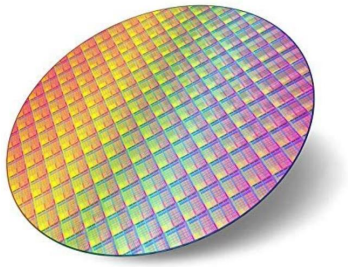
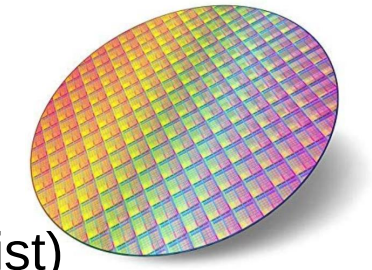
Audio Chain in a Hearing Instrument



- Oticon
- WSAudiology
- GN Hearing

- hjohansen@gnhearing.com

Audio Requirements

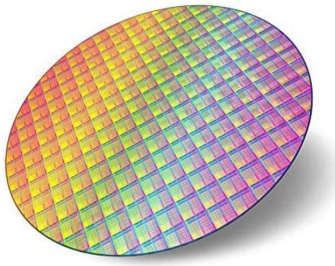


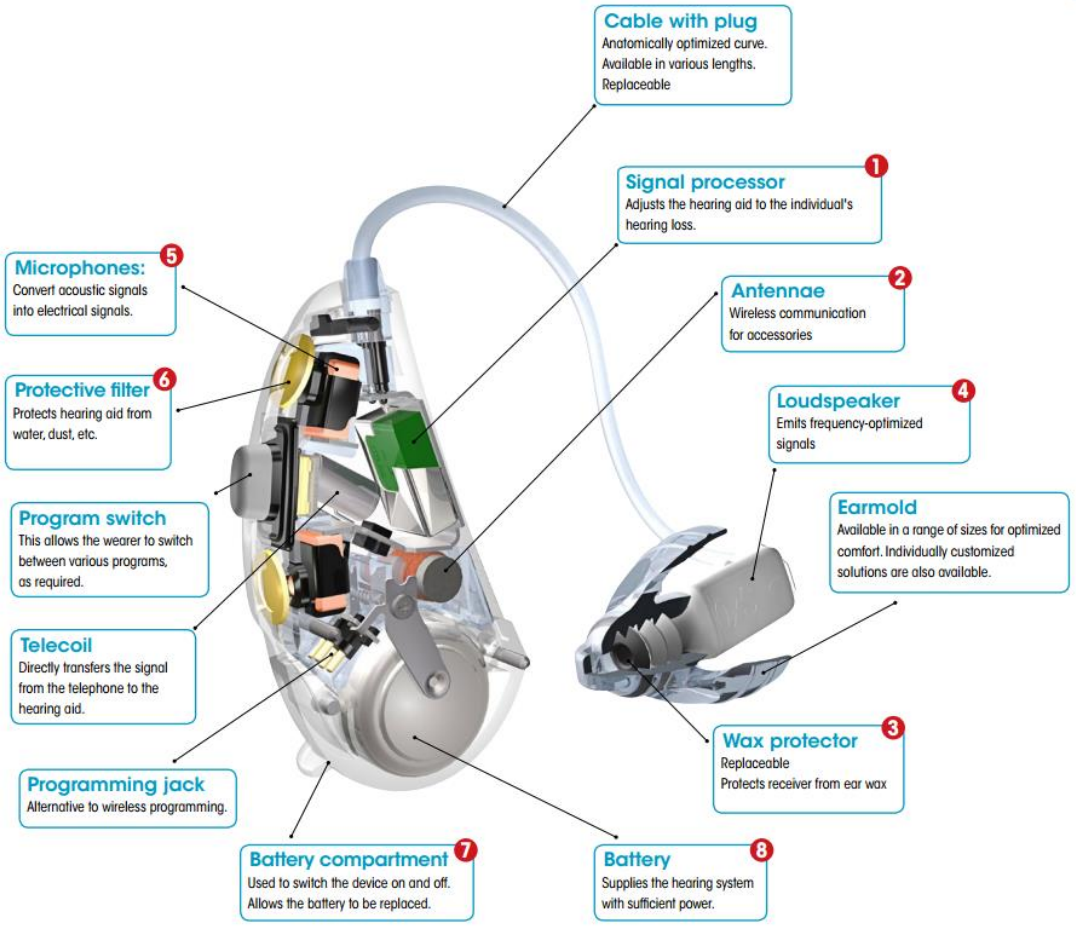
- Audio related requirements to a Hearing Instrument:
  - Bandwidth: > 10kHz => Sample Rate > 20kHz (according to Nyquist)
  - Dynamic Range: > 120dB => Resolution > 20bit (6dB per bit)
  - S/N Ratio: > 90dB
  - Power Supply: 1-2Volts (HiFi: 50-100V)

- Other Requirements:
  - Low power consumption (HiFi: No concern), Rechargeable
  - Simple/compact (minimal area)
  - Programmable sound processing, Individual fitting

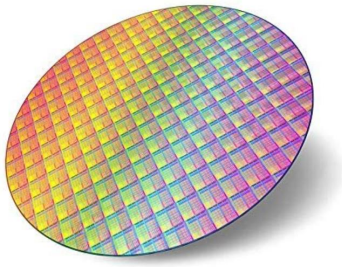
Hearing Instrument Historical Development

- Mechanical -> Analog -> Digital

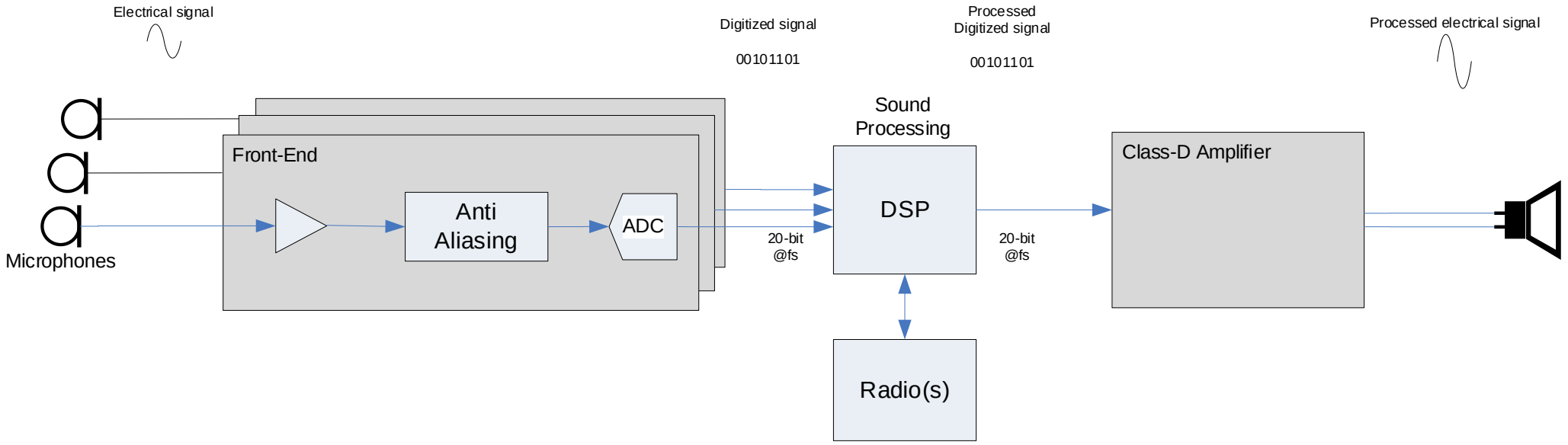




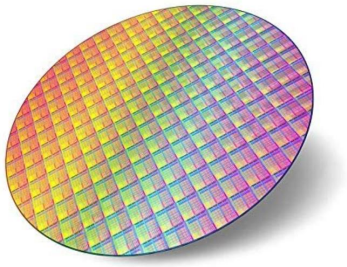
Digital Hearing Aid



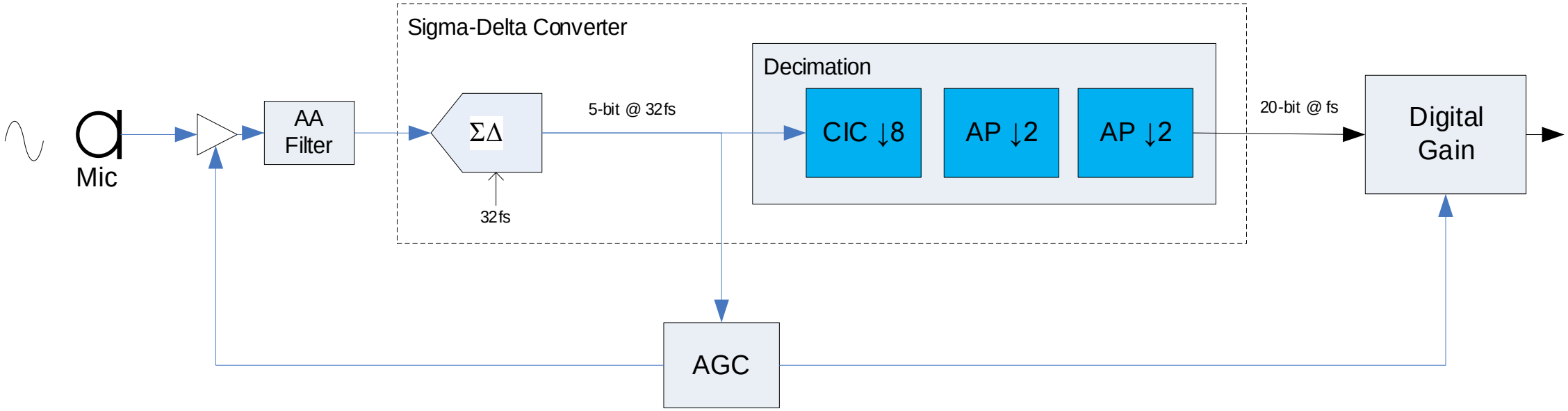
- Low Noise Analog to Digital Front-End
- Programmable sound processing (DSP)
- Wireless radios: Bluetooth (2.4GHz), MI, Telecoil
- Class-D Amplifier
- Multiple input channels (Directionality/Beam-forming, Occlusion)



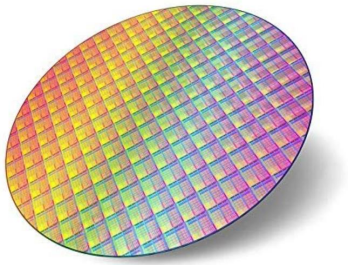
Front-End



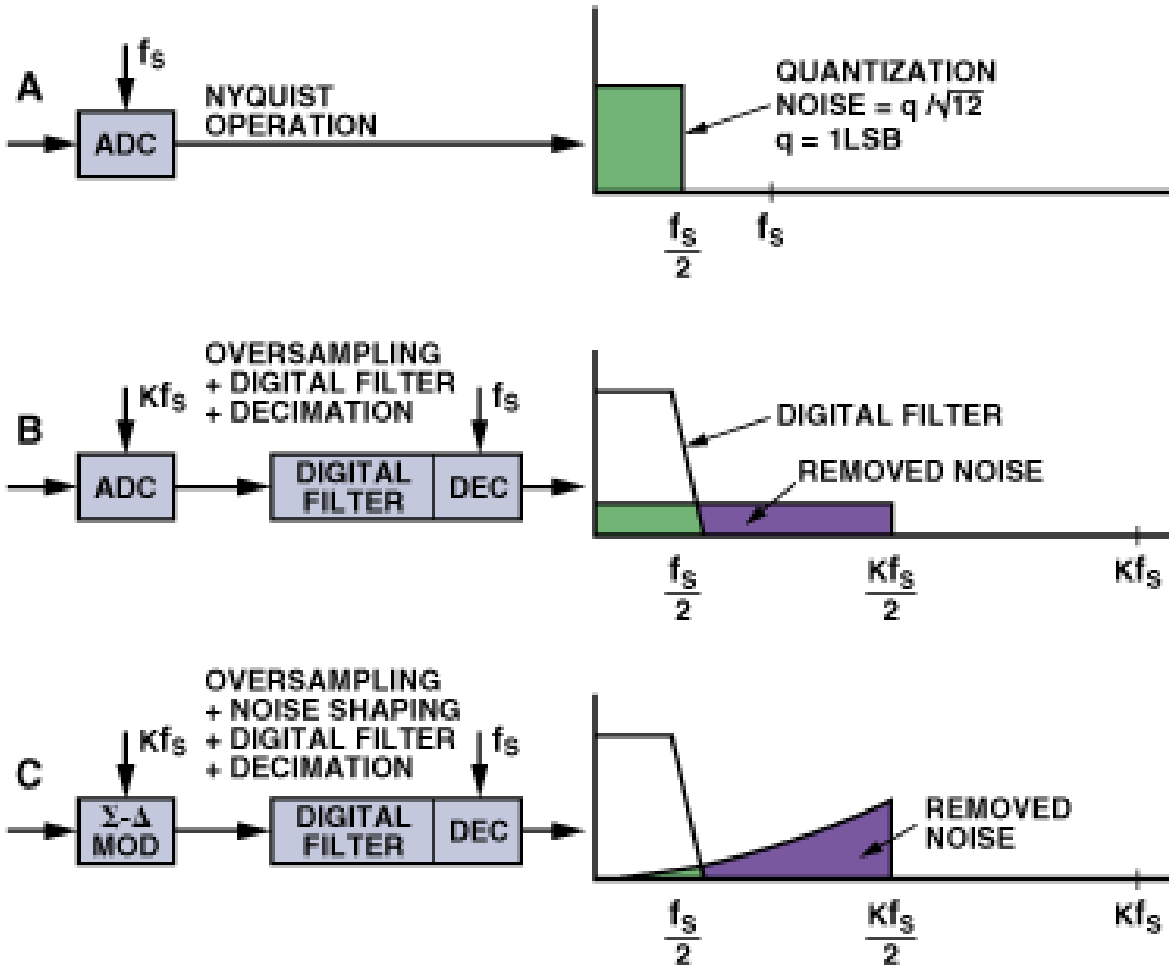
- Sigma-Delta modulation with oversampling:
  - Relaxes Anti-Aliasing filter demands
  - Reduced output resolution (e.g. 5bit) => Quantization noise, but…
  - Clever filtering moves quantization noise outside band of interest
- Decimation filter using sequence of Half-Band filters (CIC + Polyphase AllPass), power efficient
- High Dynamic range requires AGC (Click issues)



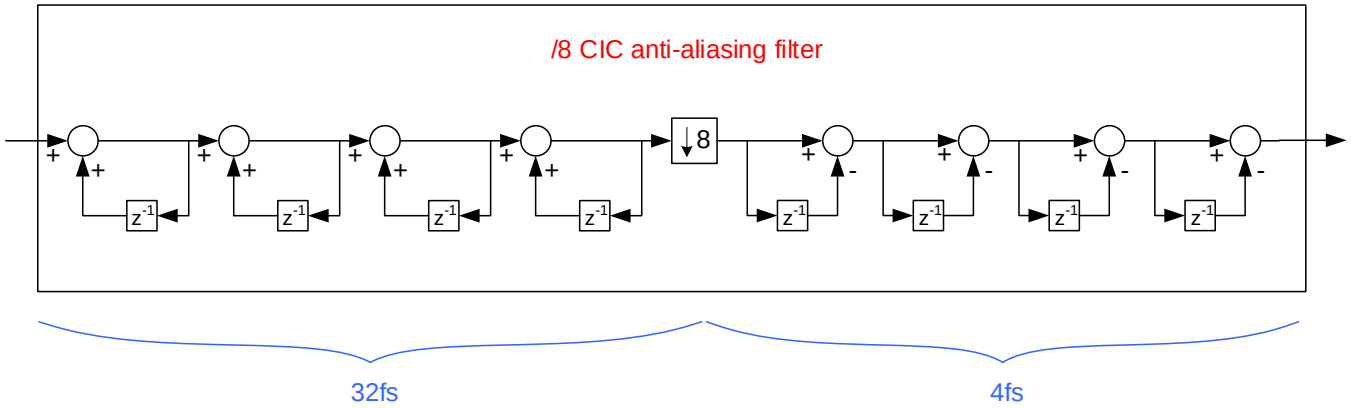
Why Sigma-Delta Modulation?

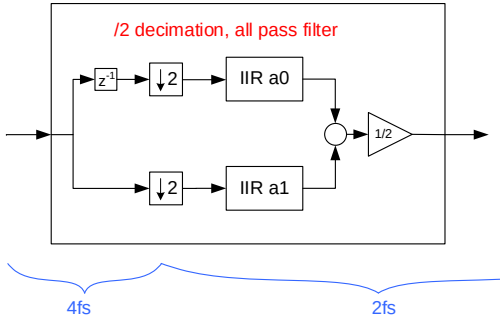


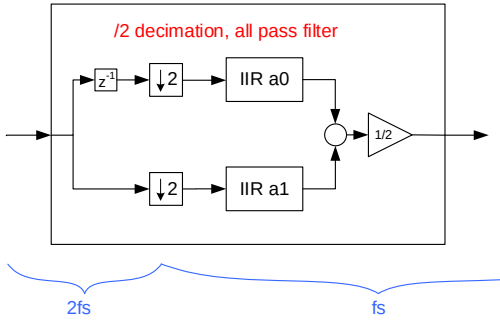
- Simple A-to-D conversion: Q-noise spread uniformly over bandwidth
- Sample rate increased by a factor K (OSR). Q-noise outside band is removed by digital filter. For each doubling of K, SNR is reduced by 3dB
- Basic Σ-Δ architecture, quantization noise is shaped



Decimation Filter

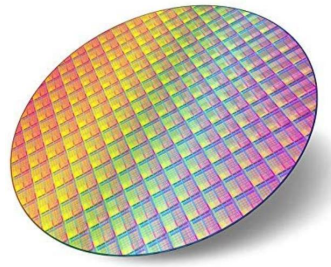




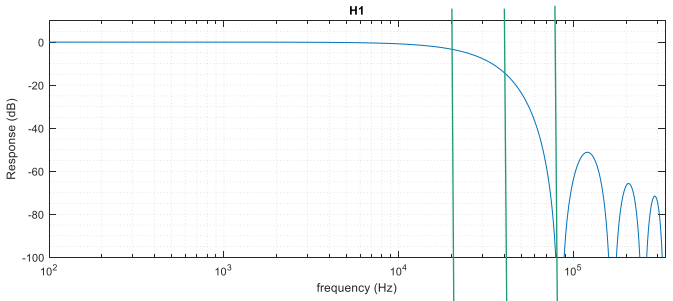


Observe how multipliers are moved to “slow” side

(Noble Identity)



fs 2fs 4fs



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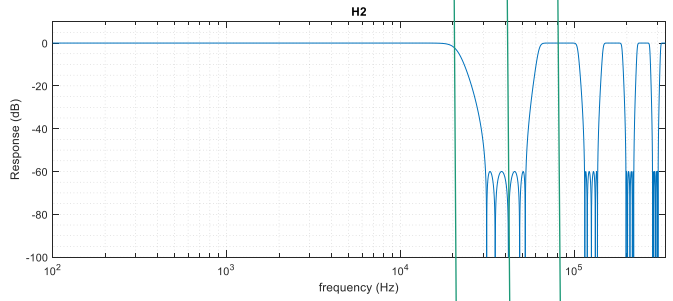

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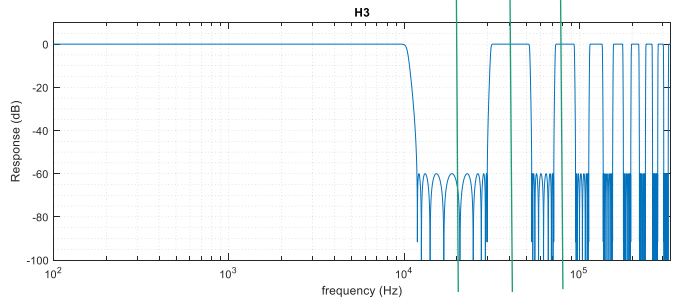

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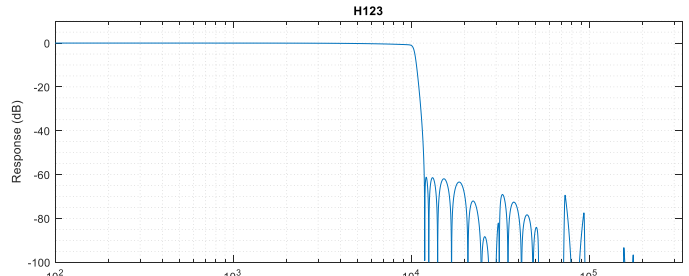
Total



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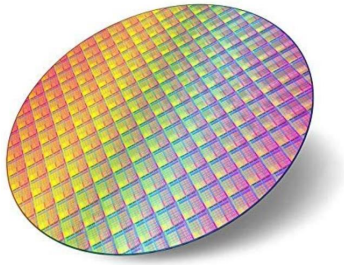
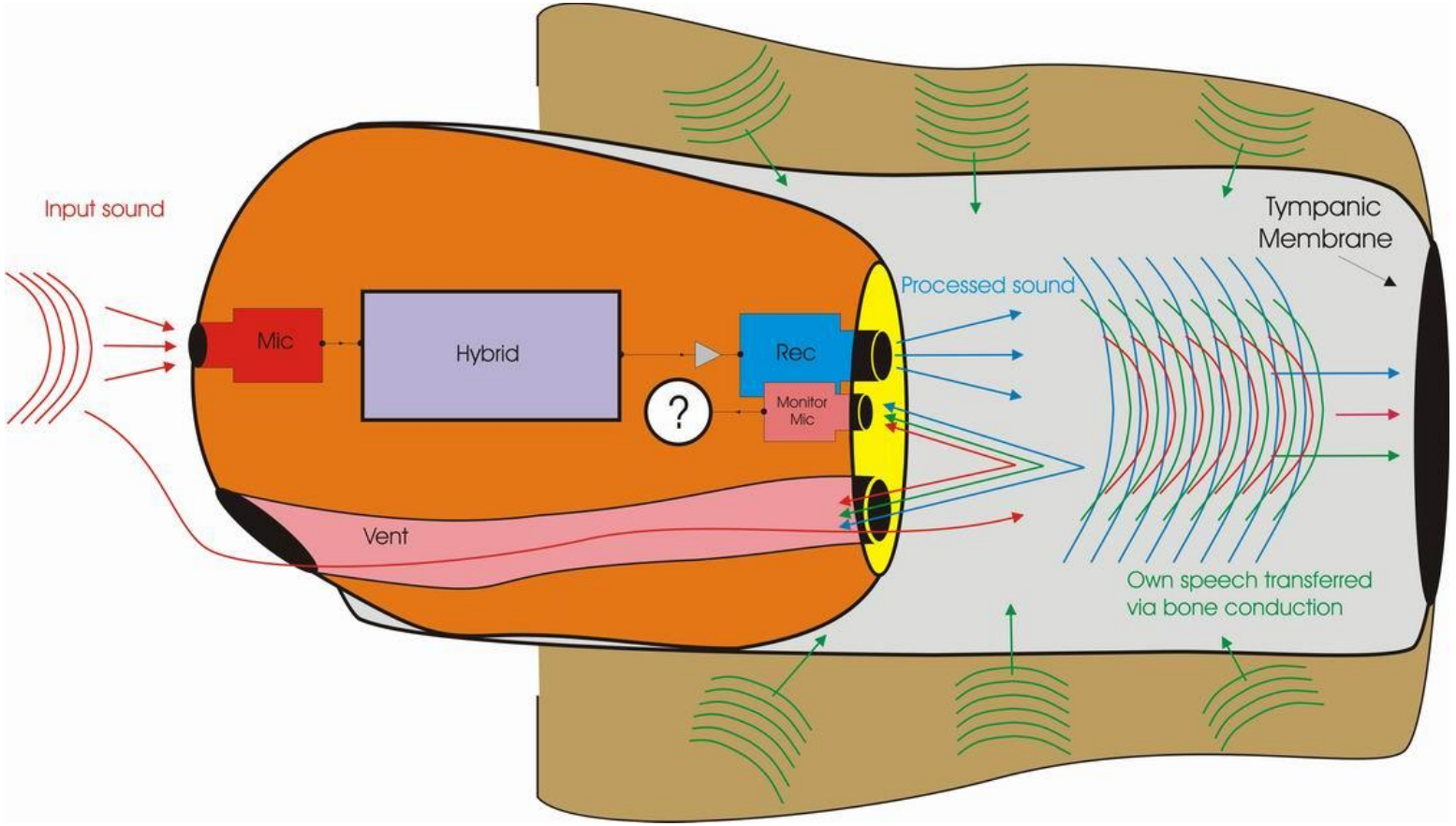
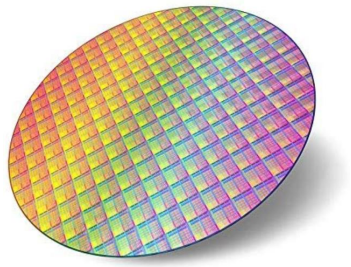
Sound Processing

- Filtering
- Compression/Expansion
- Anti-Howl
- Frequency lowering
- Occlusion
- Tinitus
- Aritificial Intelligence

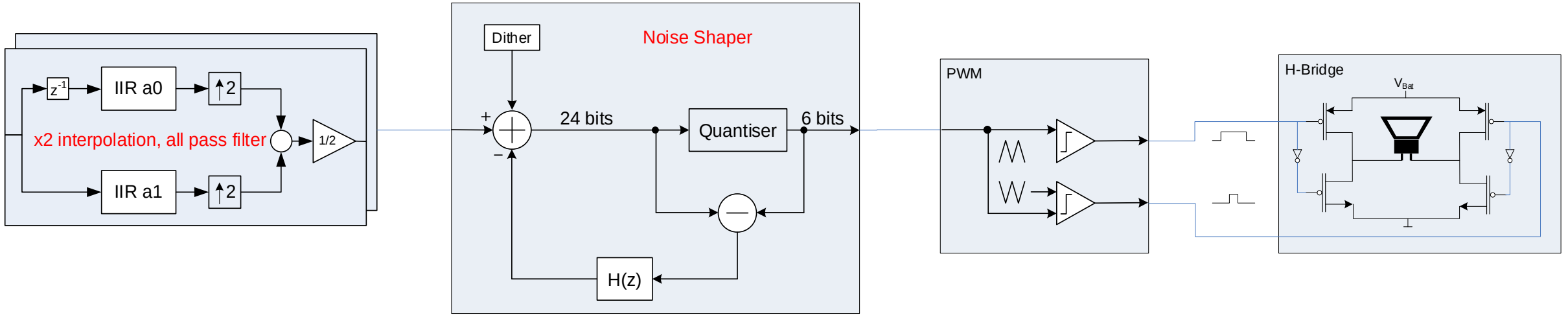




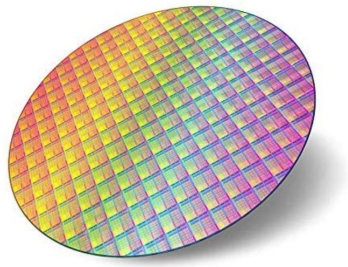
Class-D Amplifier



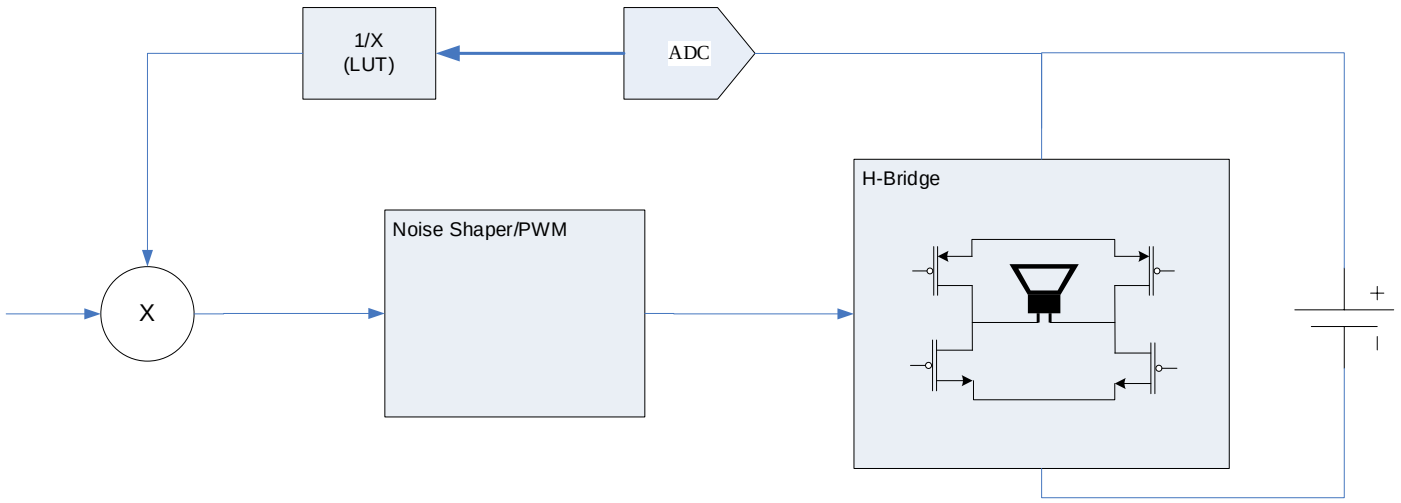
- Up-Sampling/Interpolation (similar to decimation)
- Sigma-Delta modulation with Dither addition and Noise Shaping
- PCM->PWM
- H-Bridge (Uses receiver as LowPass filter)

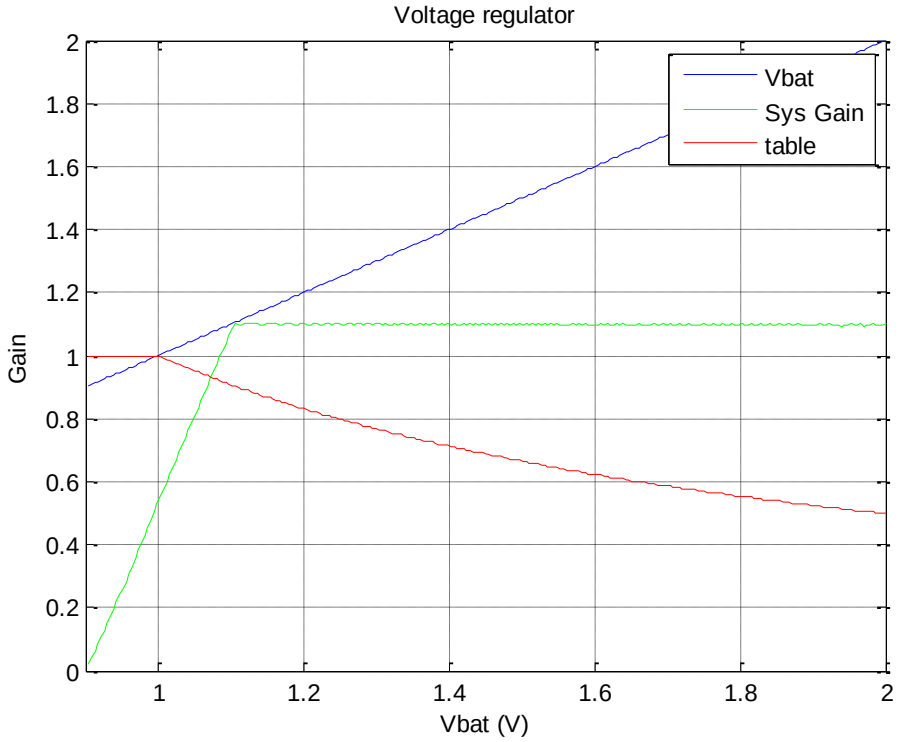


Vbat Regulator

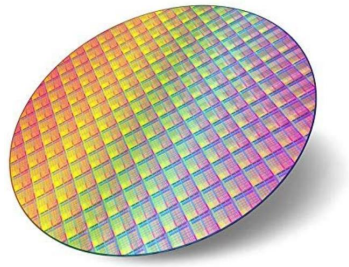


- Audio output level scales with H-Bridge supply
- Solution: Modulate digital gain with $1/V_{Bat}$ (LUT)
- System gain = K*Vbat * LUT output





Future Working Areas



- Analog
  - Low noise amplifiers
  - Sigma-Delta converters
  - MEMS microphones
  - Radios (Bluetooth, MI,…)
  - Power Management
  - H-Bridge
- Digital
  - Matlab/Simulink
  - Multiple DSP cores
  - Signal Processing
  - Multiple receivers
  - Power Amp (Class G/H)
  - Feedback
  - Audio Measurements
- SW
  - Algorithms
  - Adaptive filters
  - Occlusion
  - Directionality
  - AI

Lot's of challenges

Lot's of fun

- System Integration
  - Layout
  - Packing
  - Hybrid design
  - Rechargeability

Thank You!

Questions?