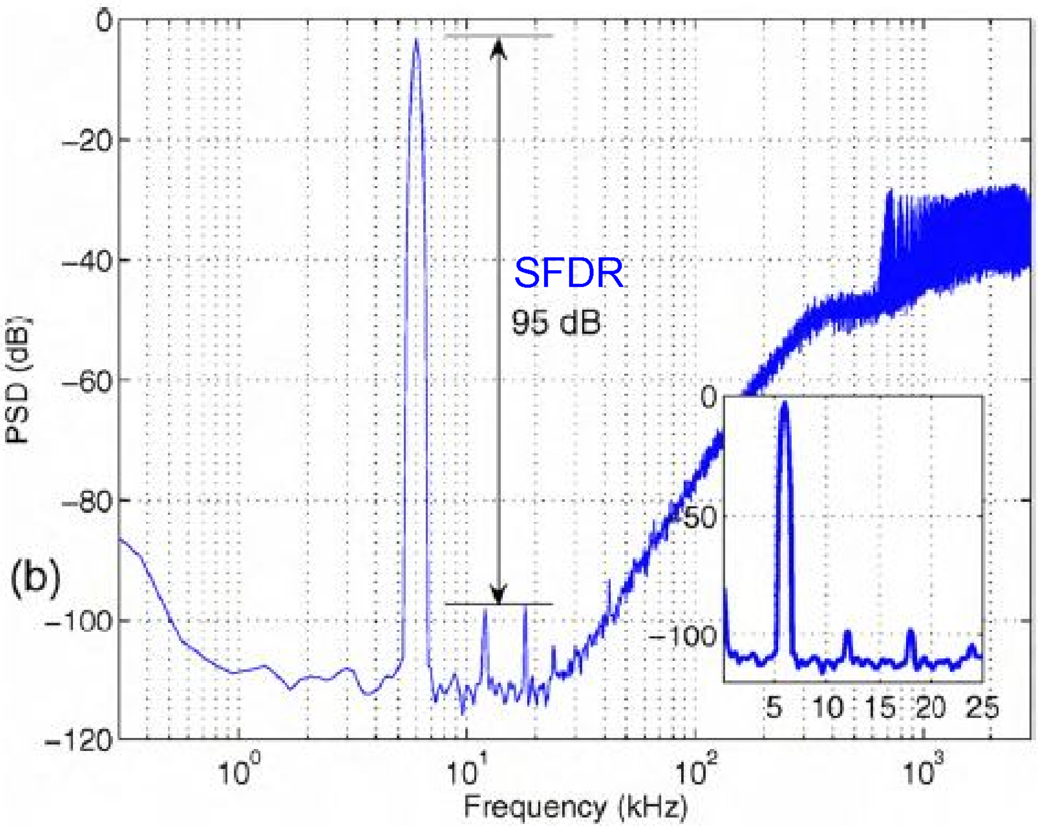


SUMMARY OF MEASURED ADC PERFORMANCE.

Signal Bandwidth/Clock Rate	24 kHz / 6.144 MHz
Quantizer Range	3.6 $V_{pp,diff}$
Input Swing for peak SNR	-1.6 dBFS
Dynamic Range/SNR/SNDR	92.5 dB/91 dB/88 dB
Active Area	0.24 mm^2
Process/Supply Voltage	0.18 μm CMOS/1.8 V
Power Dissipation (Modulator + References)	110 μW
Figure of Merit	0.0665 pJ/level

Reference [2]

Spurious (tone) Free Dynamic Range (SFDR)



Reference [2]

References

[1] M. Gustavsson, J. Wikner, N. Tan, *CMOS Data Converters for Communications*, Kluwer Academic Publishers, 2000.

[2] S.Pavan and P.Sankar, “A 110 μW Single Bit Audio Continuous-time Oversampled Converter with 92.5 dB Dynamic Range”, *Proceedings of the European Solid State Circuits Conference (ESSCIRC), Athens, Greece, September 2009*.

[3] S. Pavan, N. Krishnapura, “EE658 VLSI Data Conversion Circuits Course,” 2008, [Online]: http://www.ee.iitm.ac.in/~nagendra/videolectures/doku.php?id=start