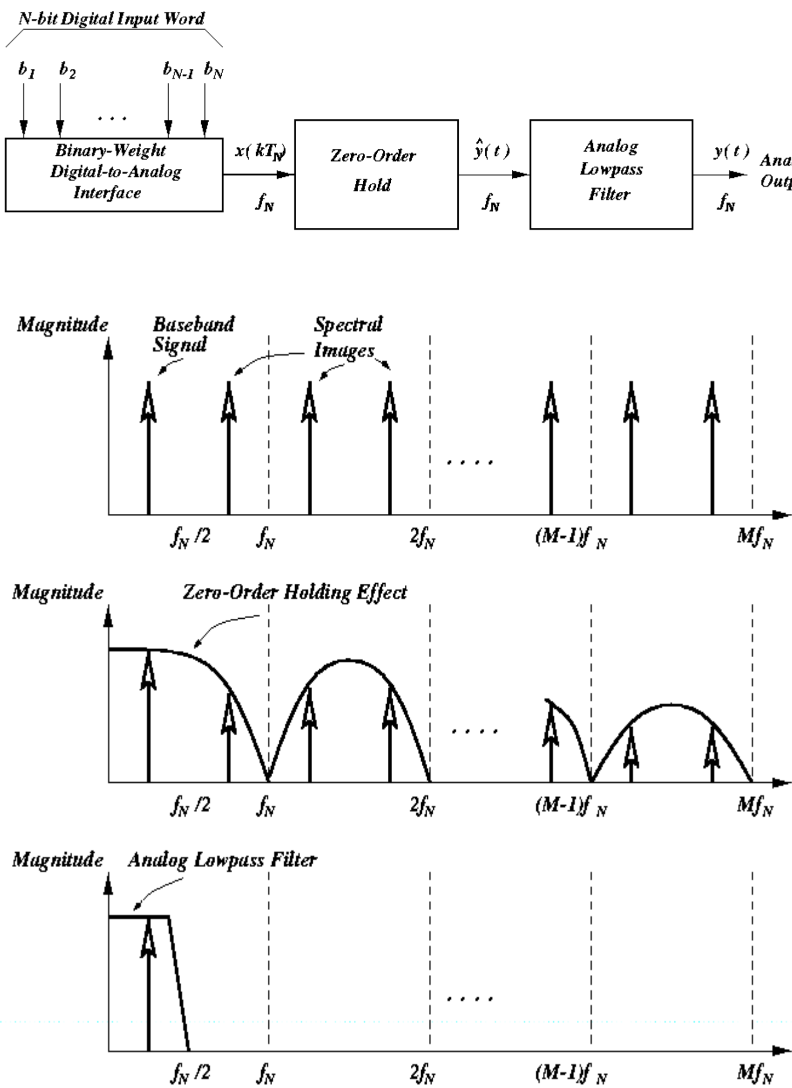
Appendix 4C: A 16/18/20 bits Input Format Sigma-Delta D/A Converter for Digital Audio Application

Outline

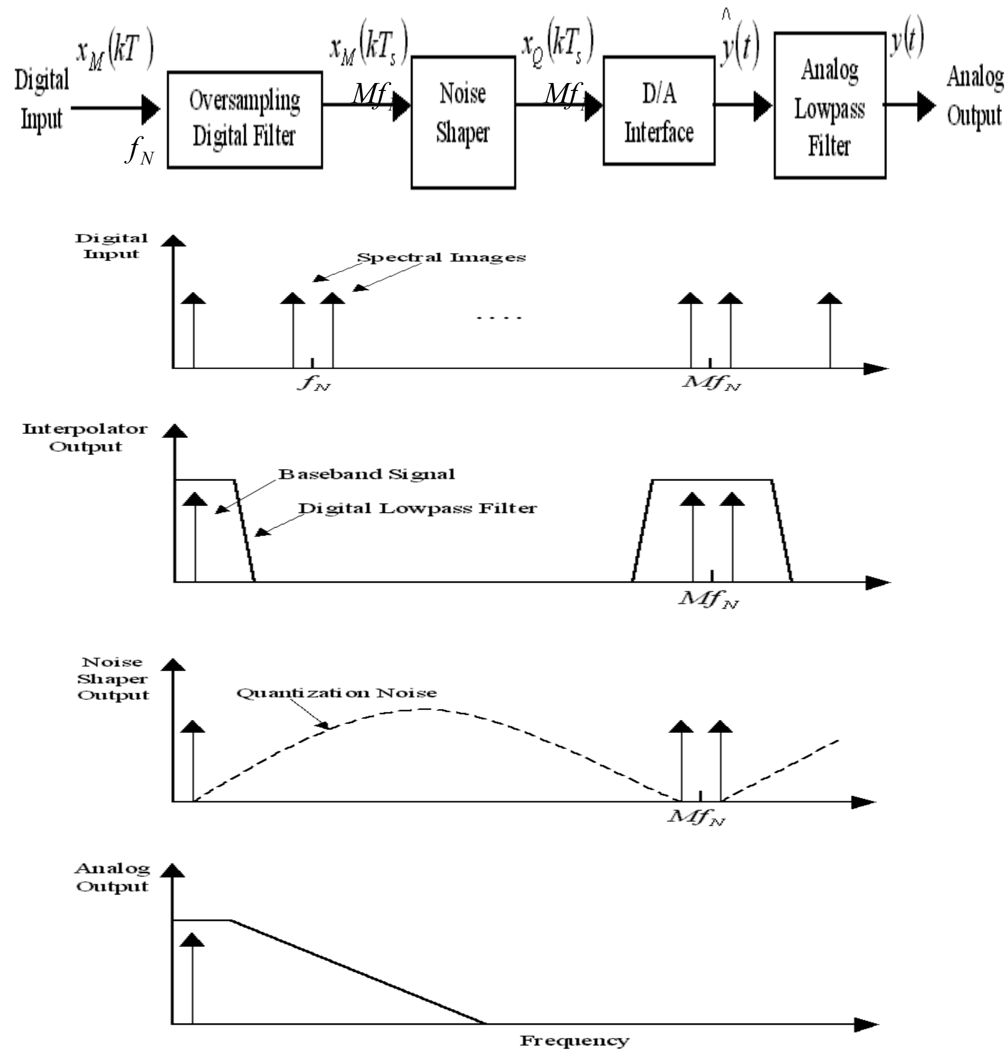
- Fundamentals of D/A conversion
  - — Compare between Nyquist and Oversampling DAC
- System design of Sigma-Delta DAC for Audio application
  - — Finite Impulse Response (FIR) Lowpass filter
  - — Upsampler
  - — Sigma-Delta Modulator (SDM)
  - — Specification
  - — Wordlength versus SNR
  - — Structure of DAC in consideration
- Hardware implementation
- Measurement
- Conclusion

Compare between Nyquist and Oversampling DAC

- Nyquist-rate DAC

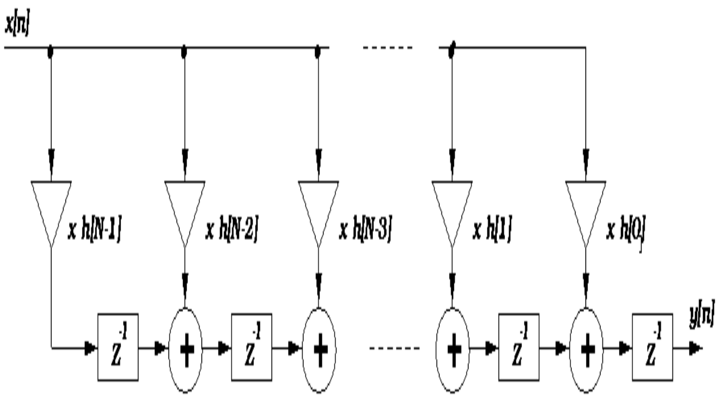


- Oversampling-rate DAC

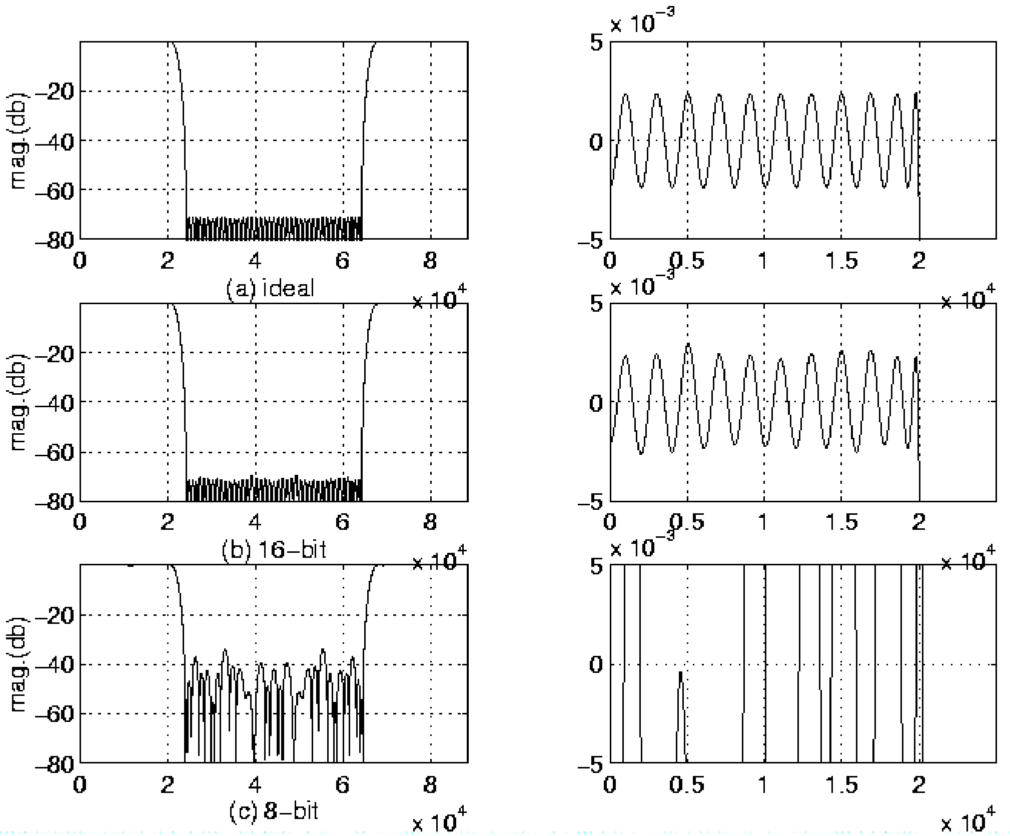


FIR Lowpass filter

- Characteristic
  - Stable & linear phase
  - Easily implemented , but large area is required
- Finite wordlength effect
  - Coefficient quantized error
  - Roundoff error
  - Overflows error

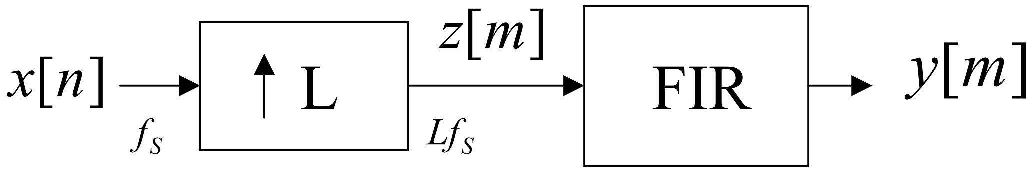


$$y[n]=\sum_{i=0}^{N-1} h[i]x[n-i]$$



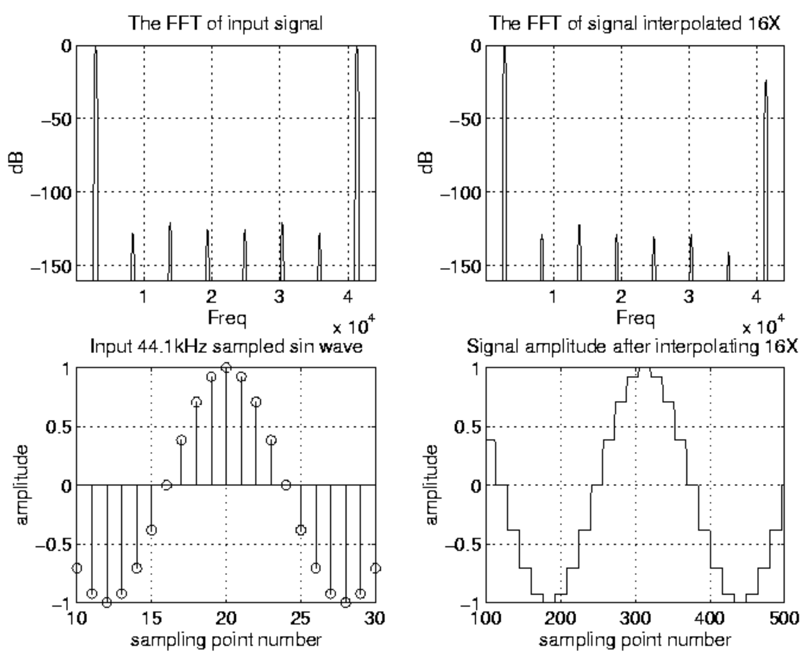
Upsampler

- Upsampling



- Duplication

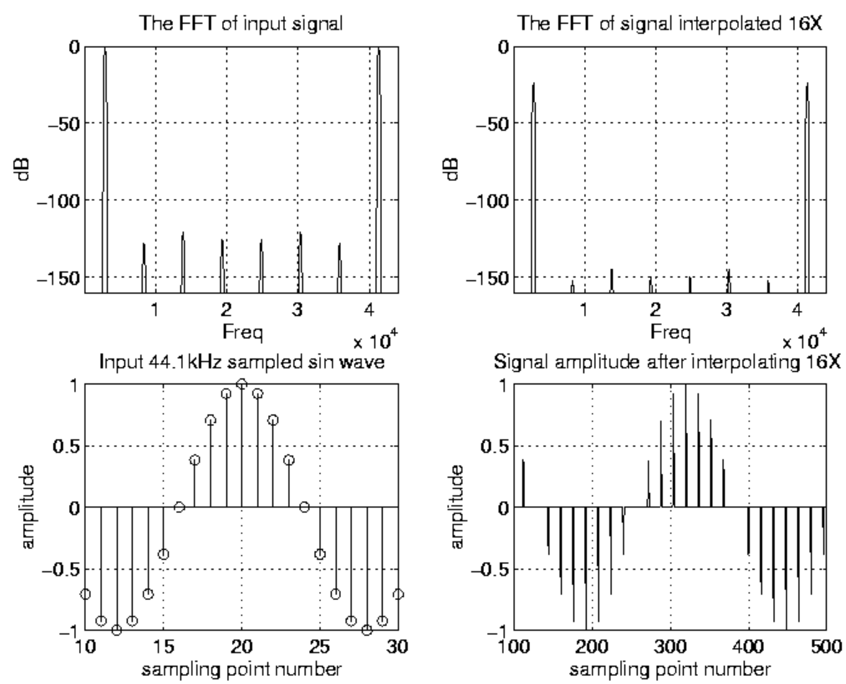
$$z[Ln] = z[Ln - l] = \cdots = z[Ln - n + 1] = x[n]$$



- Interpolate zero

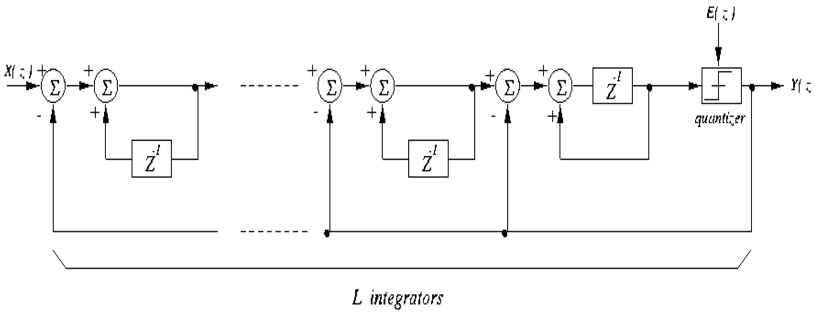
$$z[Ln] = x[n]$$

$$z[Ln - l] = \cdots = z[Ln - n + 1] = 0$$

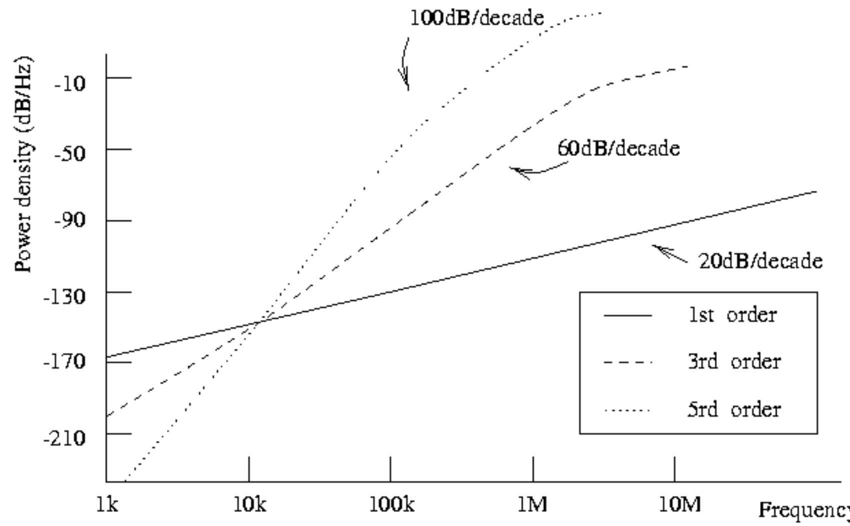


Sigma-Delta modulator

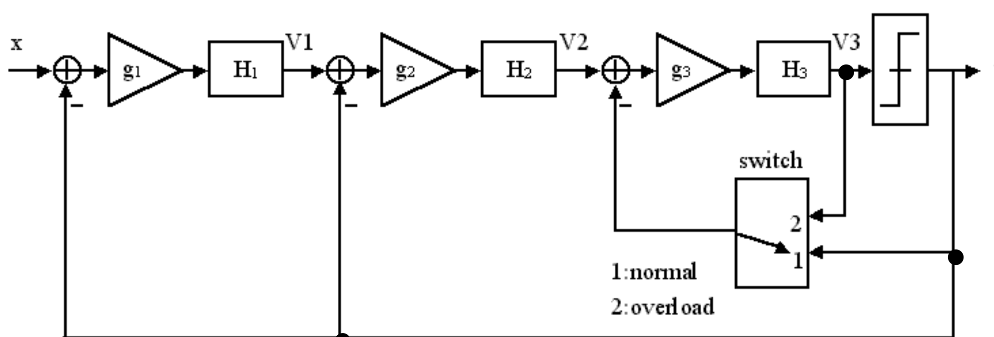
- Linear model of a high order noise shaper



$$Y(z) = z^{-1}X(z) + (1 - z^{-1})^L E(z)$$



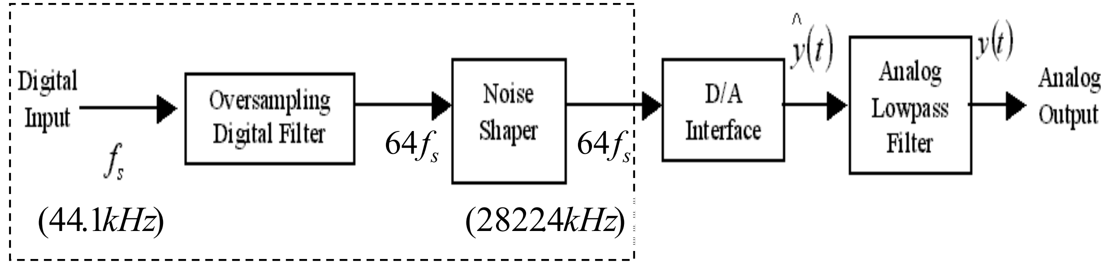
- Instability recovery method
  - Internal linear feedback (ILF)



Specification

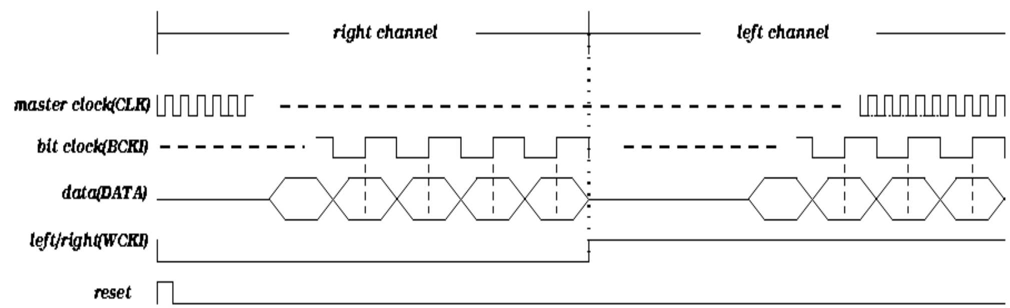
- 18-bit DAC

Parameter	Typical	Units
Sampling frequency	2822.4	kHz
Bandwidth (BW)	20	kHz
Oversampling ratio (OSR)	64	
Signal to noise ratio (SNR)	108	dB



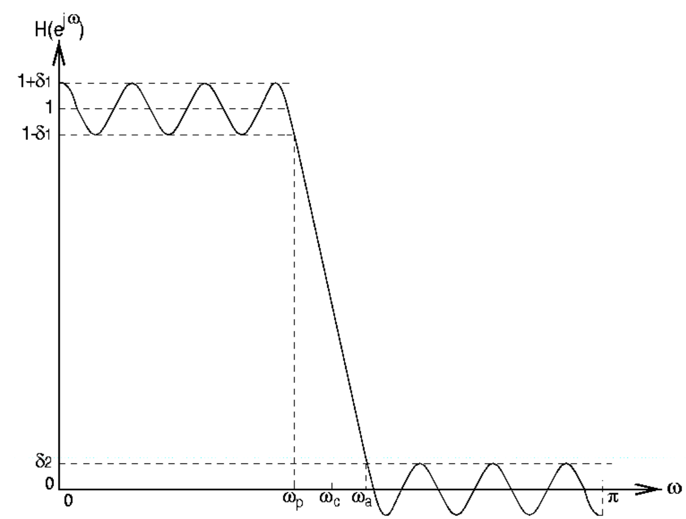
- Sony serial input data format

Parameter	Symbol	Typical	Units
Master clock	XTI	11.28	MHz
Word clock	WCKI	44.1	KHz
Data bit clock	BCKI	2.82	MHz
Input data	DATA	16/18/20	bits

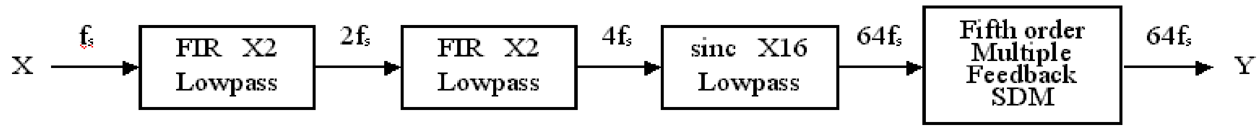


- FIR lowpass filter

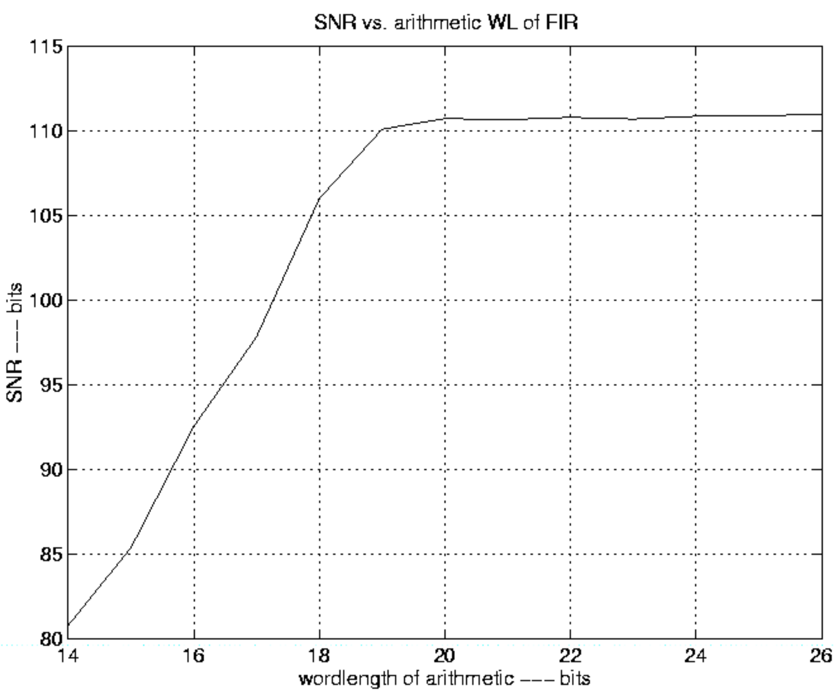
Parameter	Typical	Units
Passband edge (f_p)	20	kHz
Stopband edge (f_a)	22.05	kHz
Passband ripple (δ_1)	<0.005	dB
Stopband ripple (δ_2)	≥ 70	dB
Oversampling ratio (OSR)	64	
Signal to noise ratio (SNR)	108	dB

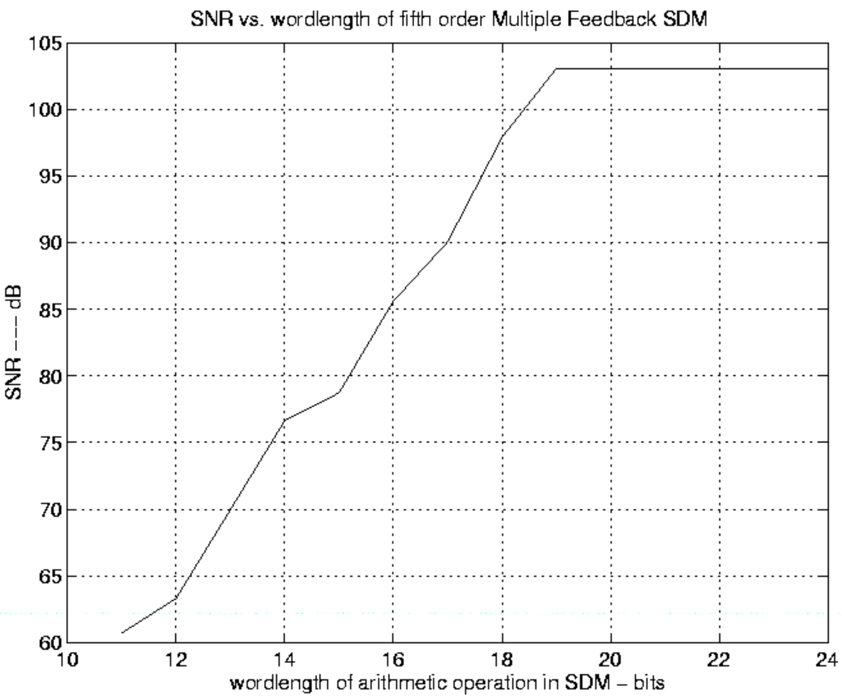


Wordlength versus SNR

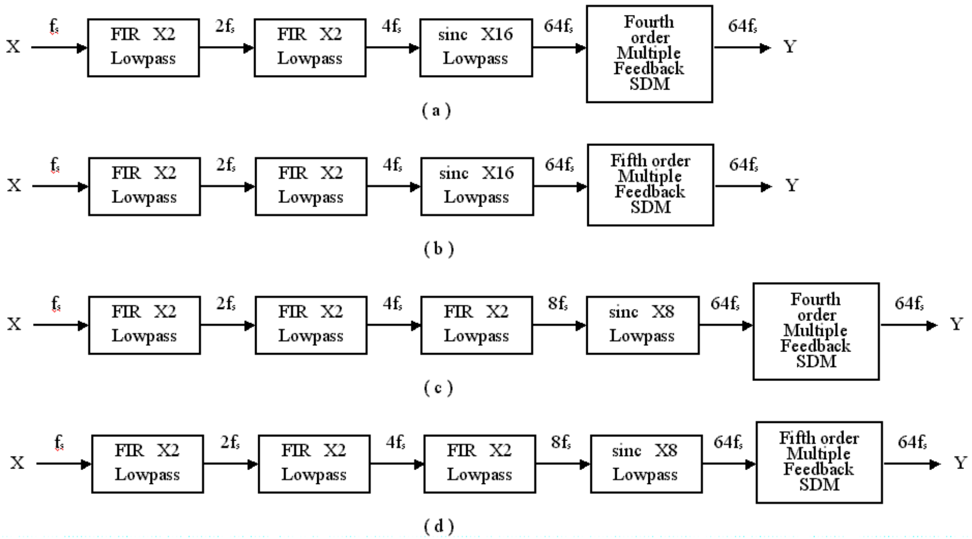


- Digital filter
  - Using Matlab to achieve the required tap.
- SDM
  - HOST generate the coefficient of SDM.



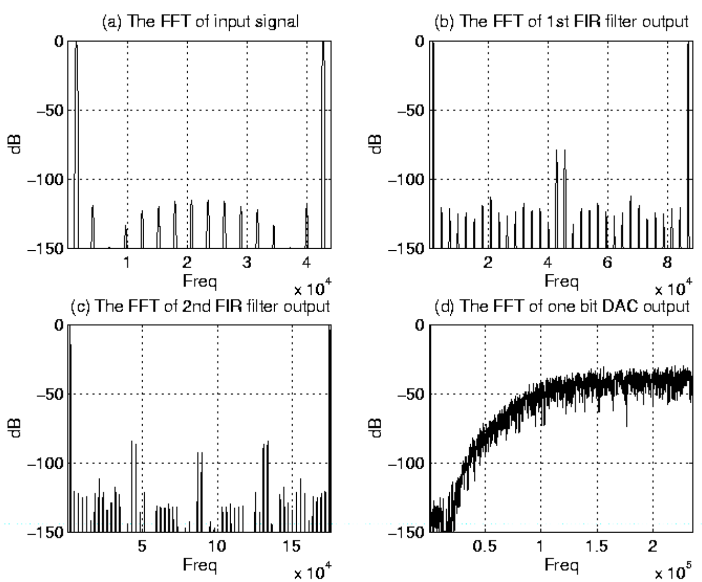


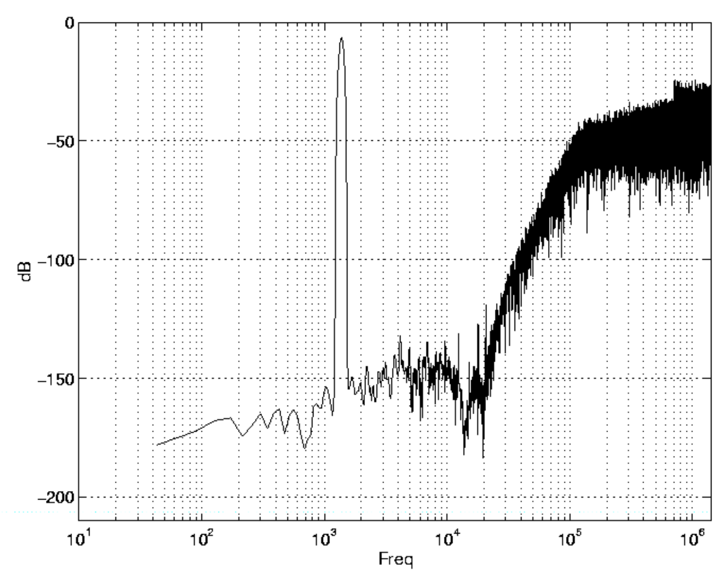
Structures of DAC in consideration



Structure type	PSNR (dB)	DR (dB)	arithmetic complexity
Type 1	100	97	30
Type 2	108	105	30
Type 3	101	96	42
Type 4	111	105	42

- System simulation for type 2





Implementation

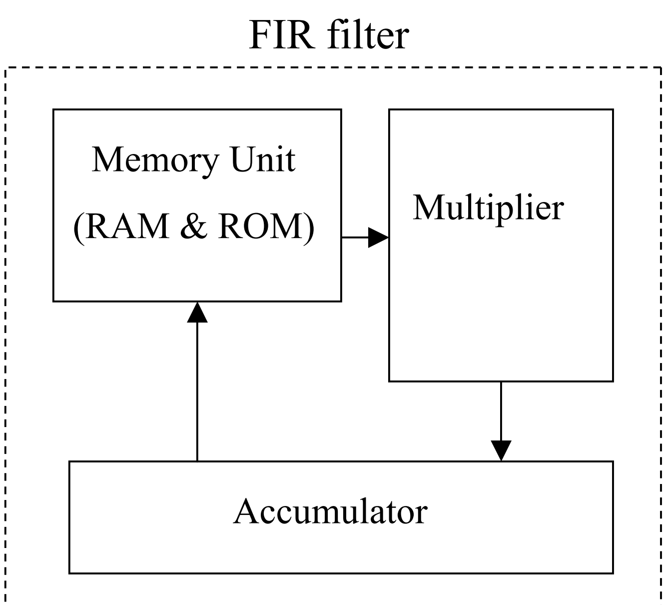
- Consideration of area

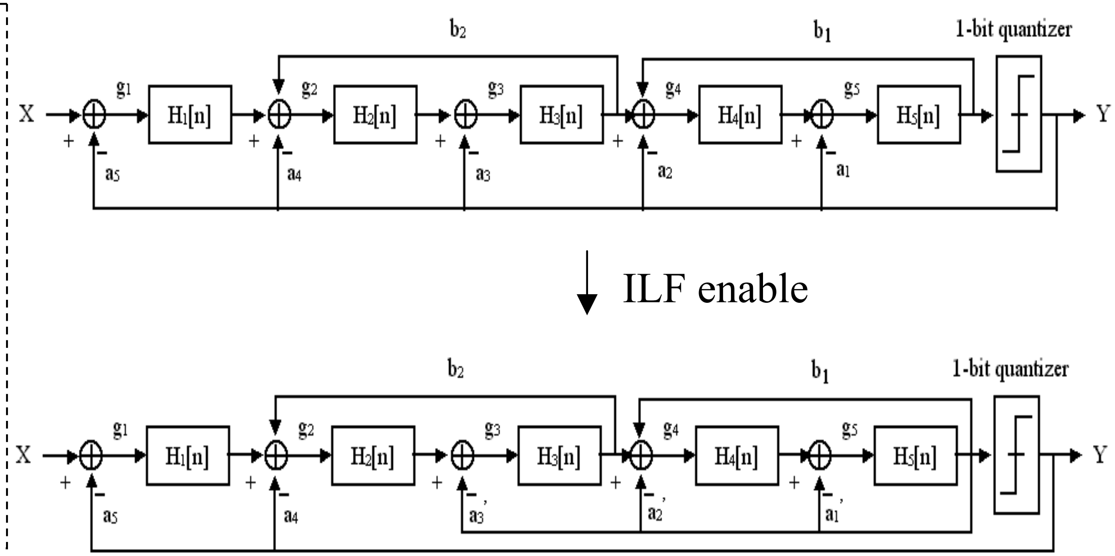
  - Half band technique , which reduce the number of tap in FIR

  - Multiplier free of SDM

  Multiplier is substituted by shift and adder with coefficients,

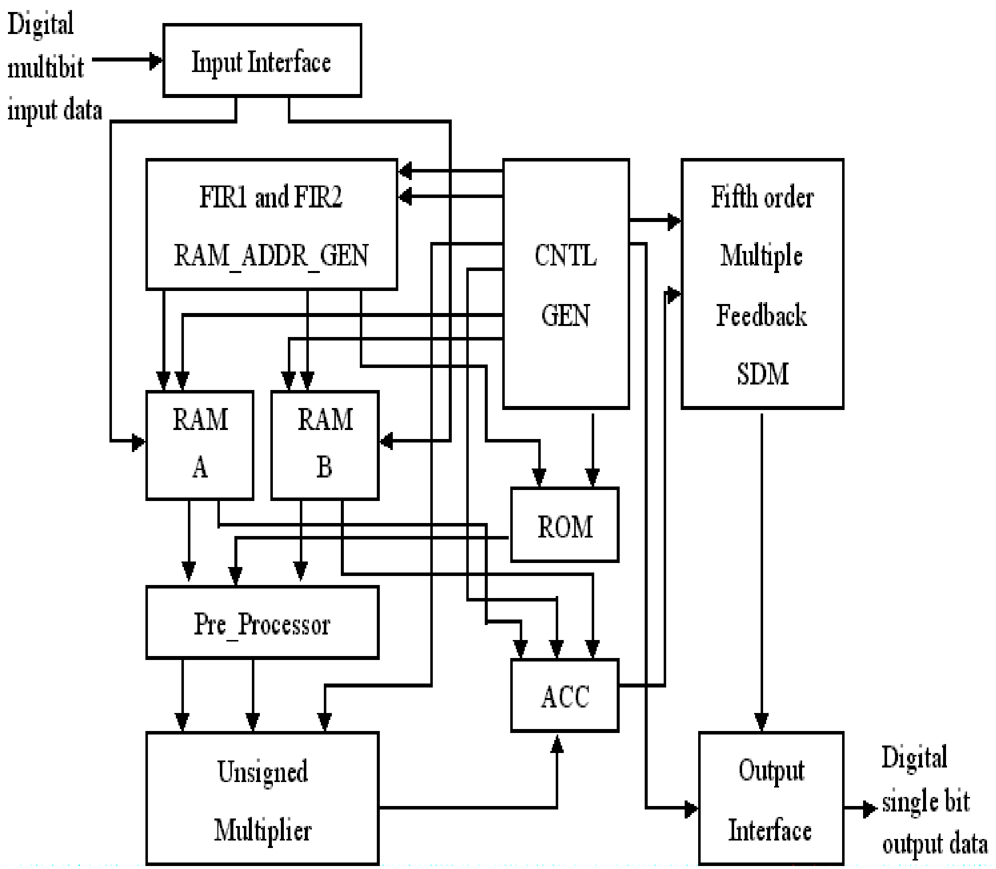
  which value are order of 2.



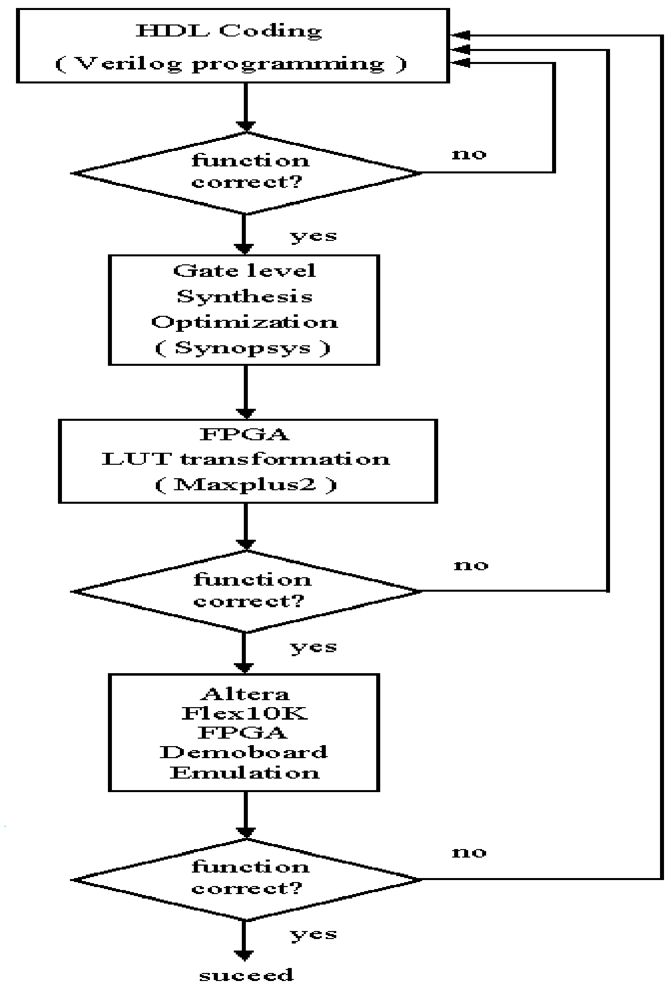


Implementation (cont)

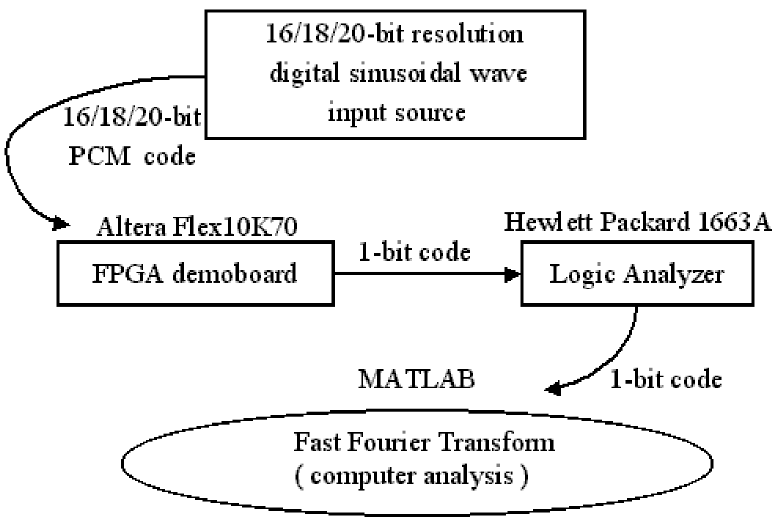
- Hardware block diagram

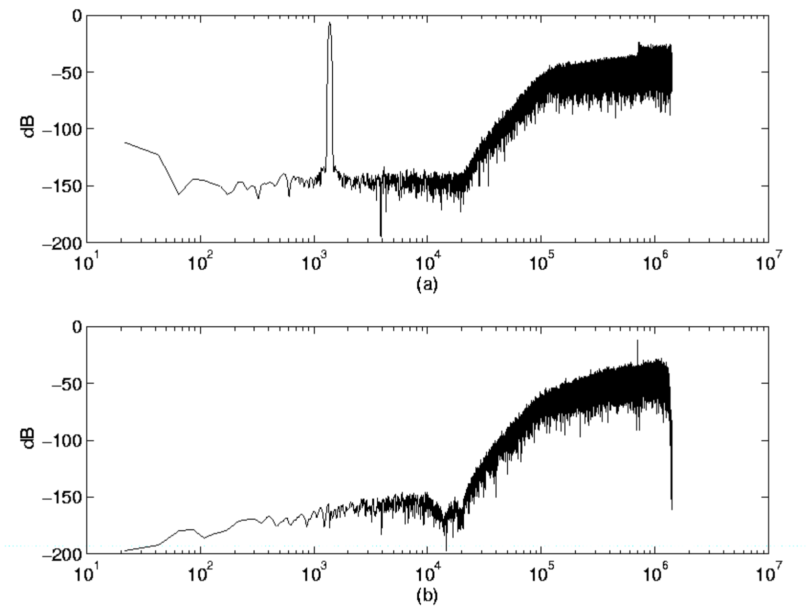


- HDL based design flow



Measurement





Input data resolution	16-bit	18-bit	20-bit
Dynamic range	92.1dB	101.2dB	109.1dB
Peak SNR	90.2dB	100dB	105dB

Conclusion

- High resolution is achieved by Sigma-Delta DAC
- Instability recovery mechanism is applied to maintain stability
- Reduction of area
  - Half band technique is used in digital filter
  - Multiplier free modulator structure
- 16/18/20 bit input format is available for audio application