Implementation of an RTZ code for feedback DAC on a Sigma-Delta modulator

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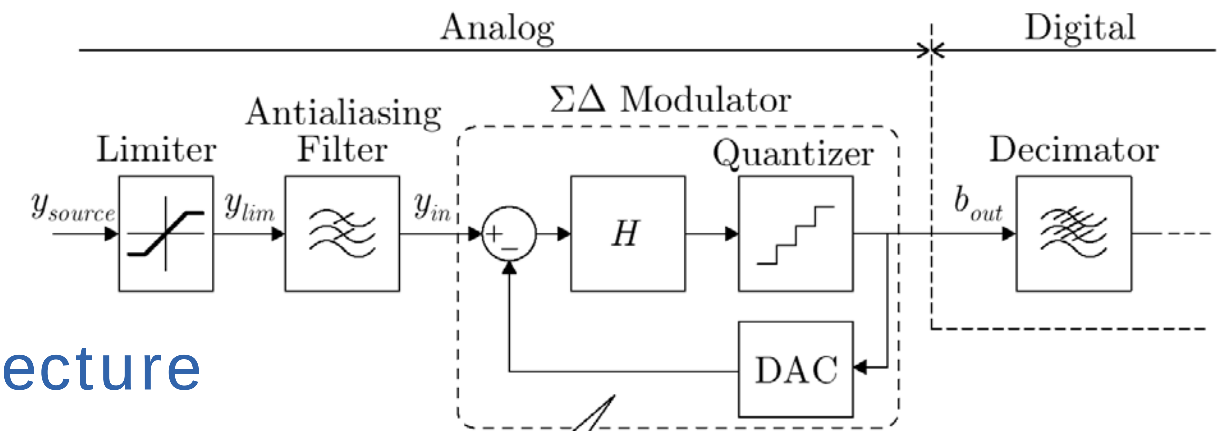
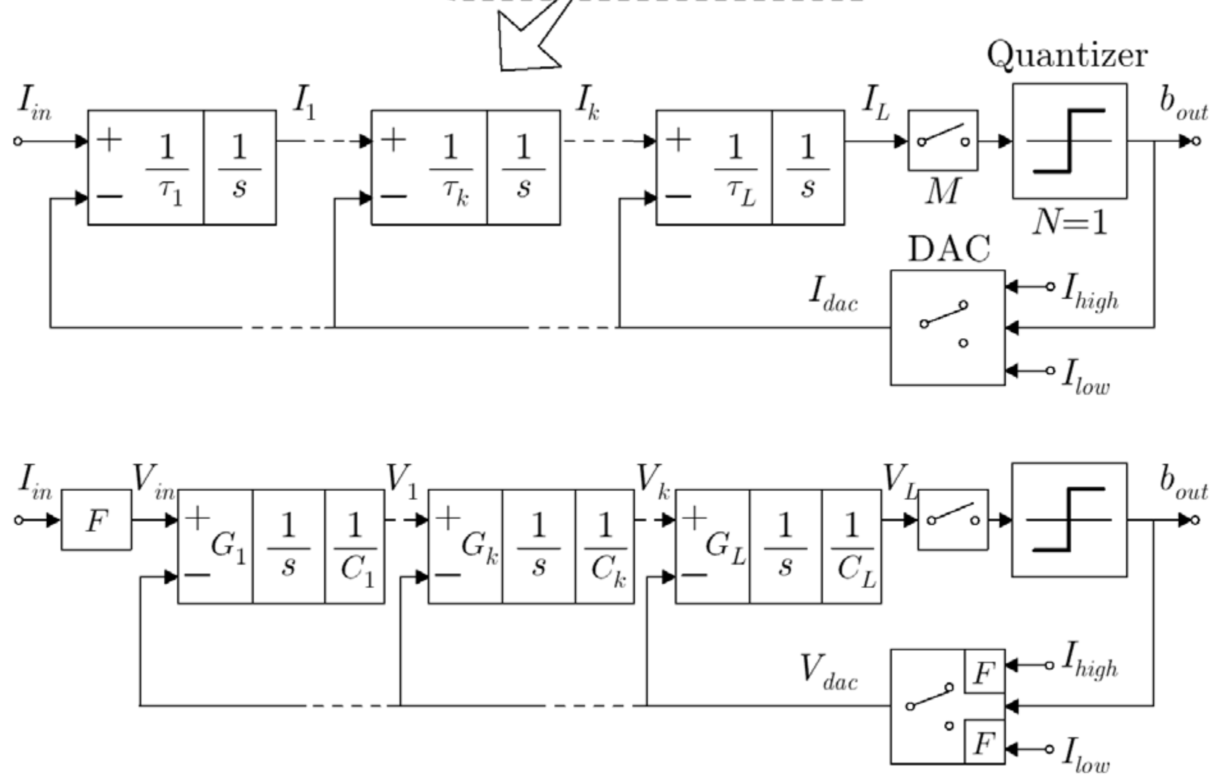


ΣΔ modulator architecture

- Continuous-time
- Single-loop
- 1-bit quantizer
- Log-domain



CMOS Log-Domain

- ✓ Very low-voltage
- ✓ Low-power
- ✓ MOS-only
- ✓ EKV equations

Simulation Issues

- ✗ High-accuracy
- ✗ Continuous-time
- ✗ Oversampling
- ✗ Pseudo-periodic

. . . need for high-level analytical modeling!

1 Introduction

2 Waveform Assymetry Modelling

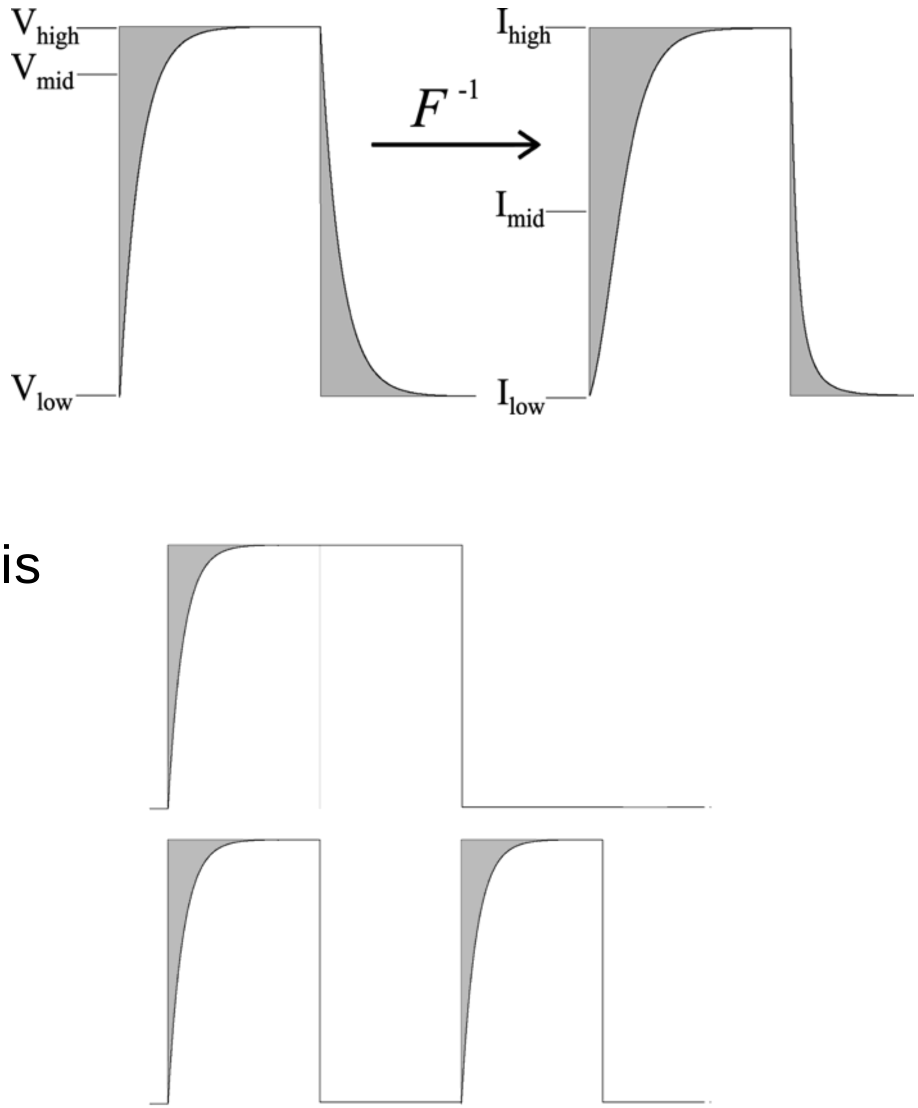
3 RTZ code consequences

4 Conclusions

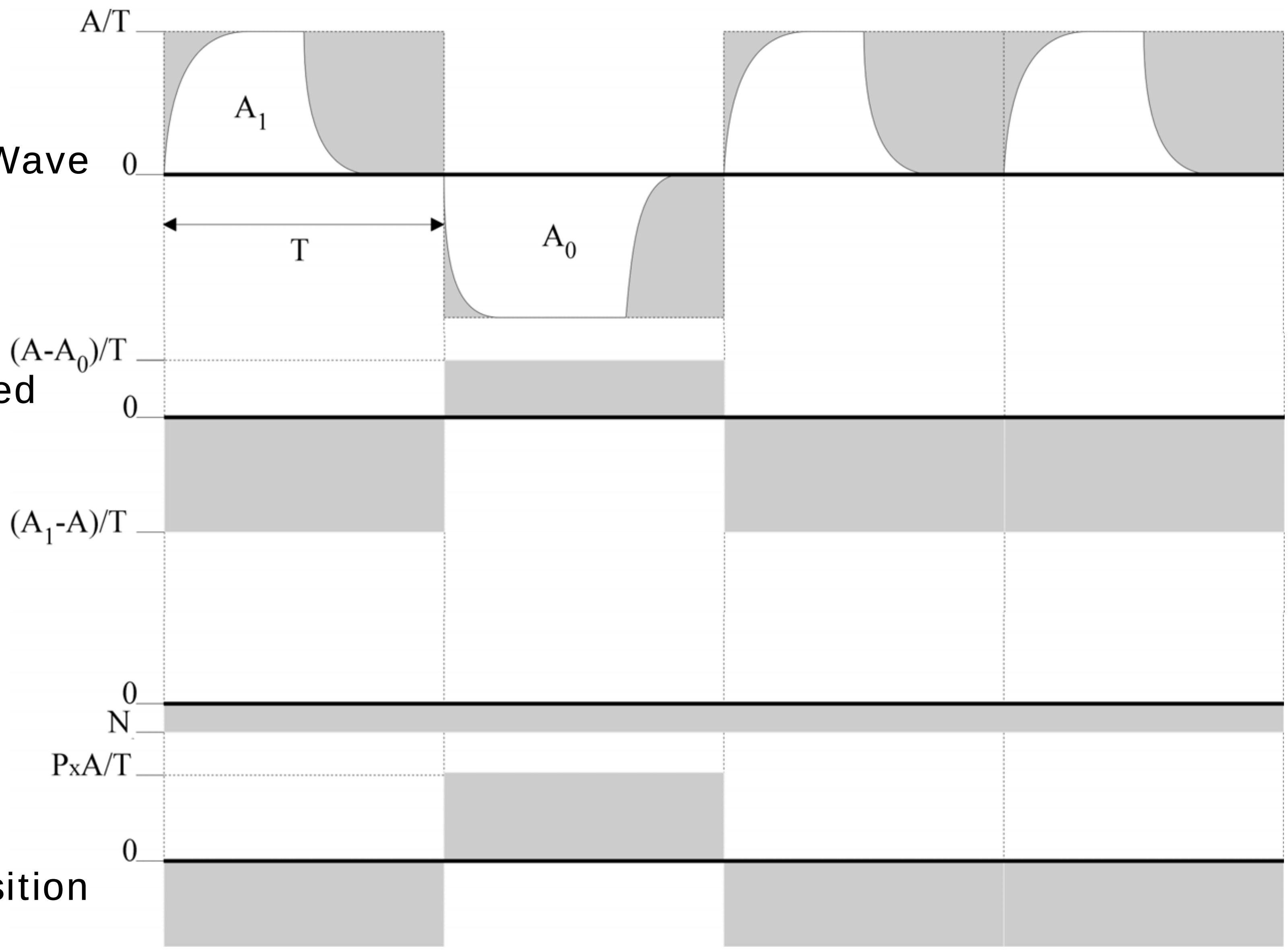
Waveform Asymmetry

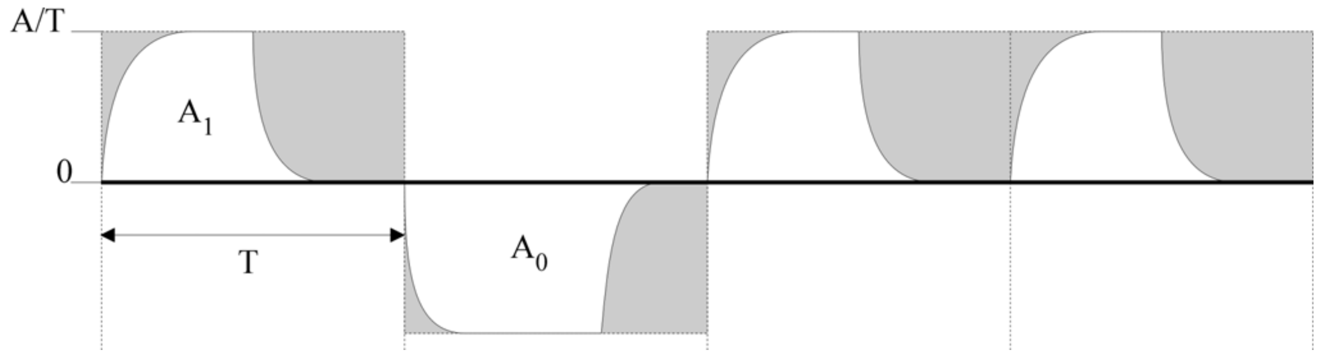
- Waveform asymmetry is enlarged due to log domain operation
- Integration error exhibits code dependency
- Error power spectral density is plain inside signal band
- Error differences must be below 0.5% to achieve 12 bits!

. . . need for another feedback code!
→ RTZ coding



- Actual Wave
- Extracted Error
- Error Decomposition



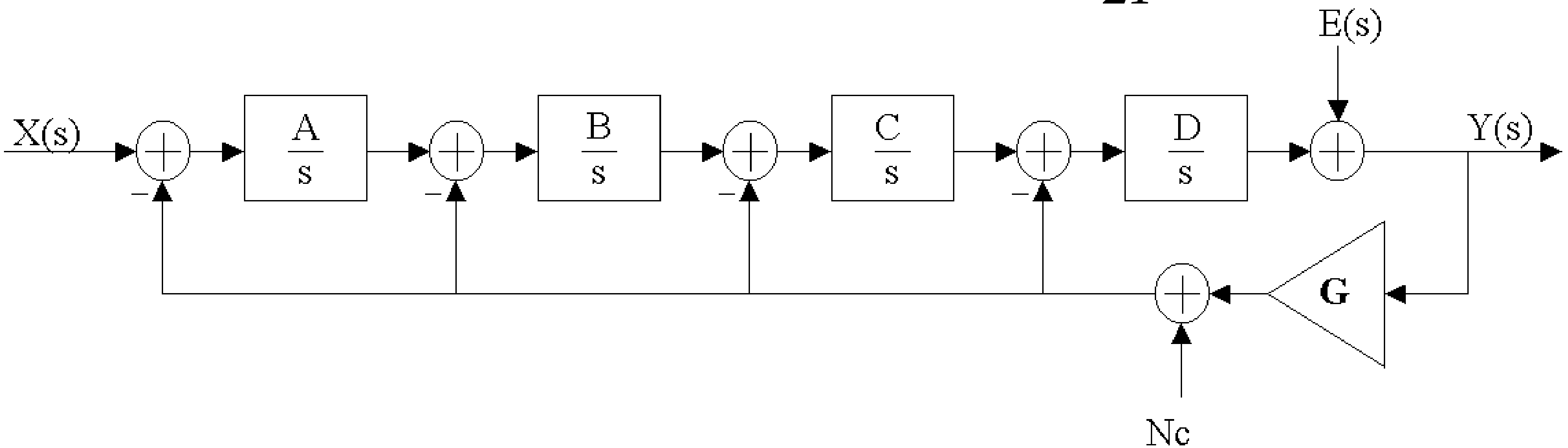


Easy parameter extraction

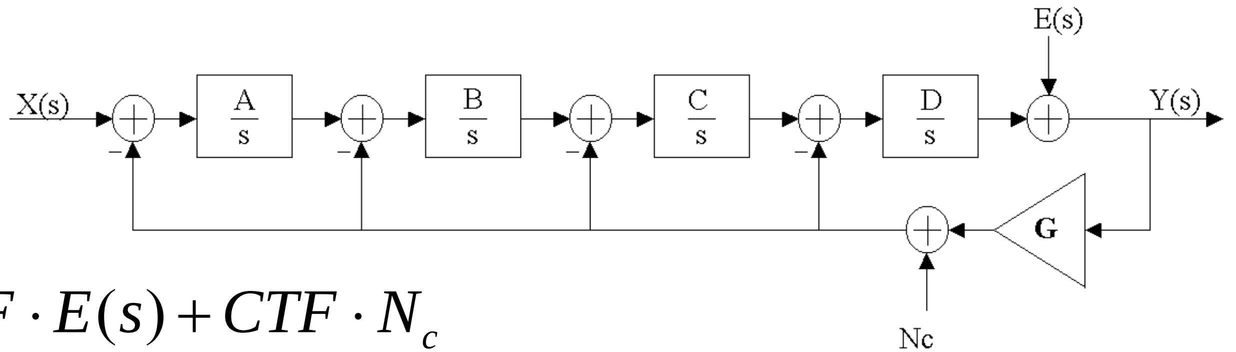
- Based on bit-area differences
- Extracted from short transient electrical simulations

$$G = 1 - P = \frac{A_1 + A_0}{2A}$$

$$N_C = \frac{A_1 - A_0}{2T}$$



Changes in transfer functions

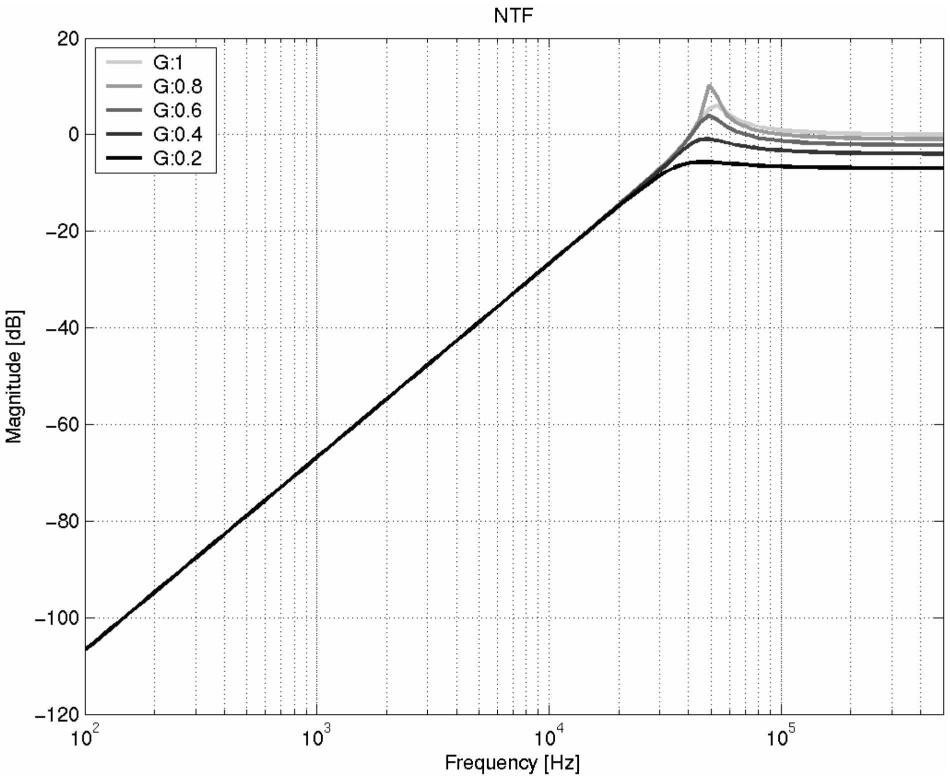


$$Y(s) = STF \cdot X(s) + NTF \cdot E(s) + CTF \cdot N_c$$

- A *G* reduction on feedback, can be viewed as a *1/G* amplification on signal

$$STF \approx 1/G \qquad CTF \approx -1/G$$

- *NTF* doesn't changes inside signal band (Quantization error *E(s)* is reduced by *G*)



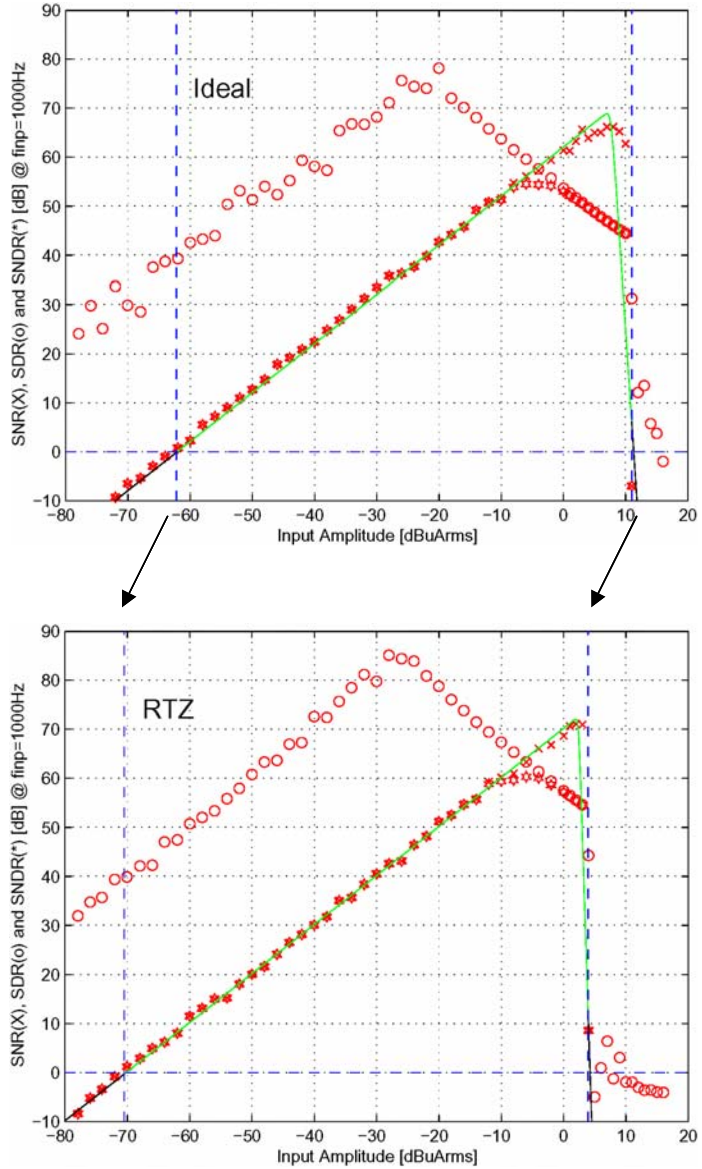
$$NTF = \frac{s^4}{s^4 + GDs^3 + GCDs^2 + GBCDs + GABCD}$$

Changes in overall performance

- Imax reduction

$$\left|I_{max}\right| = \frac{\left|I'_{max}\right| + \left|N_c\right|}{G} \Rightarrow \left|I'_{max}\right| = G\left|I_{max}\right| - \left|N_c\right|$$

- DR displacement
  - If quantization error is the main source of noise, a decrase on RTZ cycle produces a DR left-shift.
  - A dynamically changed RTZ duty cycle allows us to work on best SNR point and expands DR.



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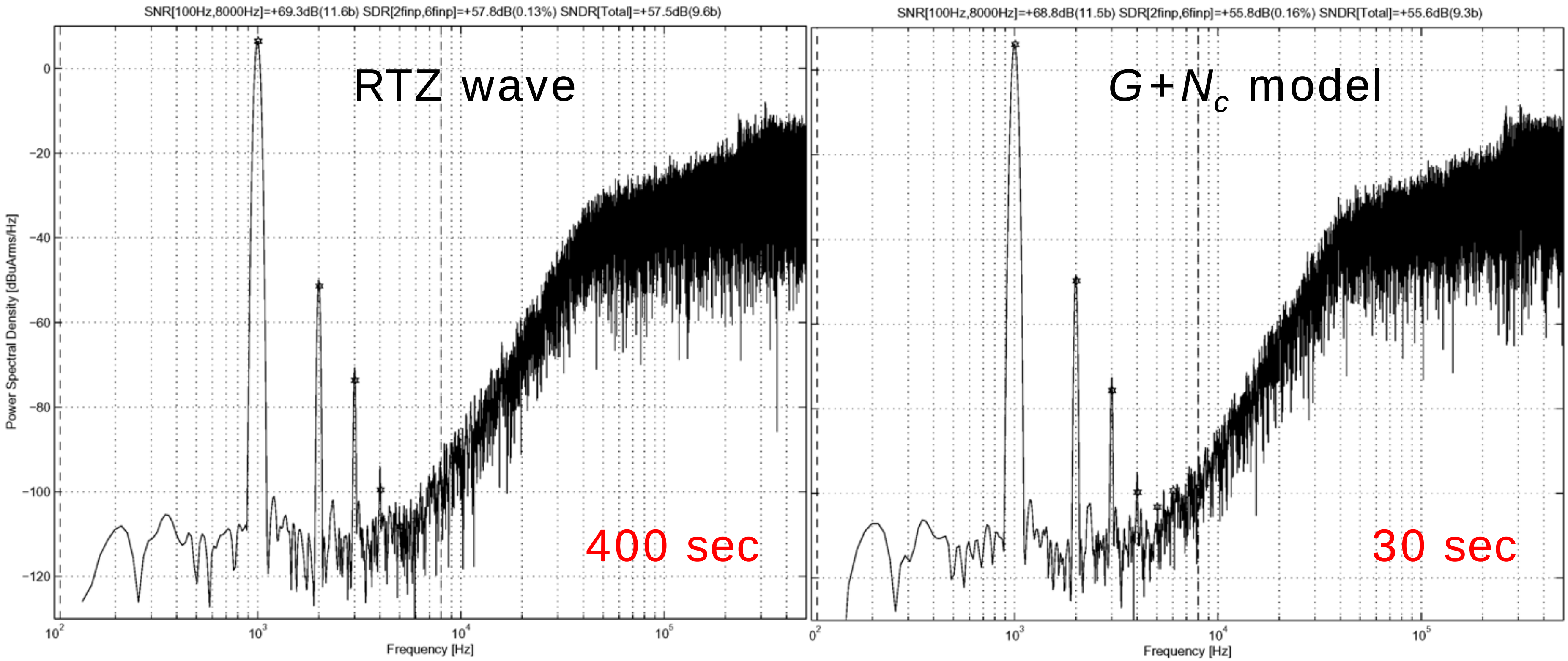
High-level simulations

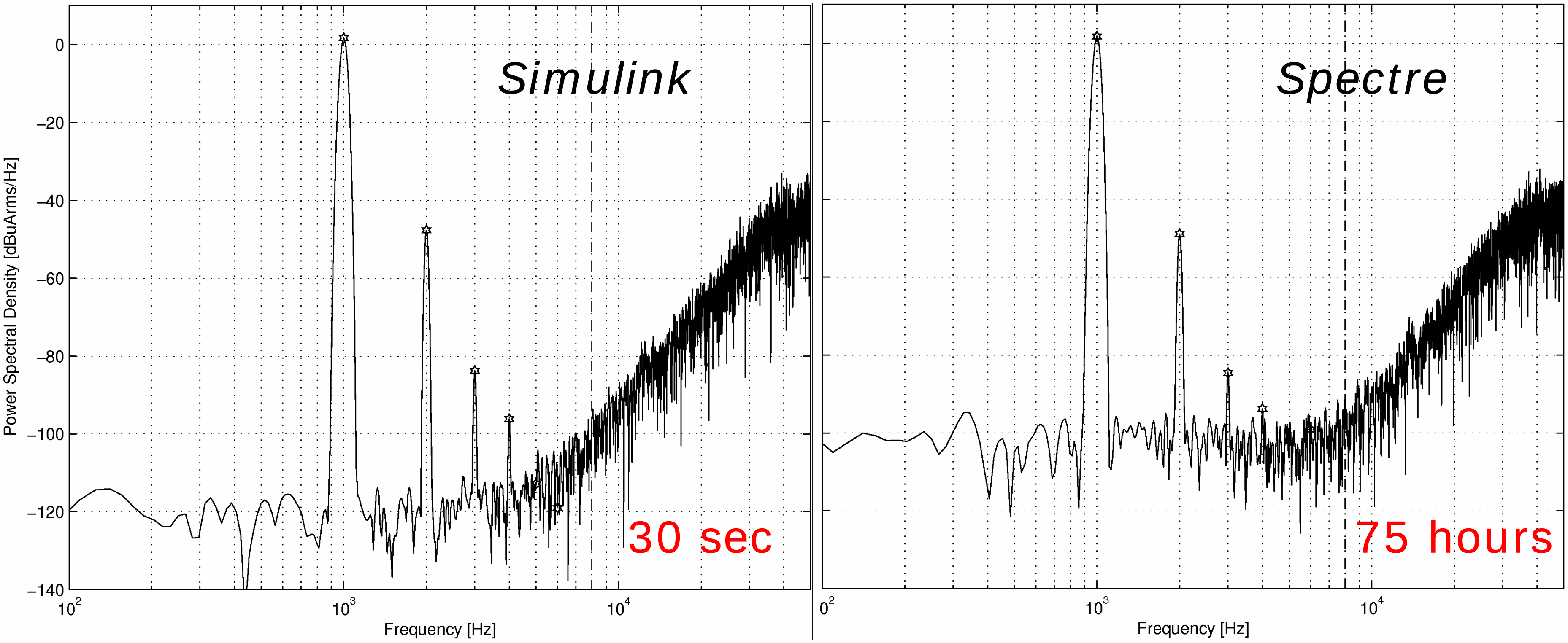
- $G+N_c$ model matches RTZ simulation
- Simulation speed improvement >10 times



Electrical vs. High-level simulations

- Electrical simulation allways needed for model validation
- Differences on noise floor due to ...

  numerical convergence , non-modeled effects



Conclusions

- Simple, fast and easy to calculate high-level model for feedback DAC on continuous-time modulators ΣΔ presented
- Simulation speed improved around 10~10000 times
- Modulator complete performance estimations can be iterated
- RTZ duty cycle can be dynamically adjusted to work on optimal operation conditions