ECE615 Mixed-Signal IC Design

Lecture 15 Slides: NTF Synthesis

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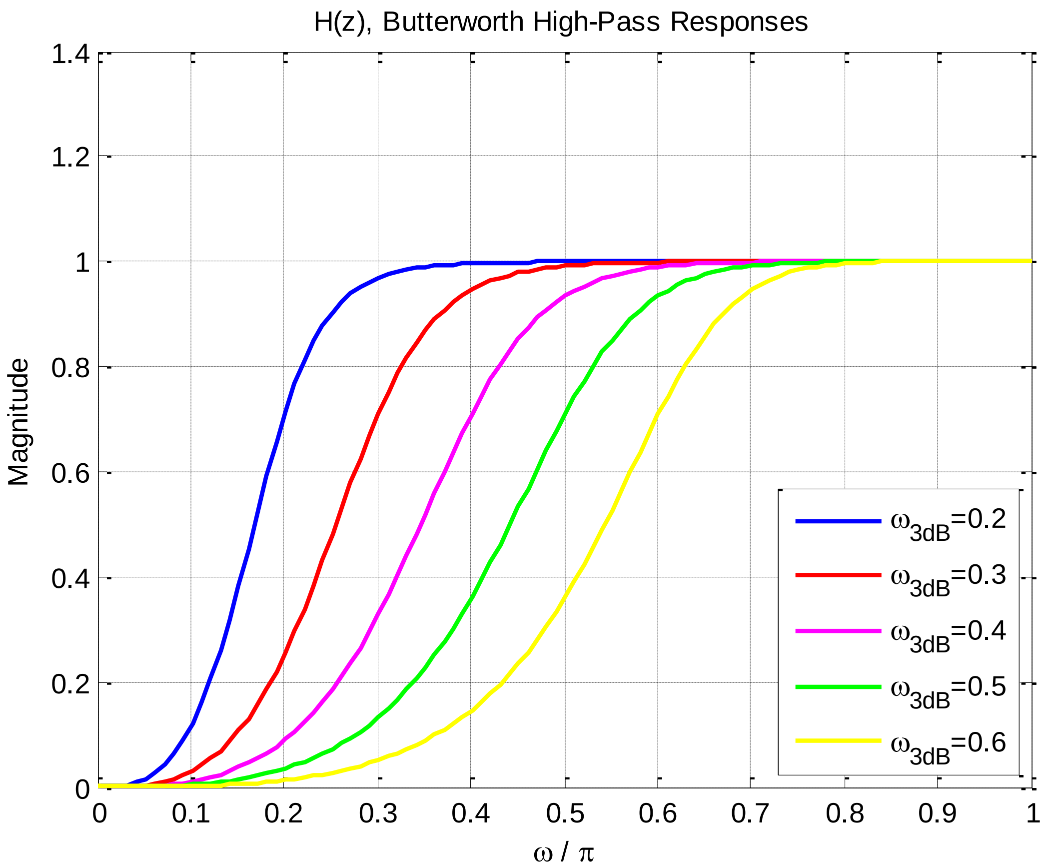
Butterworth High-Pass Responses



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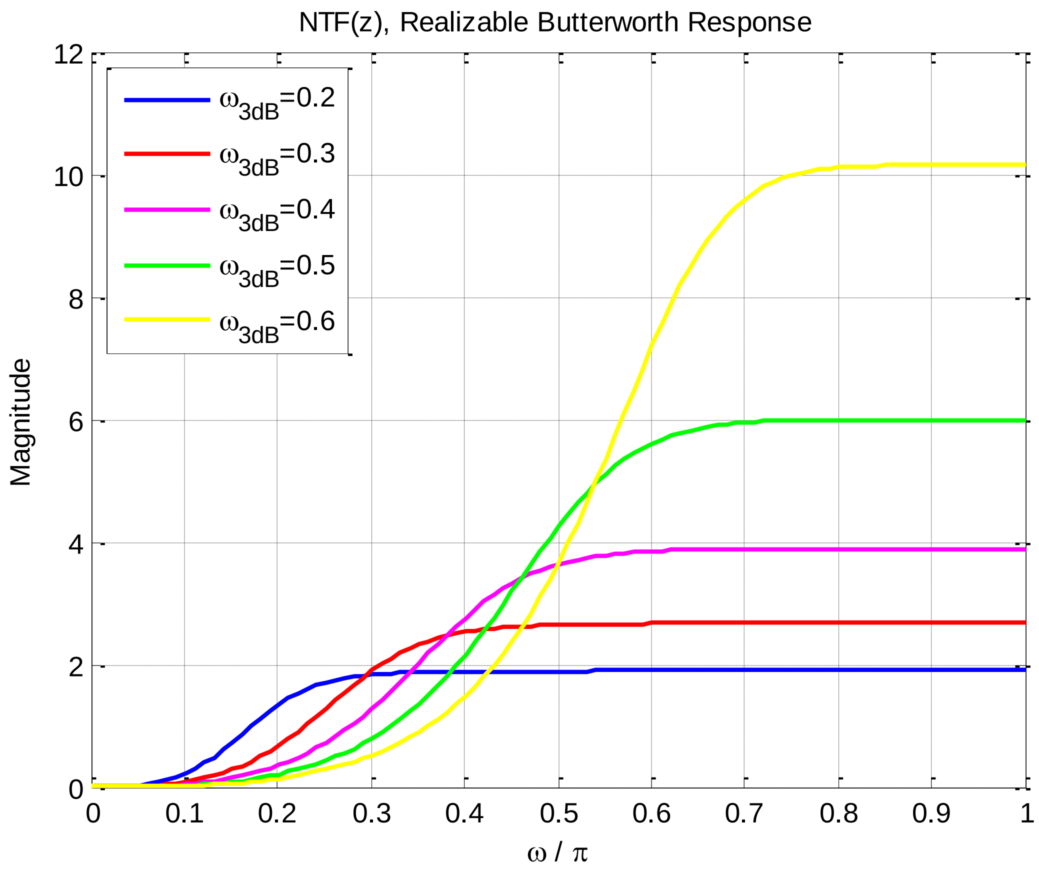
Realizable NTFs with Butterworth Response



$$NTF(z) = \frac{H(z)}{b_0}$$

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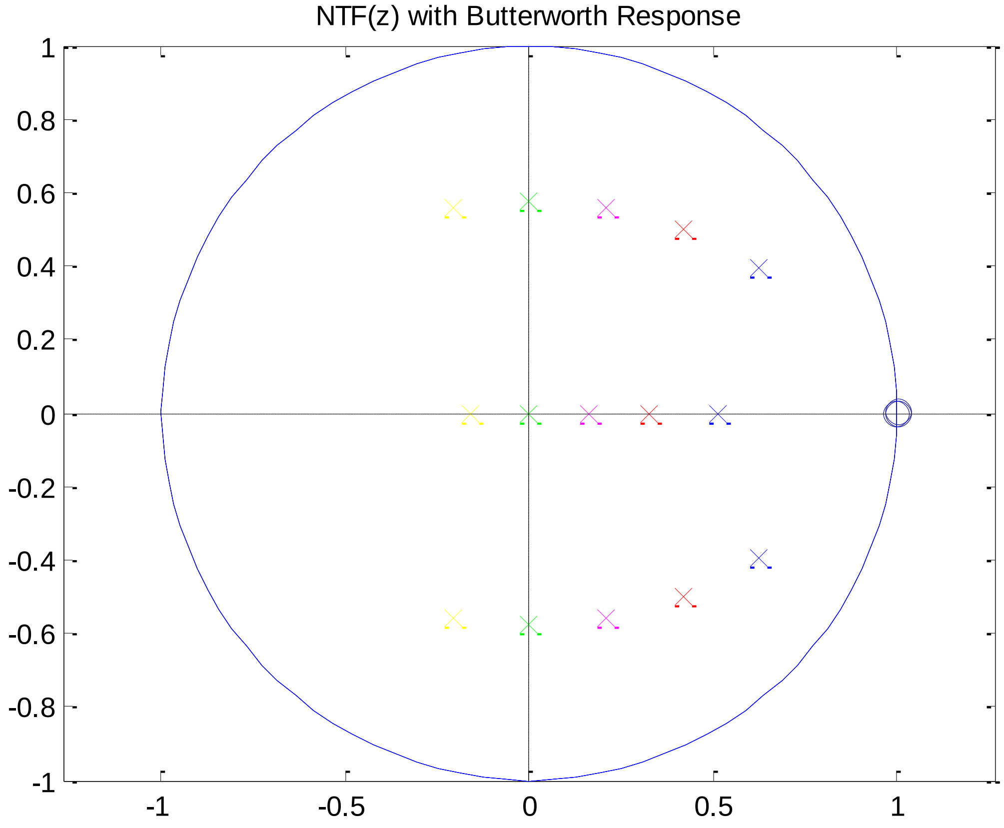
NTF Poles for Butterworth Responses

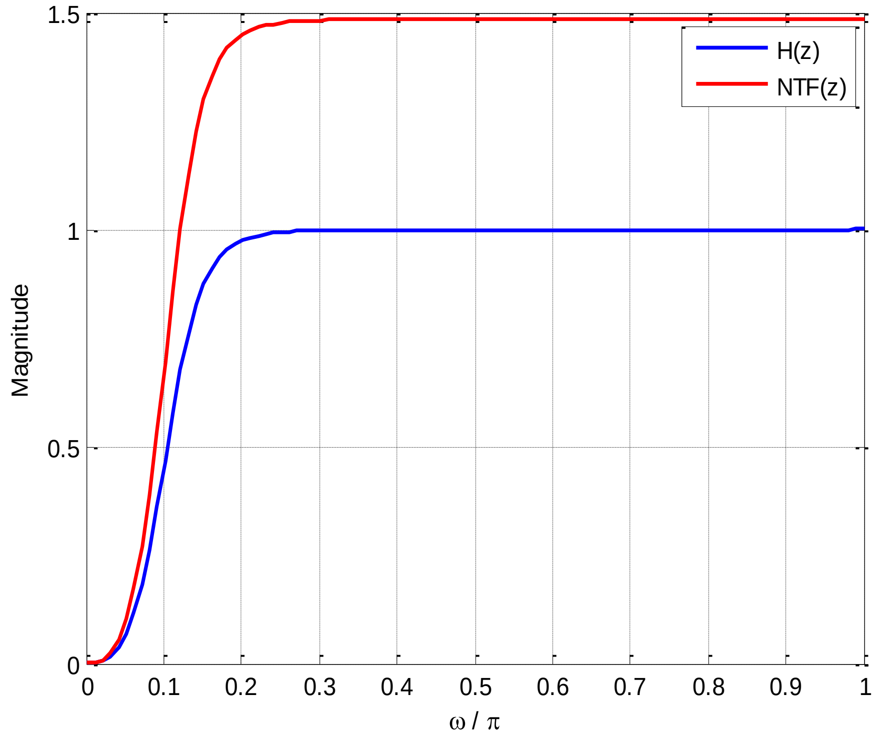


File: ButterworthResponses.m

Systematic NTF Design Example

- Specifications
  - SQNR > 120 dB
  - A signal bandwidth which results in an OSR = 64
    - Study optimal clock rate for the given process and quantizer design.
- Designer's Choice
  - Order = 3
  - Quantizer levels (nLev) = 16
  - Butterworth high-pass response for the NTF.
- Use MATLAB for finding coefficients of the HPF response.
  - [b,a] = butter(order, ω_{3dB}, 'high')
  - The cutoff frequency ω_{3dB} specifies the transfer function.

Systematic NTF Design contd.



- Start with cutoff frequency $\omega_{3dB}=\pi/8$, for the butterworth HPF H(z).
- Derive a realizable NTF using $NTF(z)=H(z)/b_0$

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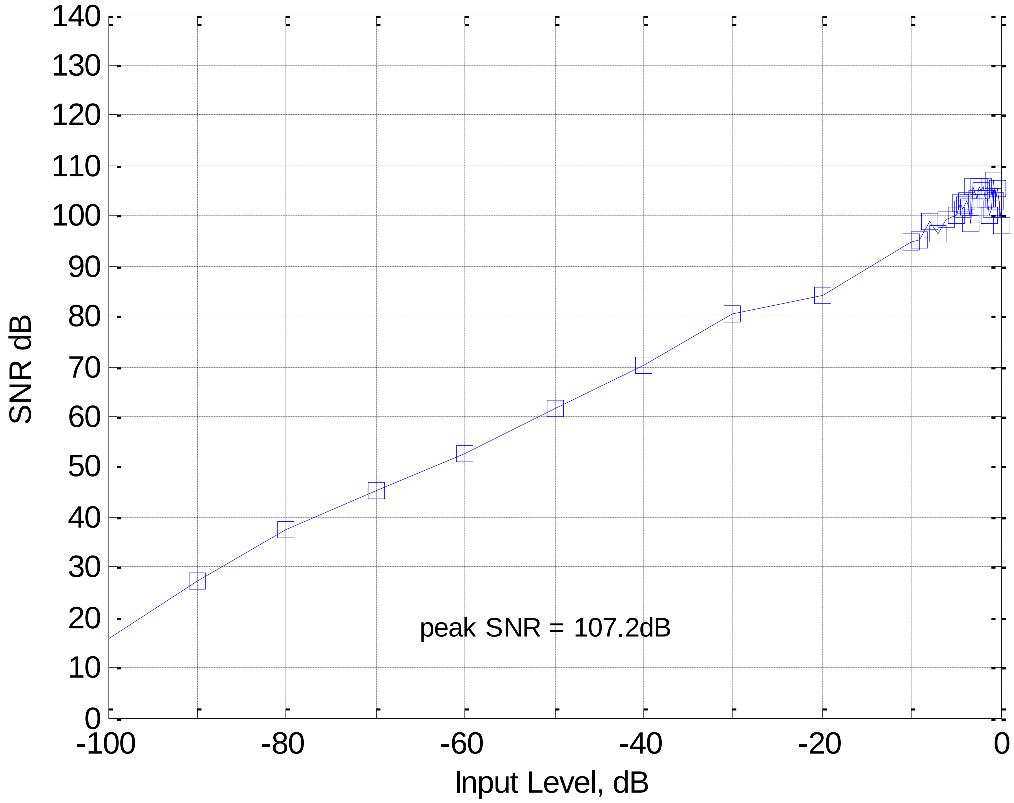
Systematic NTF Design contd.

- Map the NTF response to a loop-filter architecture (details later).
- Simulate the modulator for all possible amplitudes and input tone frequencies.
- Compute the peak SNR and MSA.
  - May use simulateDSM function in the toolbox.

Systematic NTF Design contd.



- Peak SNR = 107 dB
- MSA = 0.9

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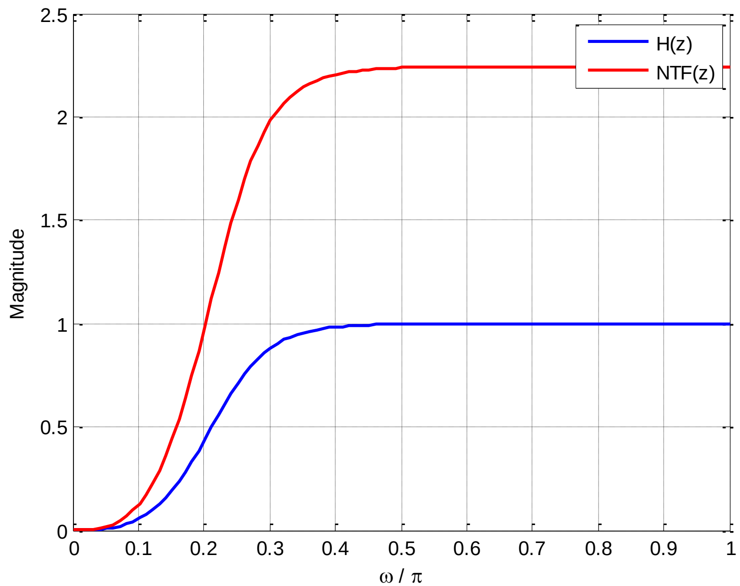
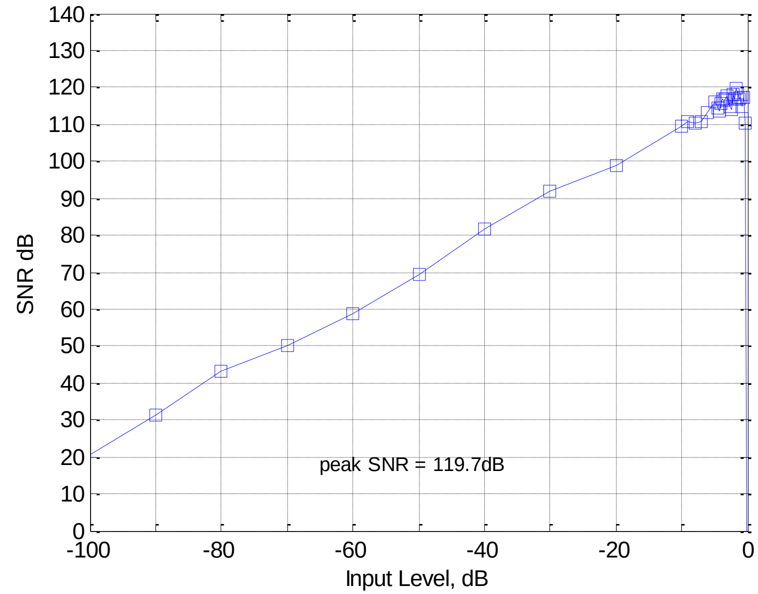
Systematic NTF Design contd.

- If SNR is not enough, repeat the entire procedure with a higher cutoff frequency for the Butterworth HPF
  - IBN ↓, SQNR ↑
  - OBG ↑ and MSA ↓
- If SNR is too high, repeat the entire procedure with a lower cutoff frequency for the Butterworth HPF
  - IBN ↑, SQNR ↓
  - OBG ↓ and MSA ↑

Systematic NTF Design contd.





- $\omega_{3dB} = \pi/4$.
- Peak SNR = 119 dB, OBG = 2.25, MSA = 0.8

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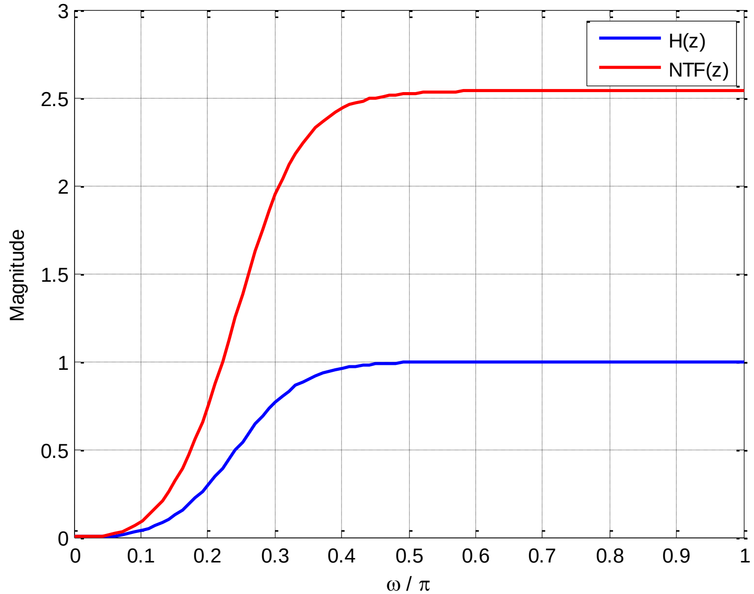
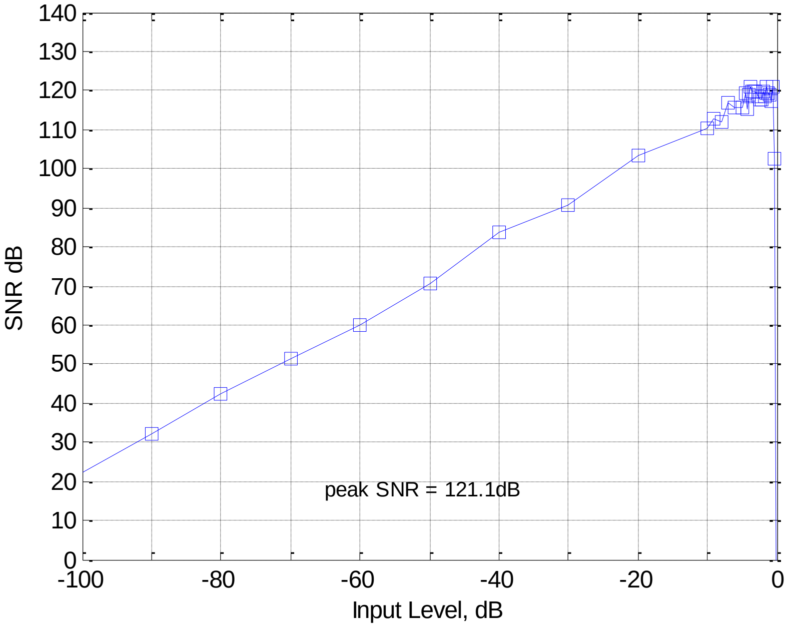
Systematic NTF Design contd.





- $\omega_{3dB}=2\pi/7$.
- Peak SNR = 121 dB, OBG = 2.54, MSA = 0.8.
  - Design closed !

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Systematic NTF Design contd.

- An advanced version of this iterative process is implemented as the function `synthesizeNTF` in the delta-sigma Toolbox.
  - Several ‘opt’ params for NTF zero (and pole) optimization.
  - Use `synthesizeChebyshevNTF` for low OSR and low OBG designs.
- CLANS algorithm by Kenney and Carley implemented as the `clans` function in the toolbox.
  - Requires Optimization toolbox.
- Exercise: Repeat the design procedure using an Inverse Chebyshev HPF response.
  - [b,a] = cheby2(n,R,w_{st});

References

[1] S. Pavan, N. Krishnapura, "Tutorial: Oversampling Analog to Digital Converters," *21st International Conference on VLSI Design*, Jan. 4, 2008. [Online]:http://www.ee.iitm.ac.in/~nagendra/presentations/20080104vlsiconf/20080104vlsiconf.pdf