BINGHAMTON UNIVERSITY
State University of New York

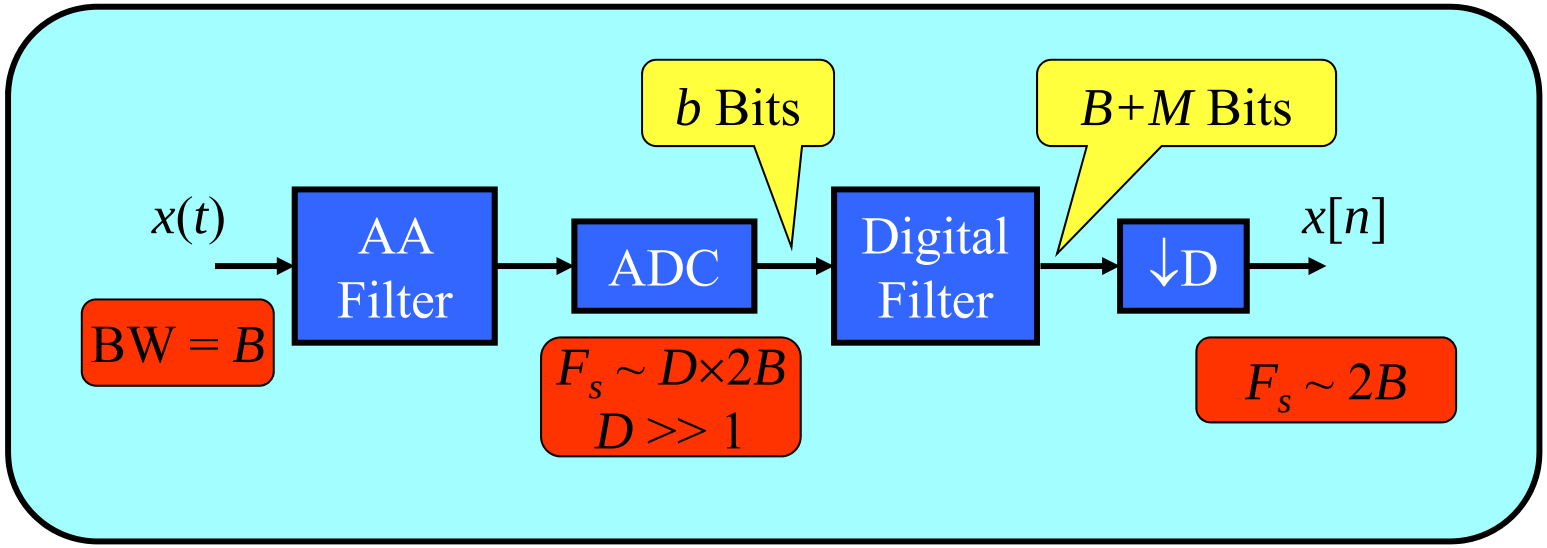
EEO 401
Digital Signal Processing
Prof. Mark Fowler

Note Set #17

- Oversampling ADCs
- Reading Assignment: Sect. 6.6 of Proakis & Manolakis

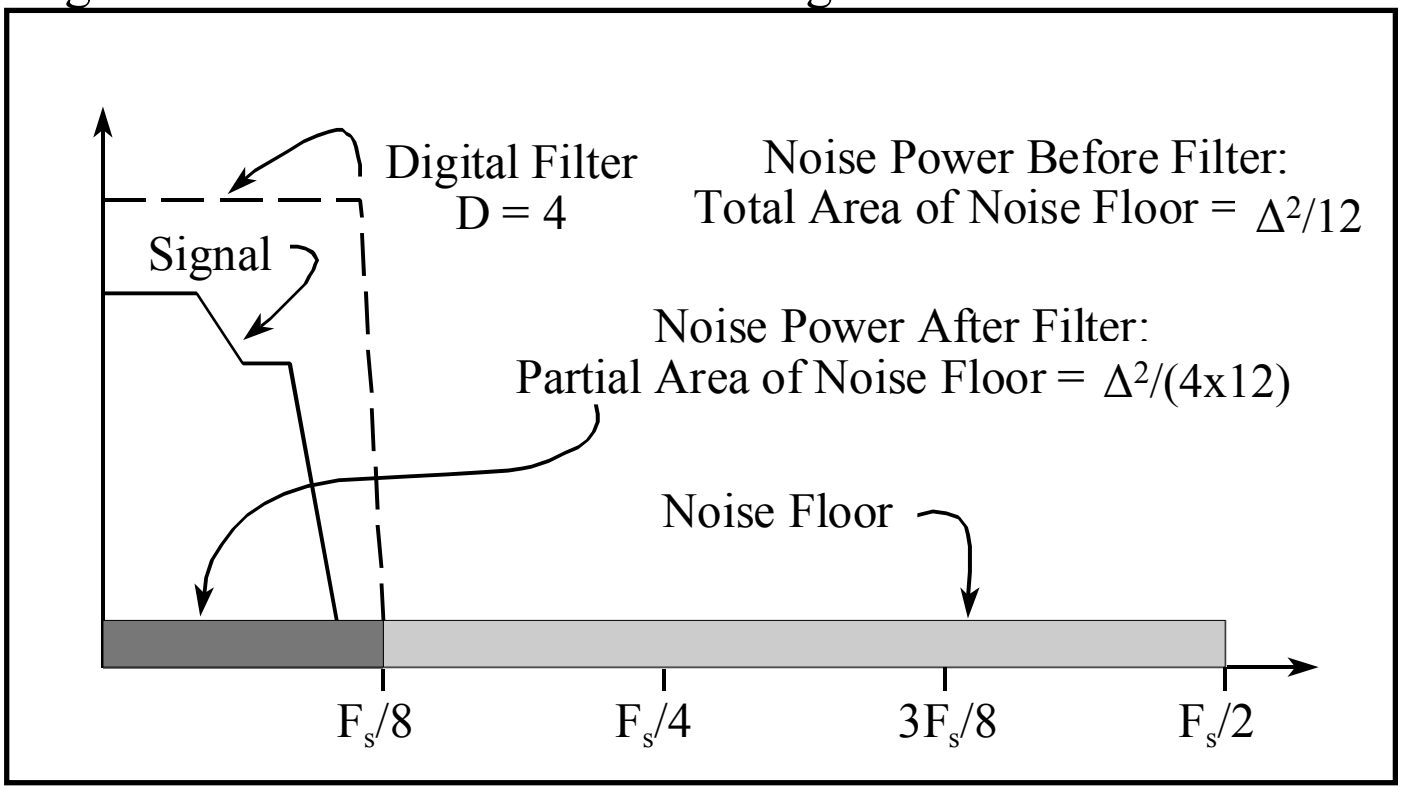
Trading BW for Bits

- **Oversample and Filter**:
  - Say You Have an ADC That Can Sample at a Rate of F_s.
  - Quantization Noise PSD is Uniformly Spread Over $-F_s/2$ to $F_s/2$.
  - If Signal Resides in Some Subband, Digitally Filter to that Band:
    - Signal Power Same, but Noise Power Reduced ➡ **Improves the SNR**
    - But… SNR is related to ENOB ➡ **Increases the Effective # of Bits!**
      - Analogous to averaging a bunch of integers to get a fractional value
    - **Increased ENOB** at the Expense of **Reduced Processing BW**



Trading BW for Bits

- **Noise Reduction View:**
  - Quantization Noise PSD is Uniformly Spread Over $-F_s/2$ to $F_s/2$.
  - Signal is Concentrated in Narrow Region

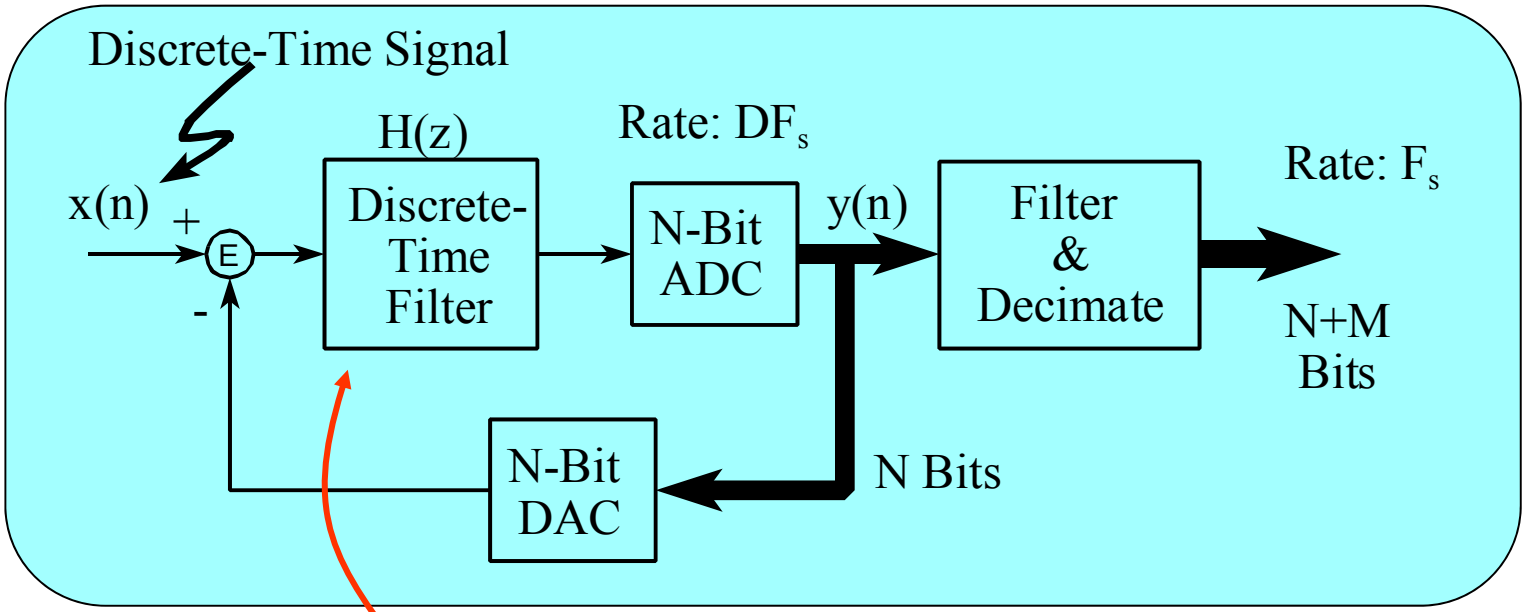


Quartering BW → 6 dB Less Noise → 6 dB More SNR → 1 More Bit

Trade Rate = ½ Bit per Octave ➔ Inefficient Trade!!!

Better Trade: Sigma-Delta ADCs

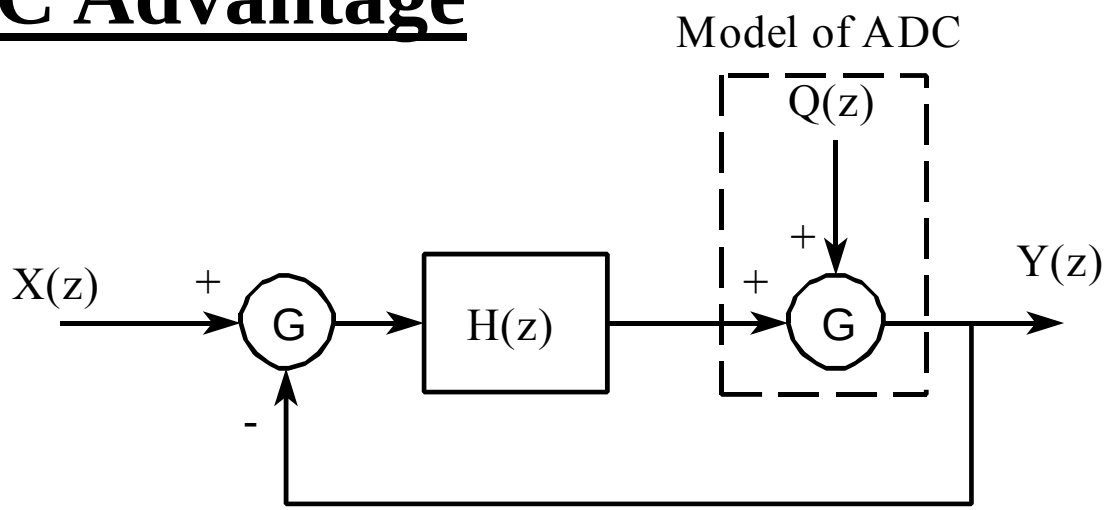
- Use VERY High Over-Sampling Rate
- Use Low-Bit ADC (sometimes even just 1 Bit)
- Use DSP Noise Shaping to Non-Uniformly Spread Noise
  - Push Most of the Quantization Noise Out of the Signal Band



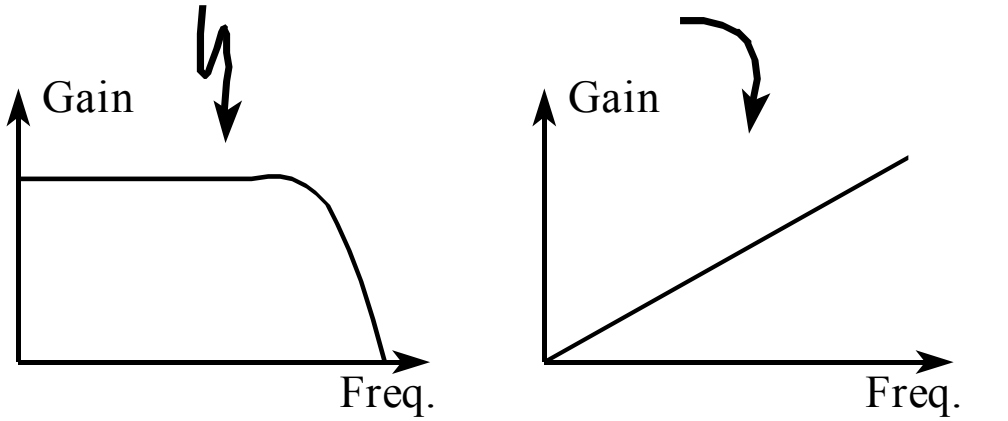
Design Filter $H(z)$ to:

- Pass Signal w/ Minimal Distortion
- Attenuate Quantization Noise in Signal Band

Σ-Δ ADC Advantage



$$Y(z) = \frac{H(z)}{1+H(z)} X(z) + \frac{1}{1+H(z)} Q(z)$$

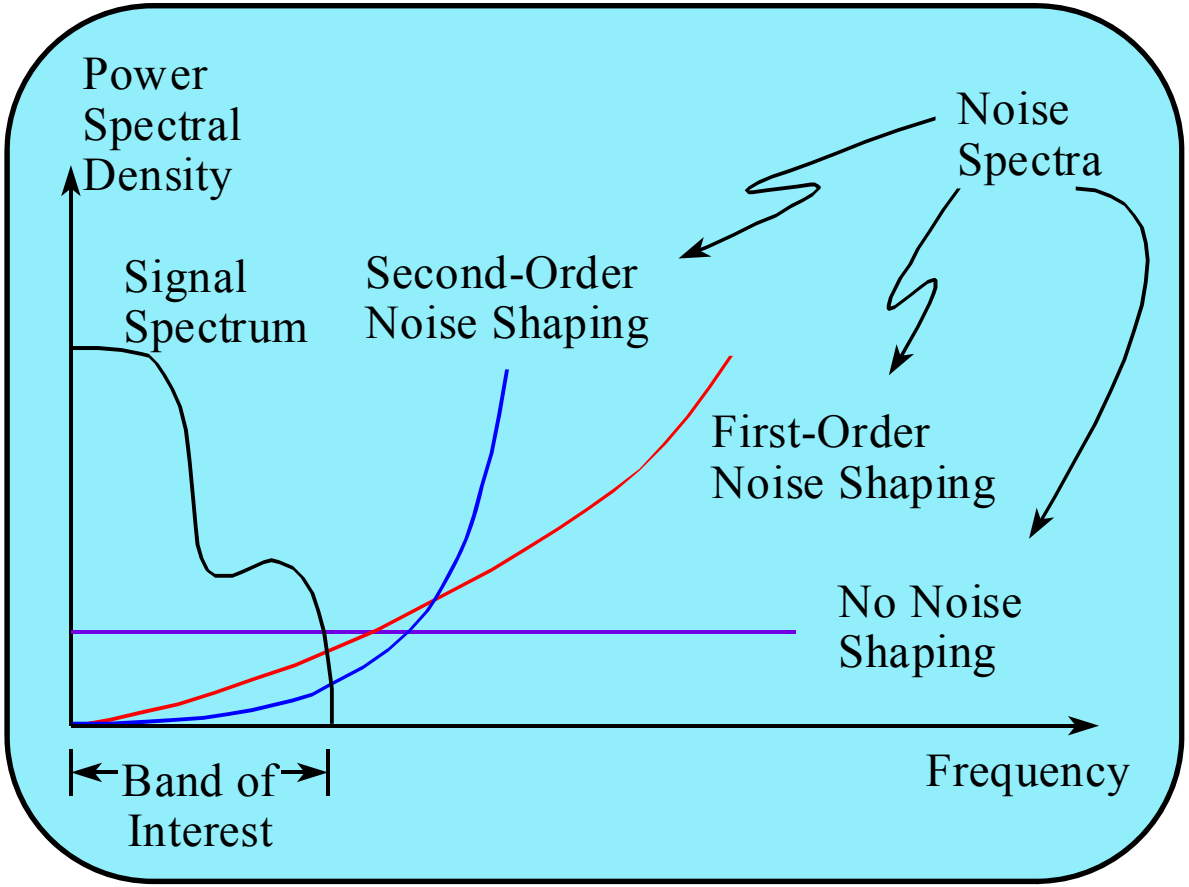


Signal Transfer Function

Noise Transfer Function

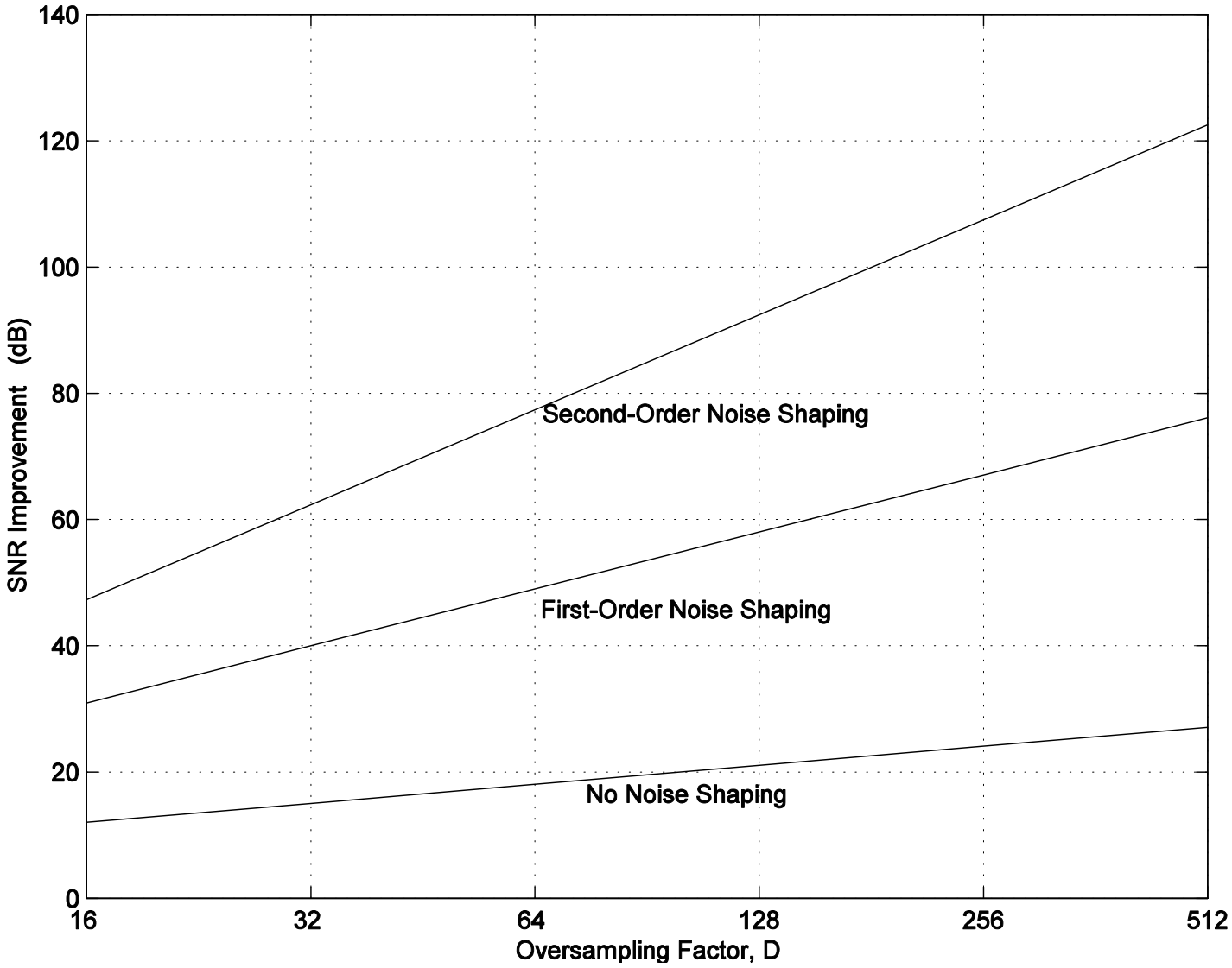
Σ-Δ ADC Performance

- Two Main Factors Impact Performance:
  - Oversampling Rate *D*
  - Order of the Noise Shaping (1st, 2nd, 3rd, etc.)



Noise Shaping	Trade Rate
None	0.5 Bits/Octave
1st Order	1.5 Bits/Octave
2nd Order	2.5 Bits/Octave

Σ-Δ ADC Performance



Σ-Δ ADC Summary

- Advantages of Sigma-Delta ADCs is Three-Fold:
  - Oversampling makes the Anti-Alias Filter Easy!
  - Noise Shaping Pushes ADC Noise Outside Signal Band
  - Low-Bit ADCs can be Made Closer to Ideal than High-Bit ADCs
- Disadvantage
  - Hard to get Extremely Wide Processing BW
  - But progress is being made…