



HIGH END AUDIO DAC CONVERTERS

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Audio



Video



Imaging





Main Topics

- Topology Comparison.
- Building Blocks Overview.
- De-emphasis. (WHY?)
- DAC Implementation
- Conclusion:
Show FFT's of DAC prototype.





TOPOLOGY COMPARISONS

NON-OVERSAMPLED

-Converts each data point at the sample rate. (Ex 44.1kHz)

Pros:

-Straightforward approach, just convert the sample at the sample rate.

Cons:

-Jitter Sensitivity is high.

-SINC roll-off is an issue.

-Analog Reconstruction Filter is tough to build.





TOPOLOGY COMPARISONS

OVERSAMPLED

-Data is up-sampled then converted to analog at a faster rate.

Pros:

- Jitter sensitivity can be reduced.
- SINC roll-off can be addressed in digital domain.
- Analog Reconstruction Filter is much easier to implement.
- Can be “Linear Phase”
- Noise Shaping is an option.

Cons:

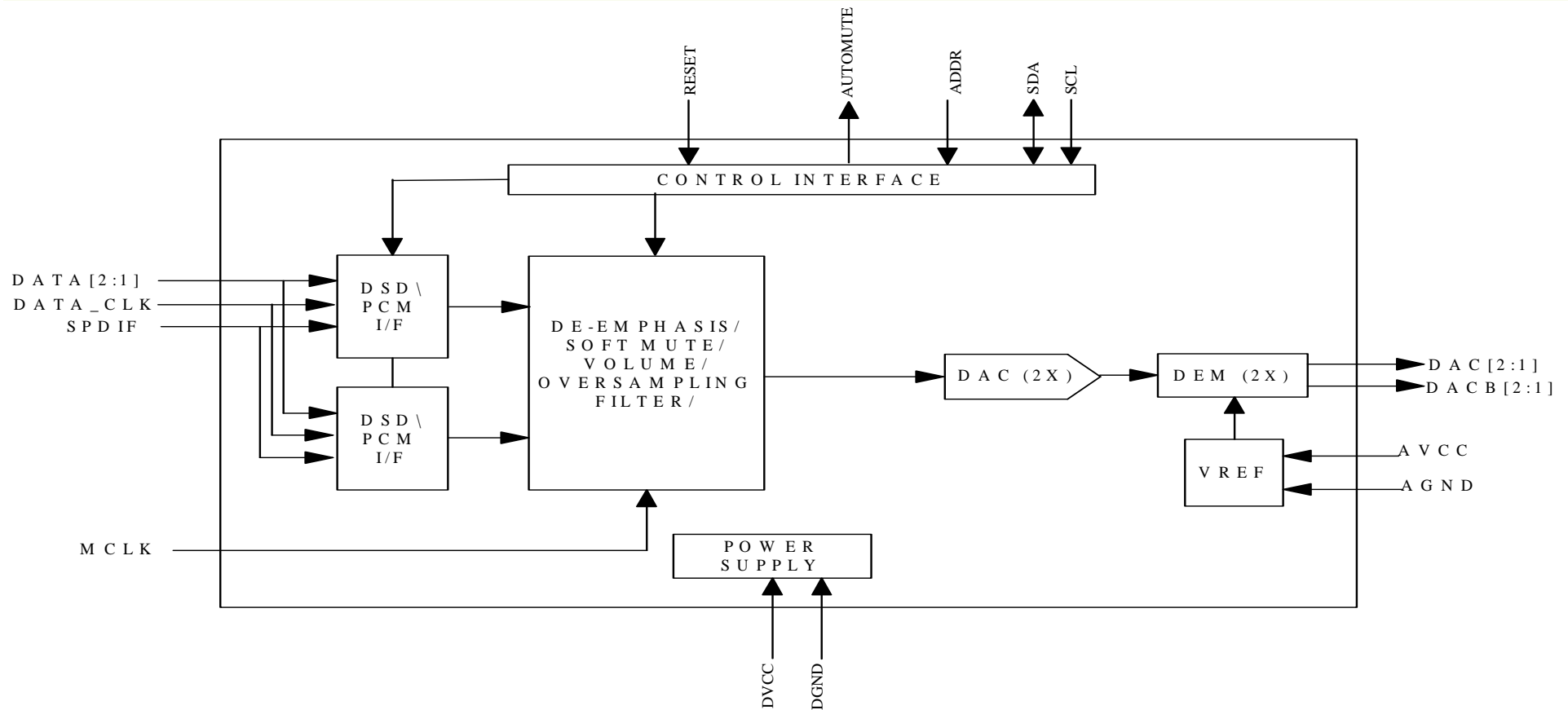
- Need an Over-sampling Filter in digital domain.
- Digital noise on chip is increased.
- Clocking is more complex.





BUILDING BLOCK OVERVIEW

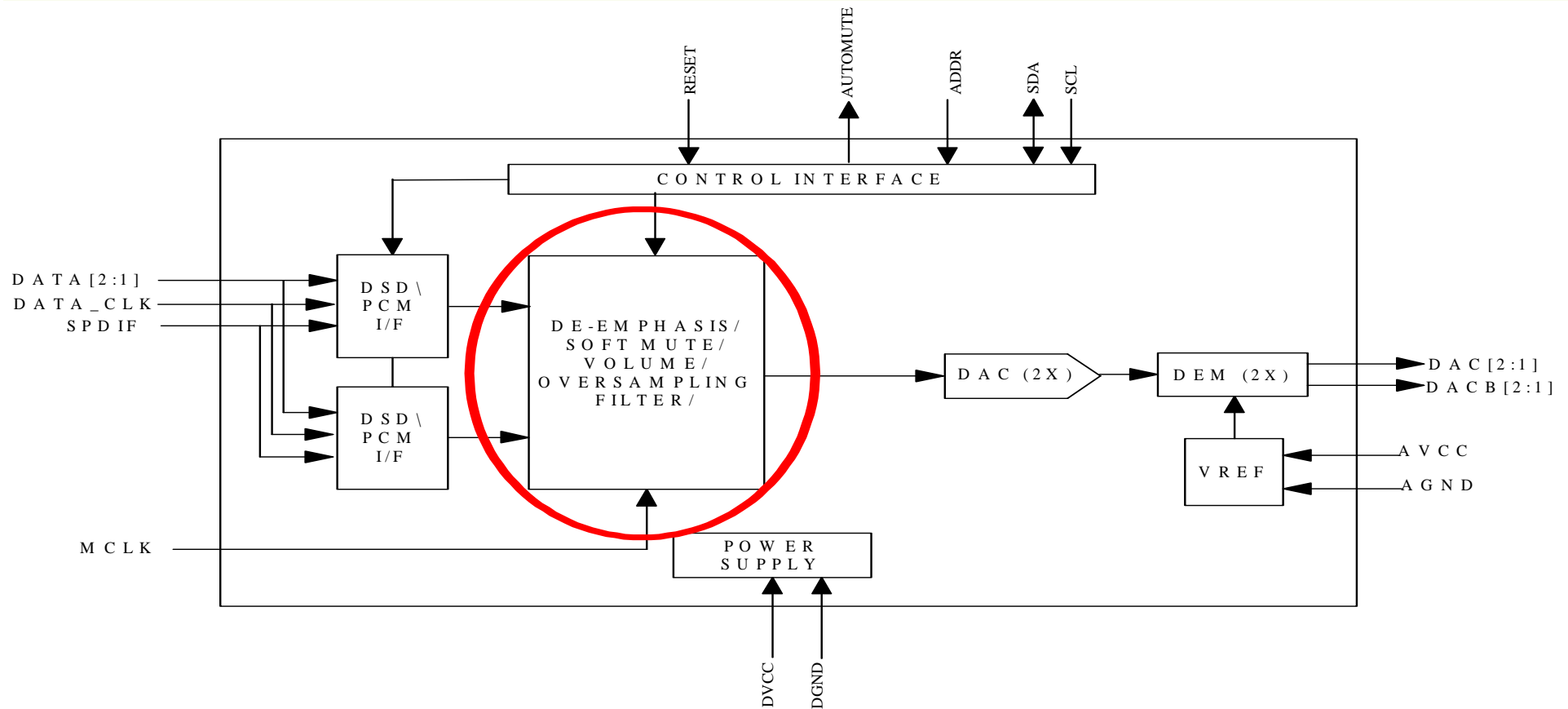
Typical Over-Sampling Audio DAC Block Diagram





DE-EMPHASIS

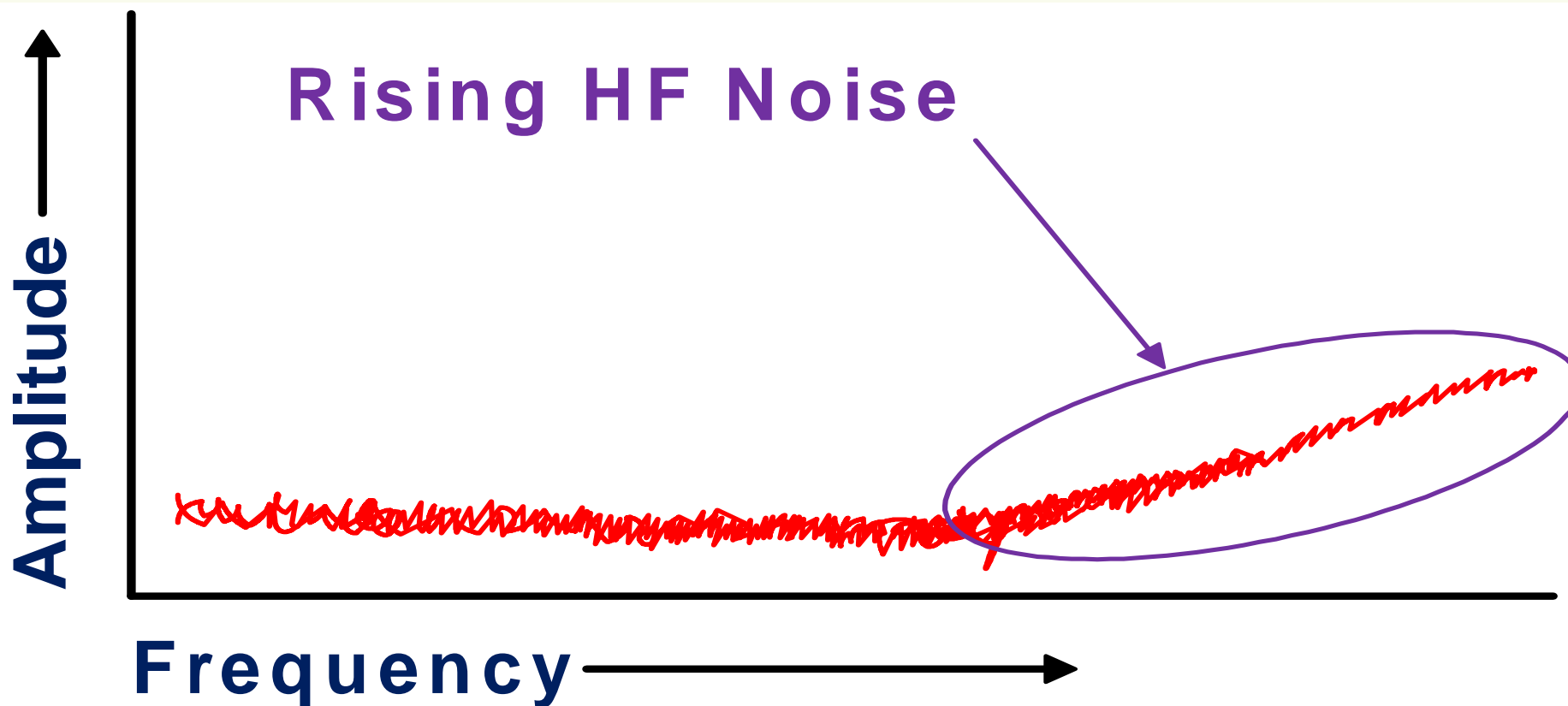
Typical Over-Sampling Audio DAC Block Diagram





EMPHASIS

- In Early days of digital recording ADC, DAC performance was not great.
- The converters exhibited a rising noise floor in the upper end of the Audio Band

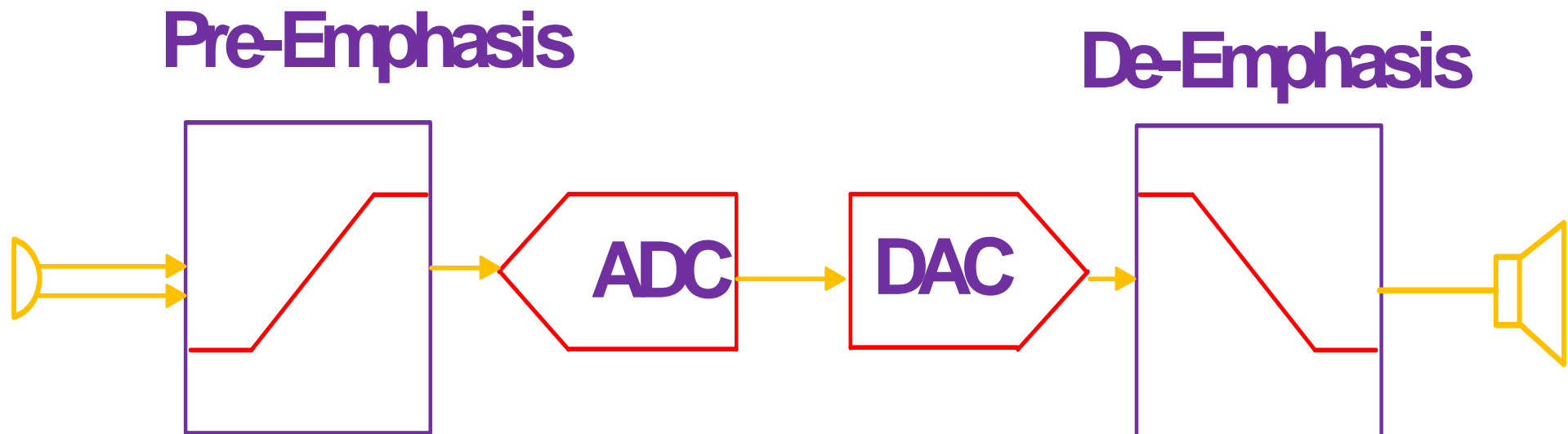




EMPHASIS

-SOLUTION

-Apply “Pre-Emphasis” in analog domain before digitizing, then use a “De-Emphasis” filter in the analog domain after reconstruction.





EMPHASIS

-RESULT

-Original analog signal is reconstructed with flat frequency response, however the un-used headroom in the HF of the Audio band is now used.

-TODAY

-DAC's / ADC's no longer have this noise issue, but some recordings out there have been digitized with "Pre-Emphasis"

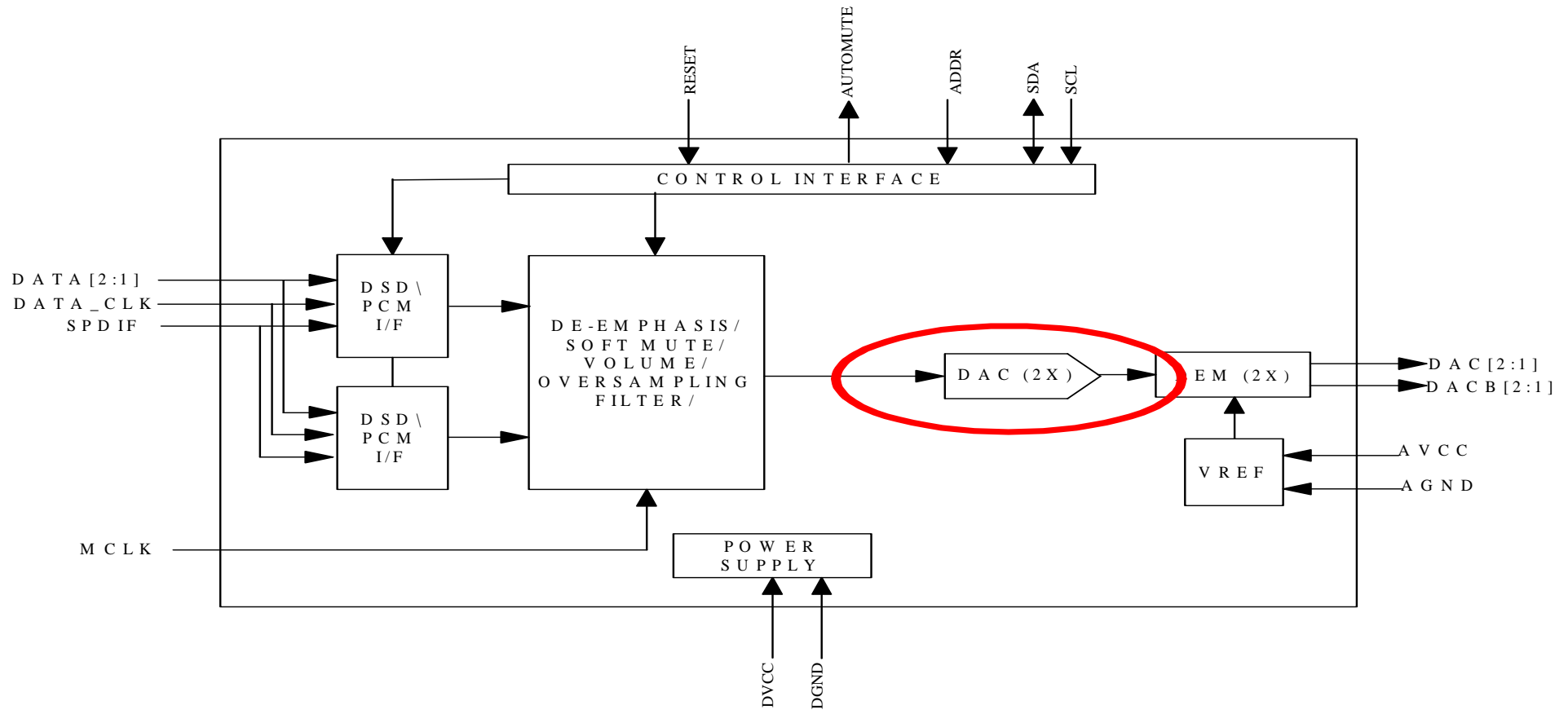
-Today's DAC's must be able to flatten frequency response with recordings that were "Pre-Emphasized"





DAC

Typical Over-Sampling Audio DAC Block Diagram





DAC

For Over-Sampled DAC there are choices.

-Delta-Sigma

- Single-bit output.

- Performance around -110dB DNR

- Spurious/Idle Tones can be a problem

-Multi-Bit

- Multi-bit output.

- Performance around -120dB DNR

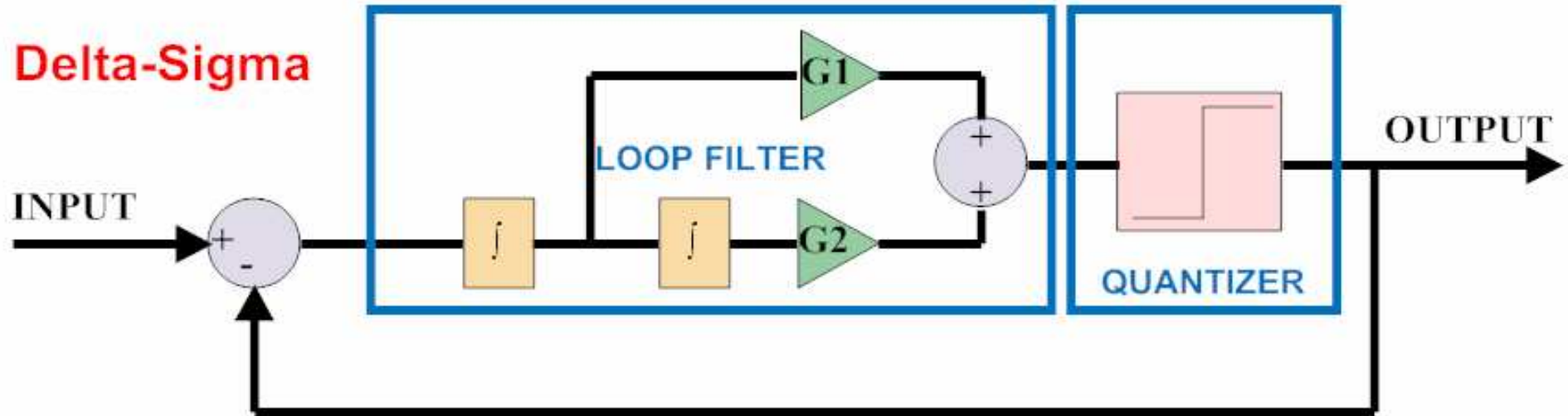
- Spurious/Idle Tones much less of a problem



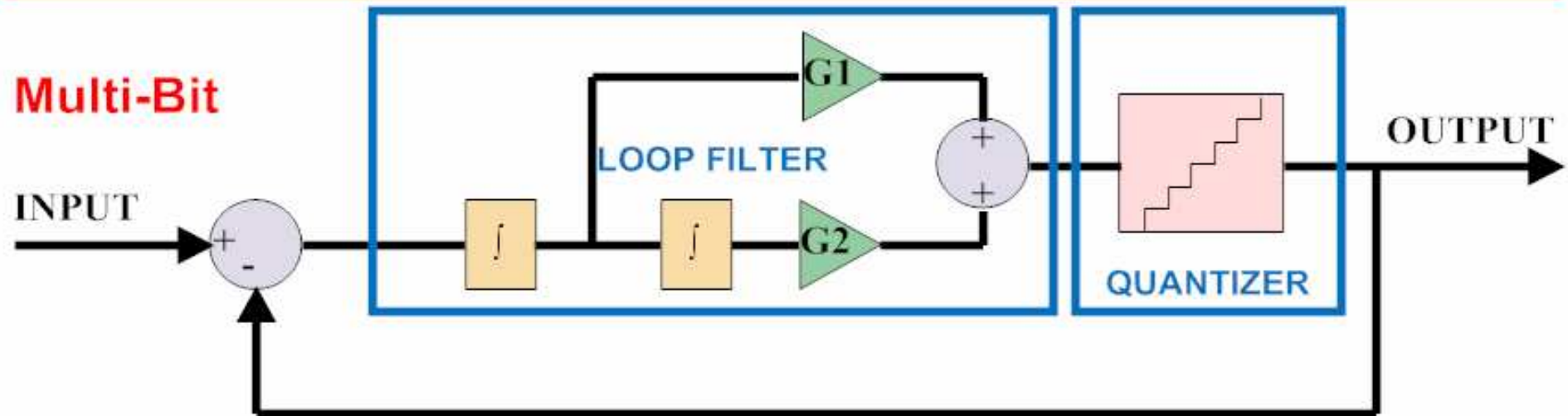


DAC

Delta-Sigma



Multi-Bit





Digital To Analog

- Digital circuitry makes noise on chip.
- Analog circuits are susceptible to noise.

PROBLEM!!

HOW TO CREATE GOOD ANALOG PERFORMANCE?



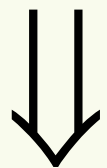


Methodology

-Uncorrelated Noise
Adds "RSS"

$$R_{total} = \sqrt{\sum_{i=1}^{i=N} (R_i)^2}$$

$N = 1000$



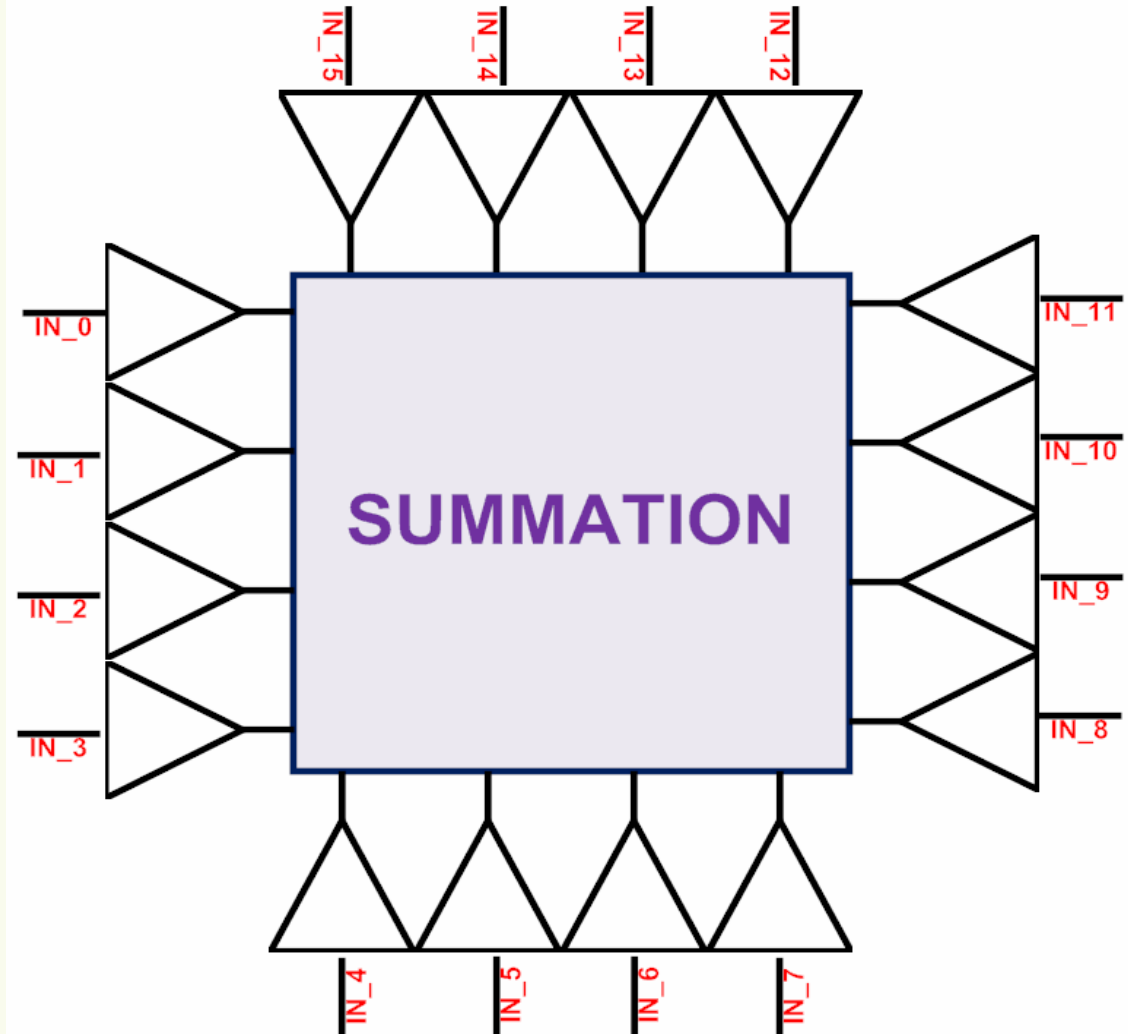
$30dB!!$





Methodology

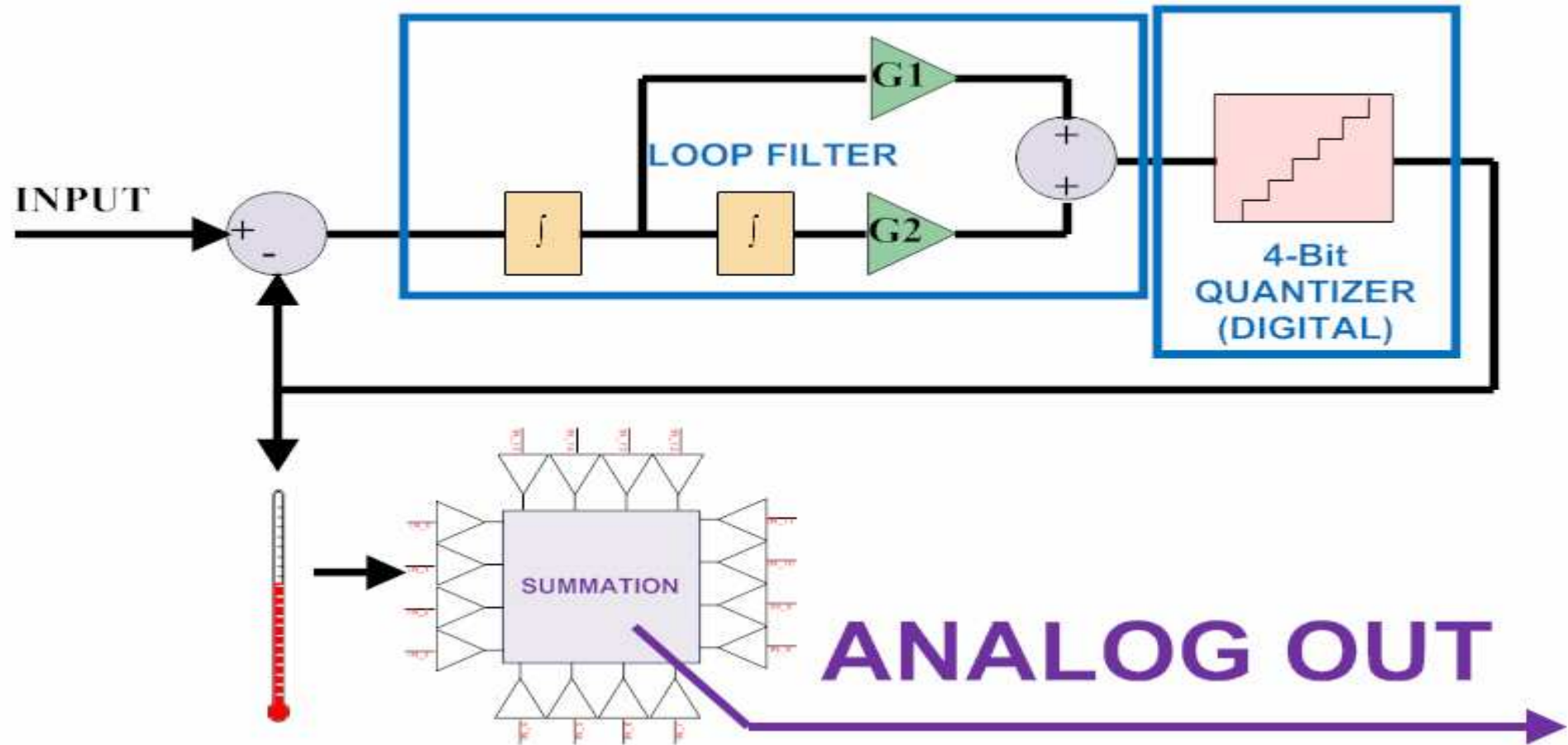
- Add up Many DAC's that have
Correlated Signal
and
Uncorrelated Noise
- Need some scheme
to drive the DAC's





MULTIBIT NOISE SHAPED DAC

-Map N bits to 2^N bits (Thermometer Encode)





DEM

DYNAMIC ELEMENT MATCHING “DEM”

-Quantizer in digital control loop is ideal, however the implementation of the quantizer in analog domain is not!

-Must be able to somehow compensate for the errors in the analog “quantizer”

-DEM does just that, it can move the errors to be out of the bandwidth of interest, and therefore can be filtered off.

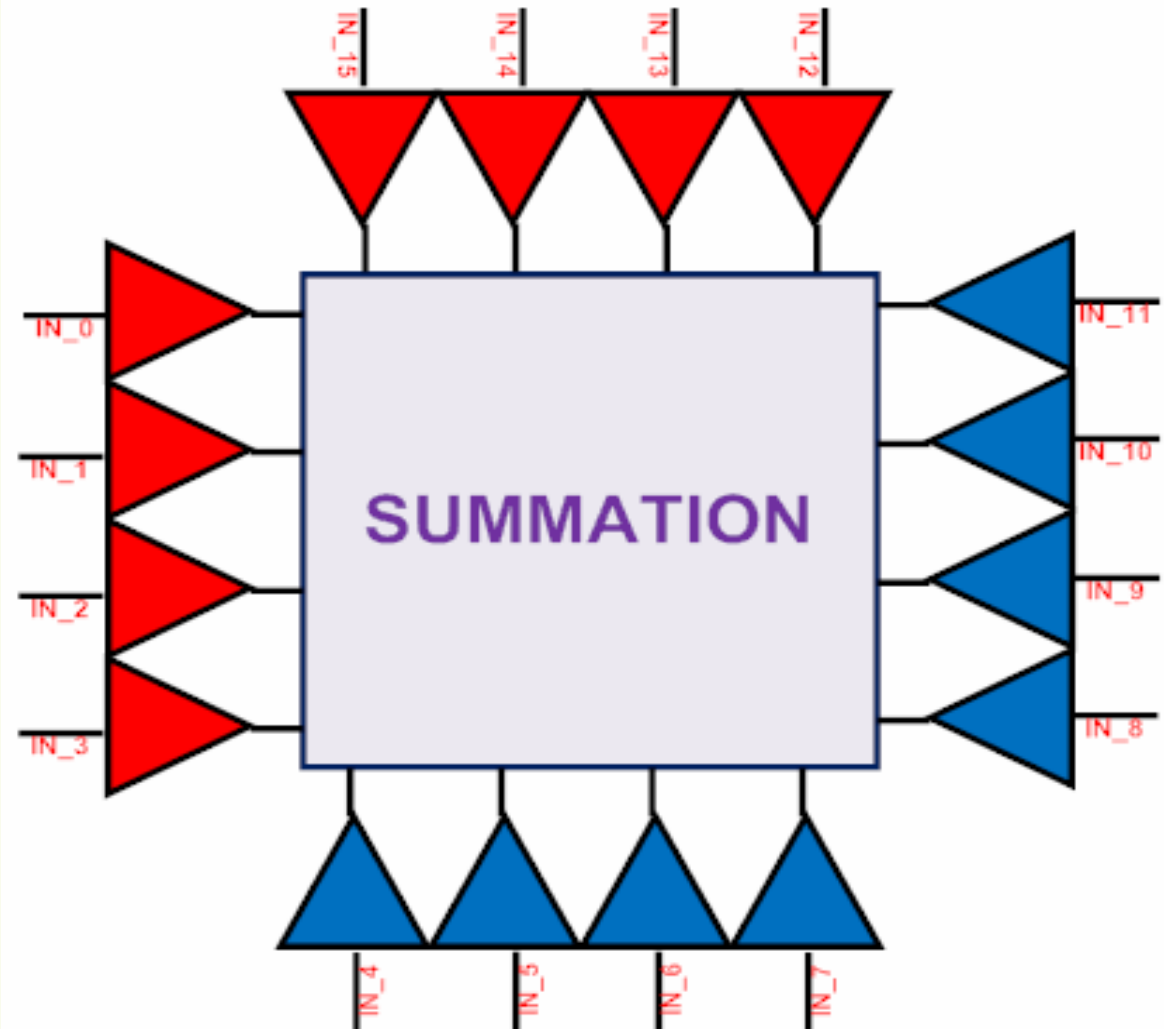
-Decouples which individual “DAC” is contributing to a certain level in the output. (Linearity, THD improved)





DEM

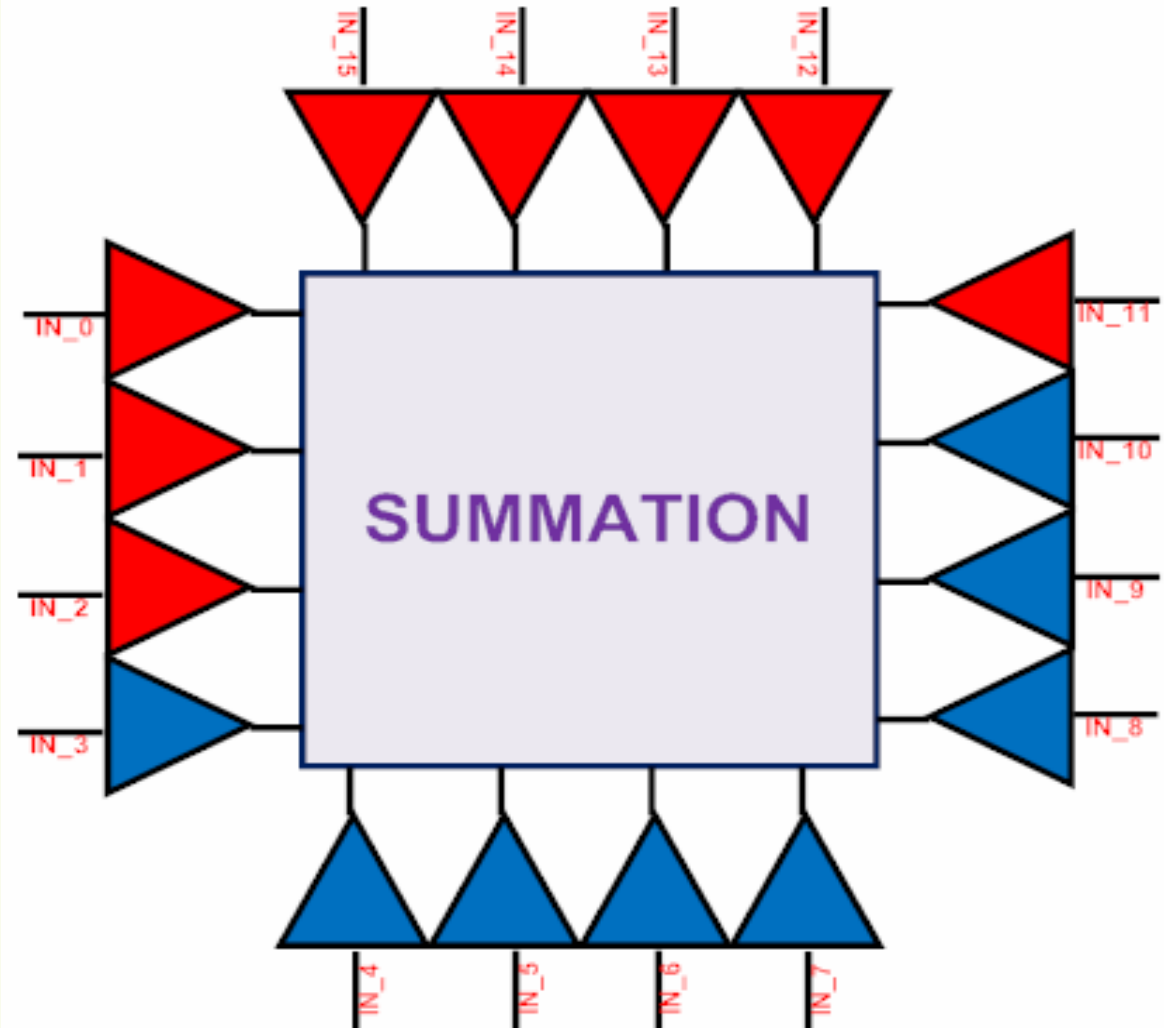
-Use Barrel Shifting
DEM Scheme.





DEM

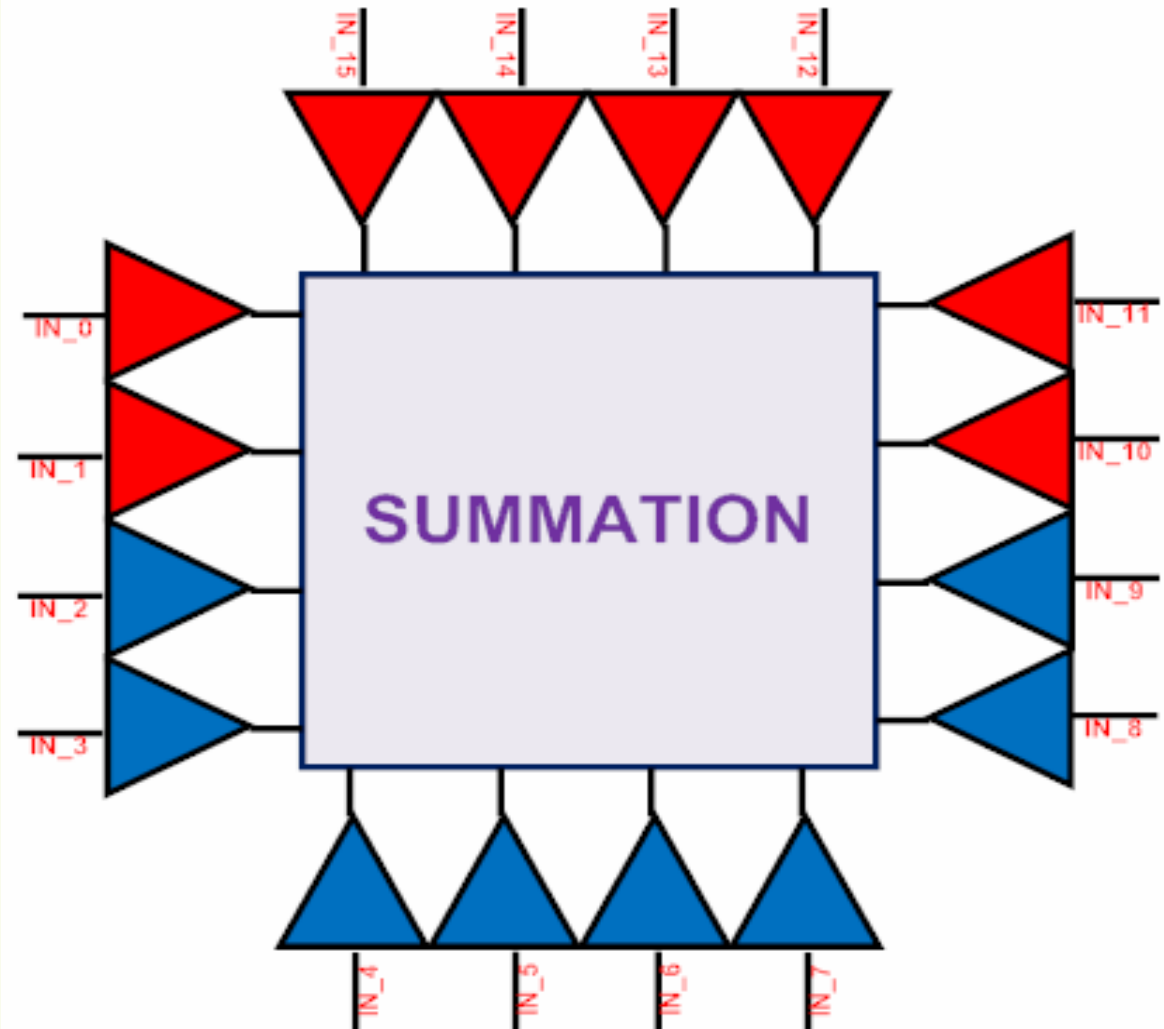
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DEM

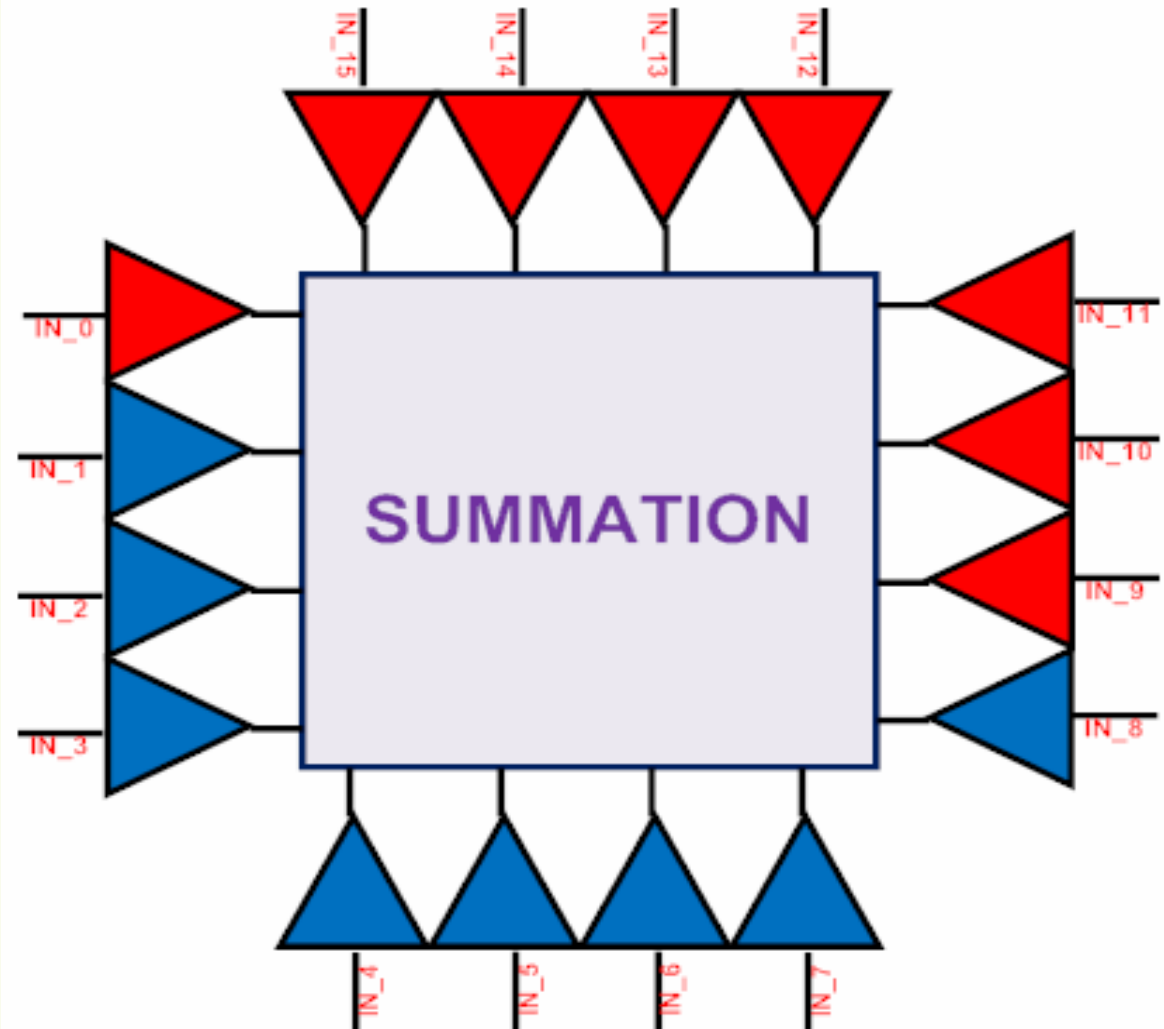
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DEM

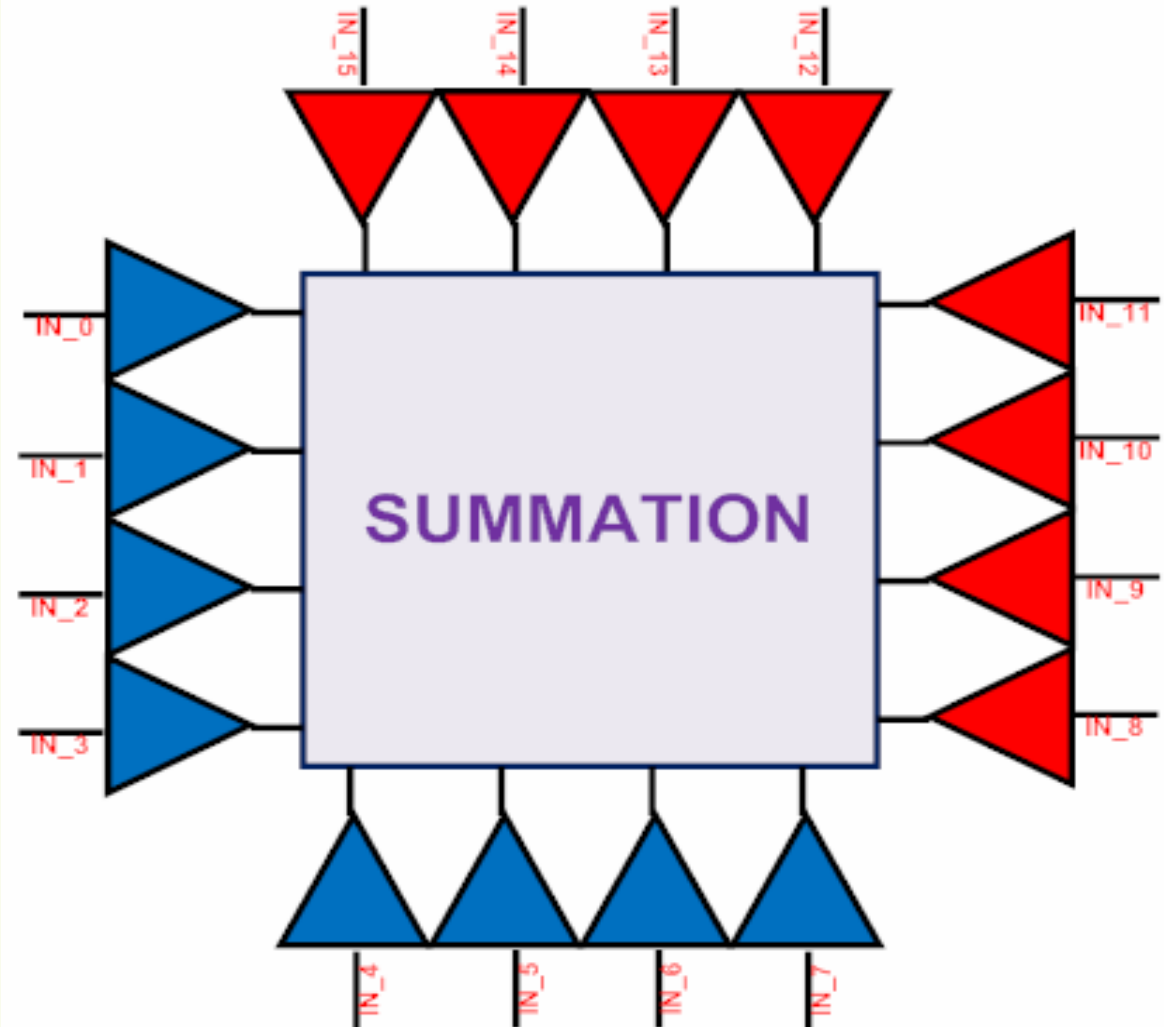
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DEM

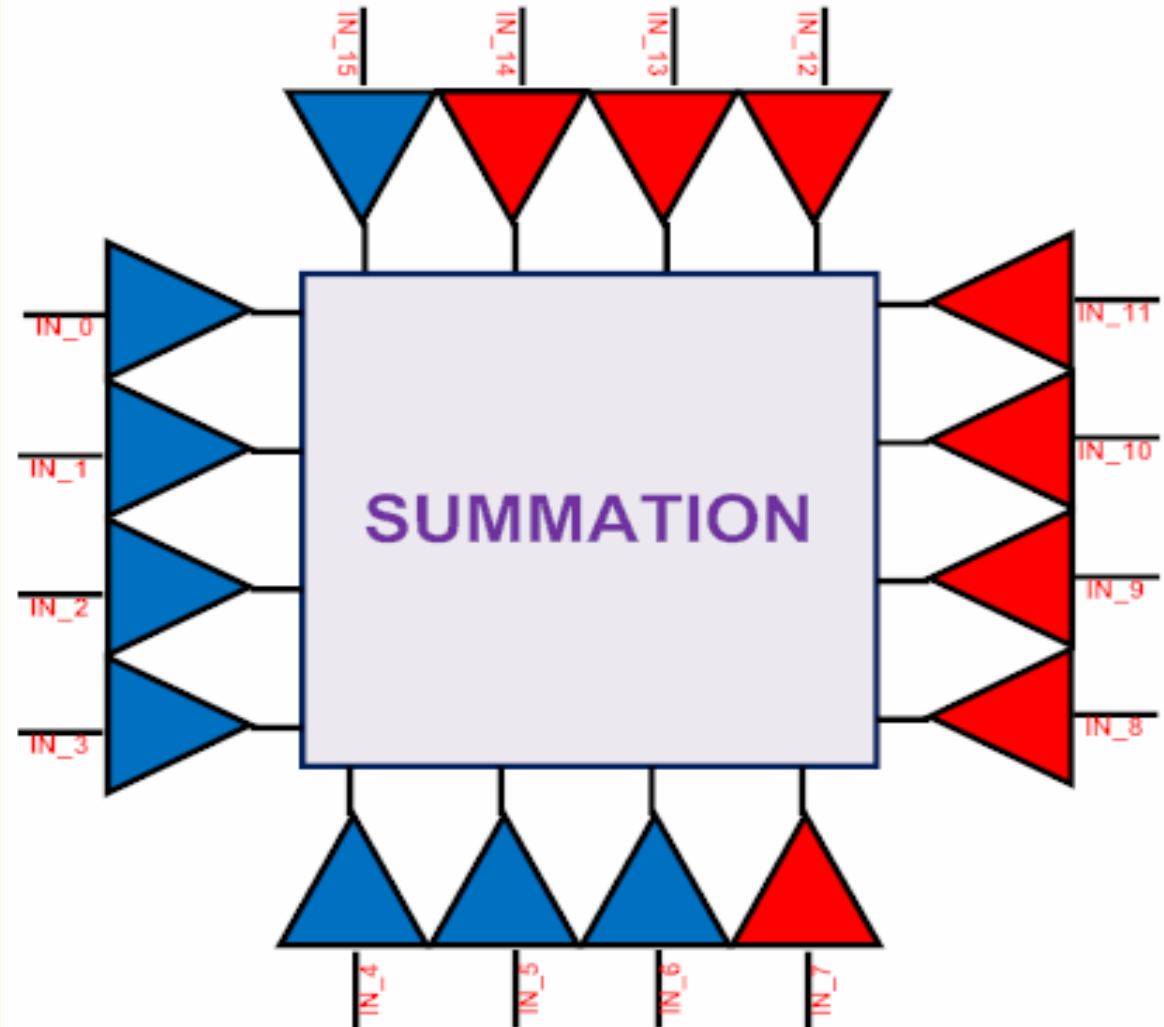
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DEM

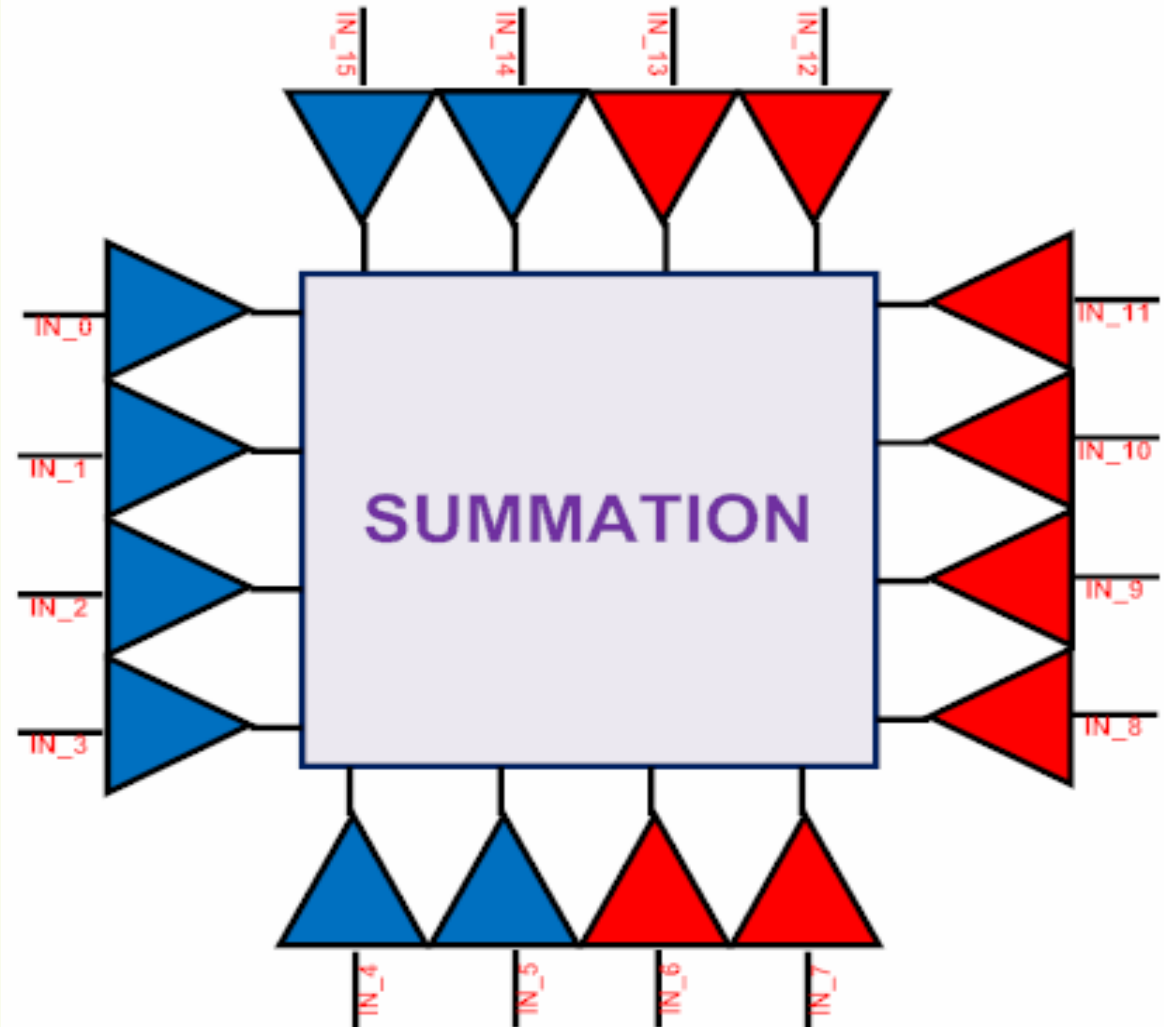
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DEM

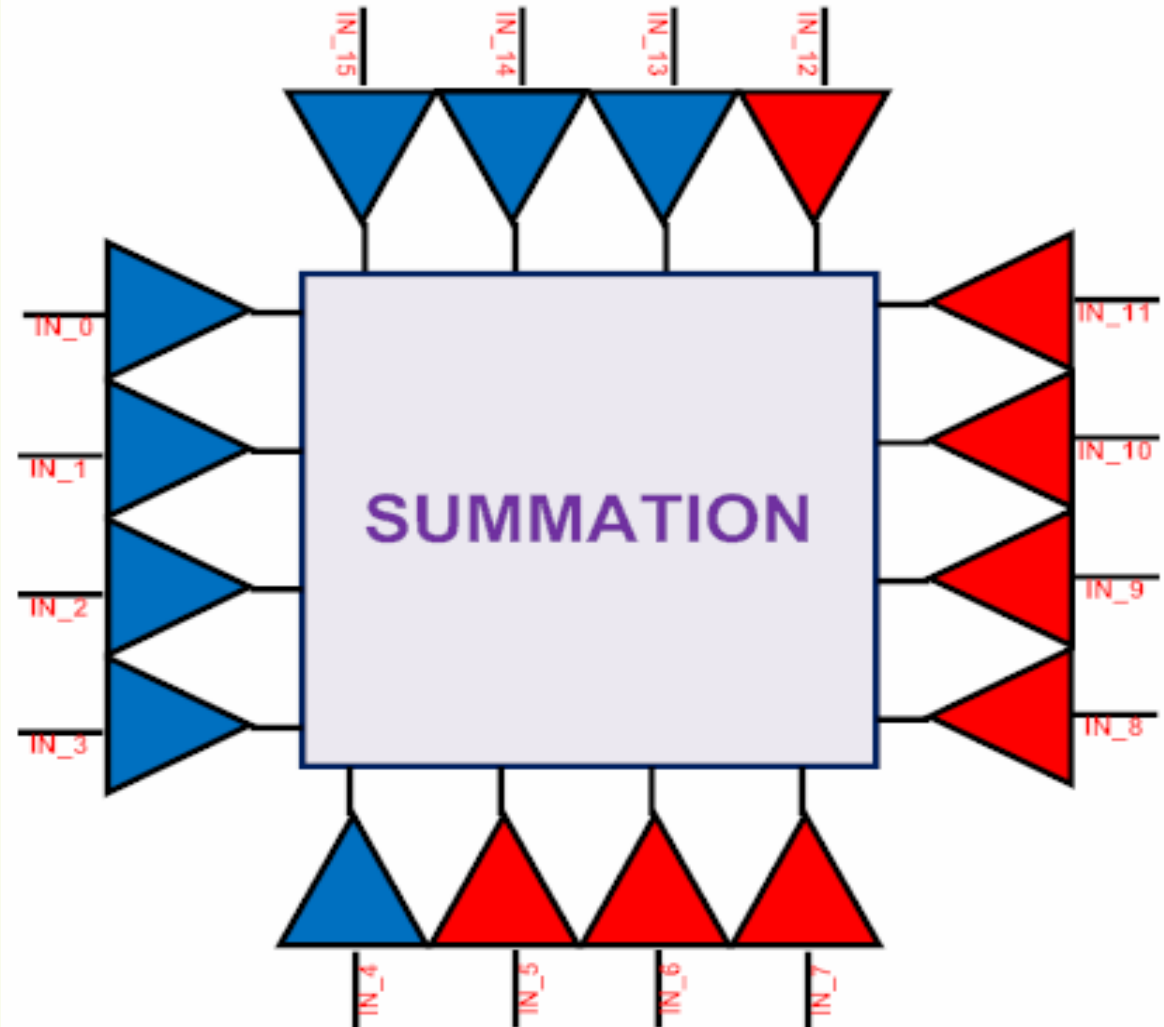
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DEM

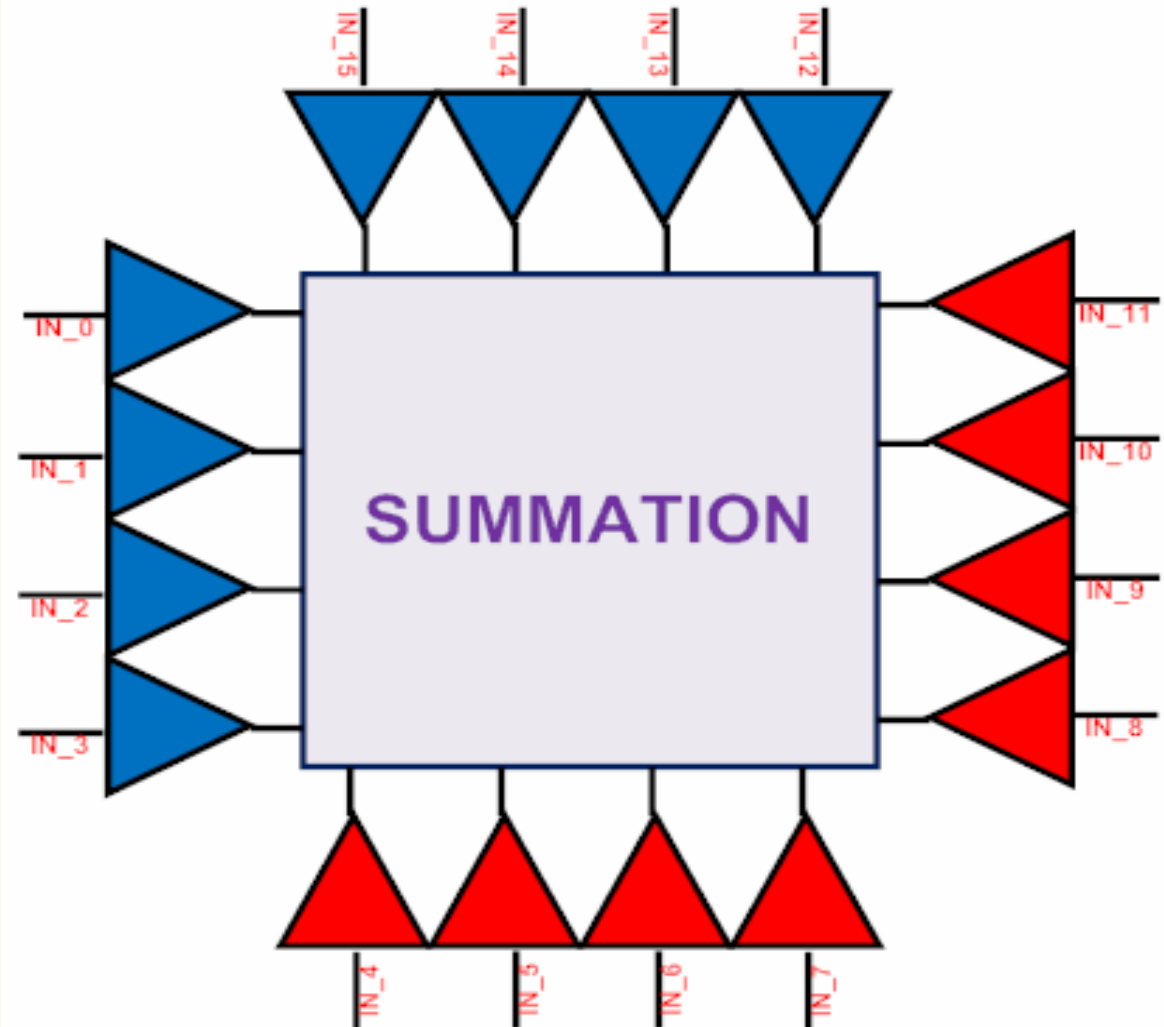
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DEM

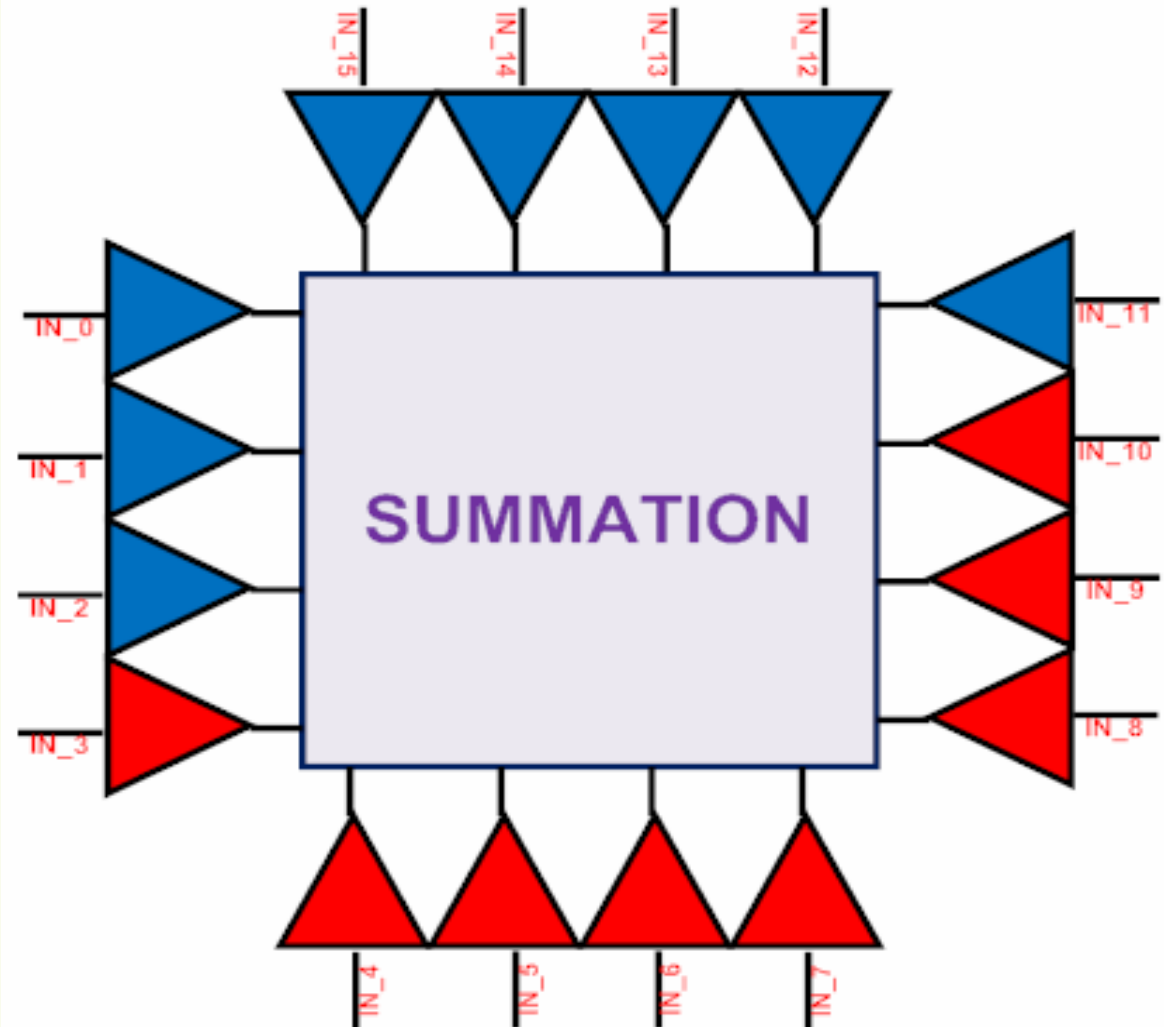
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DEM

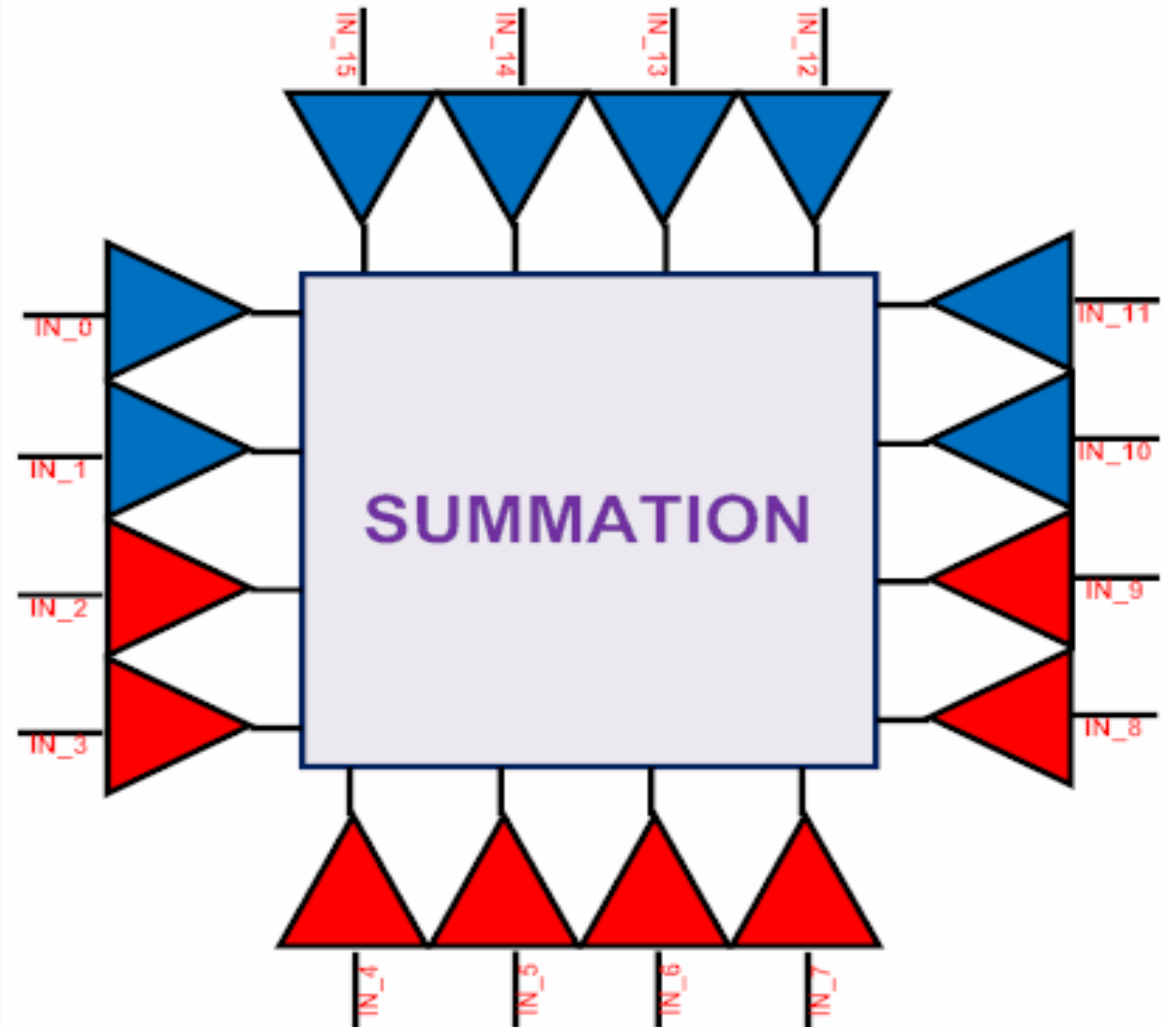
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DEM

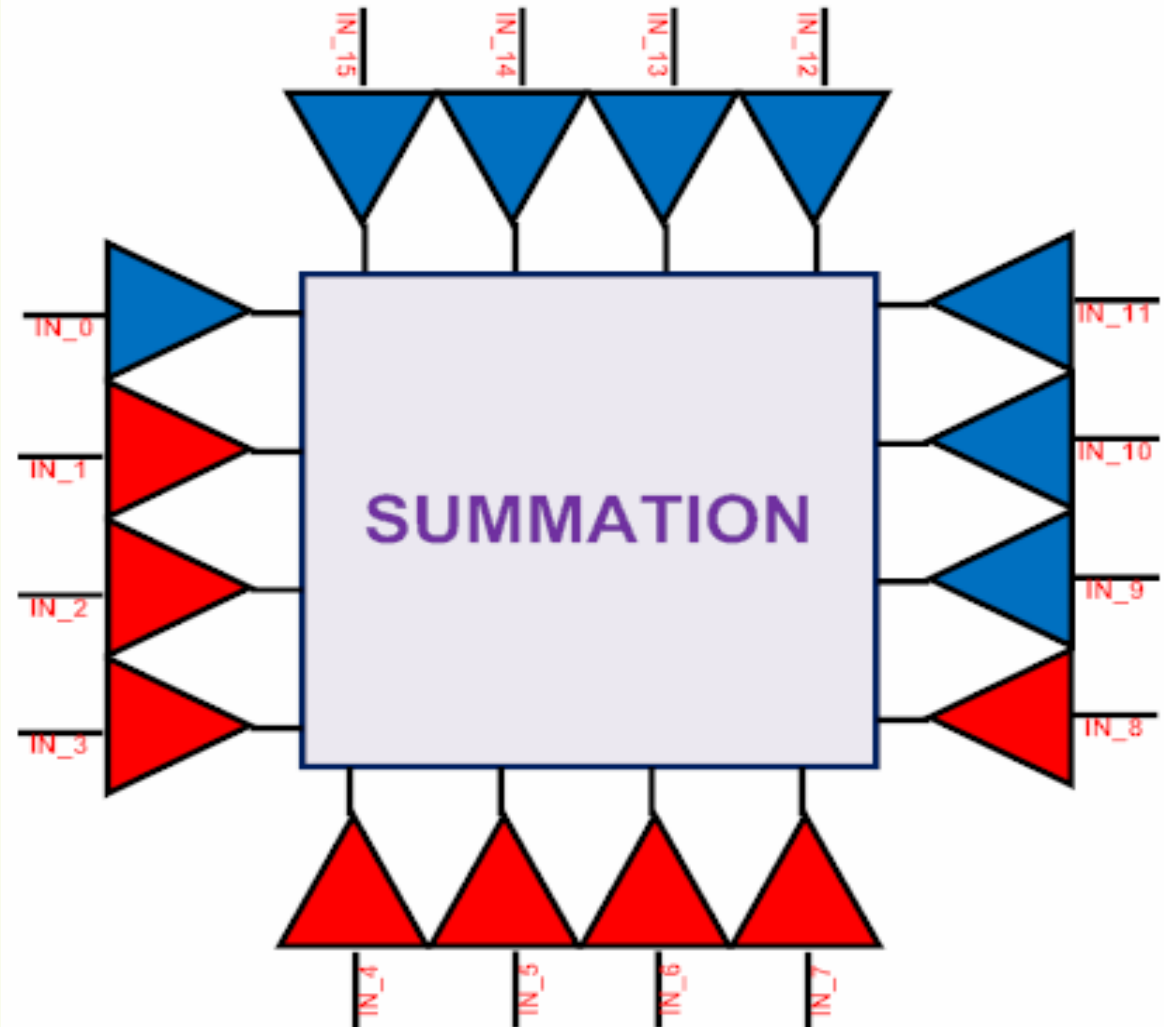
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DEM

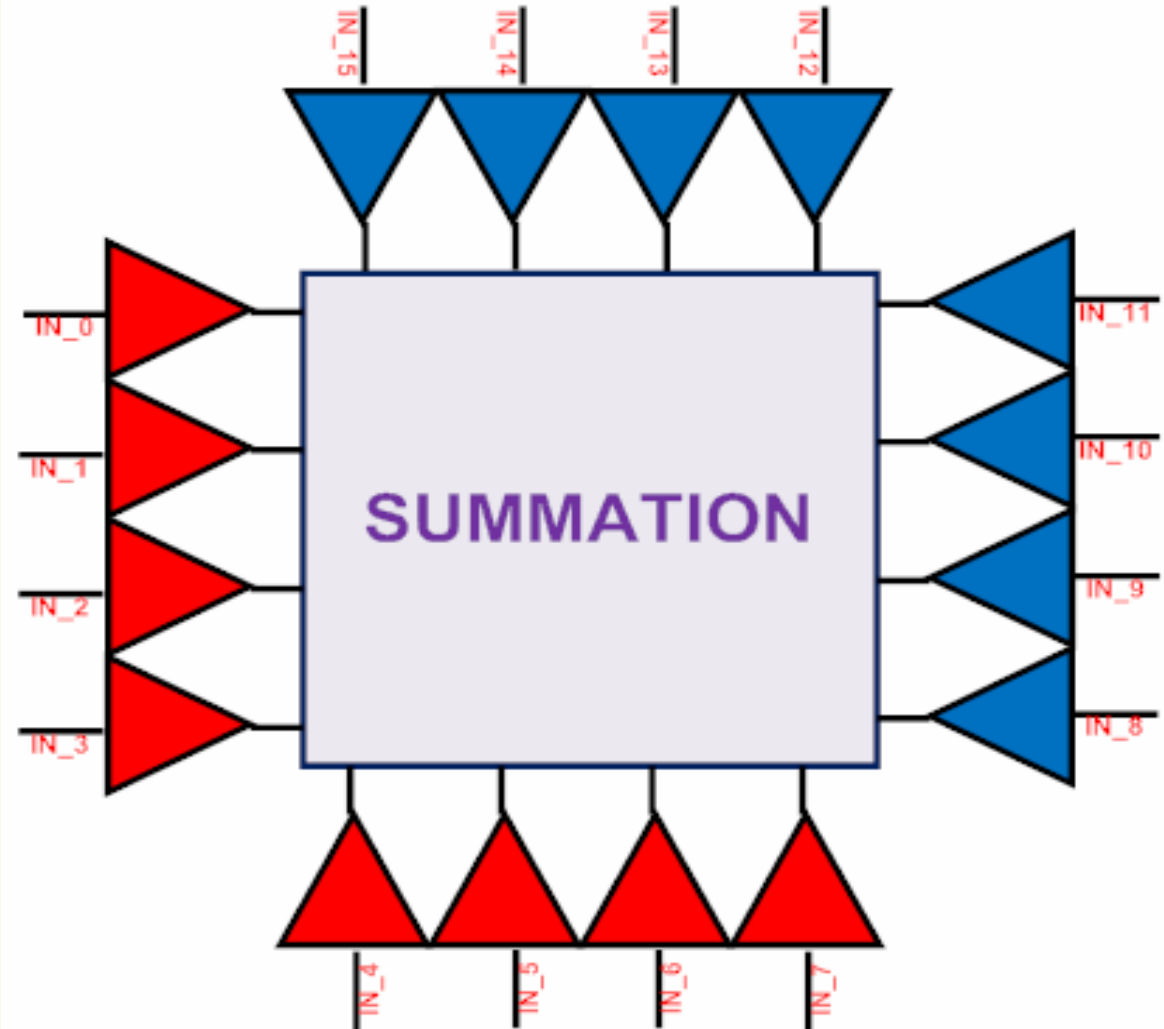
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DEM

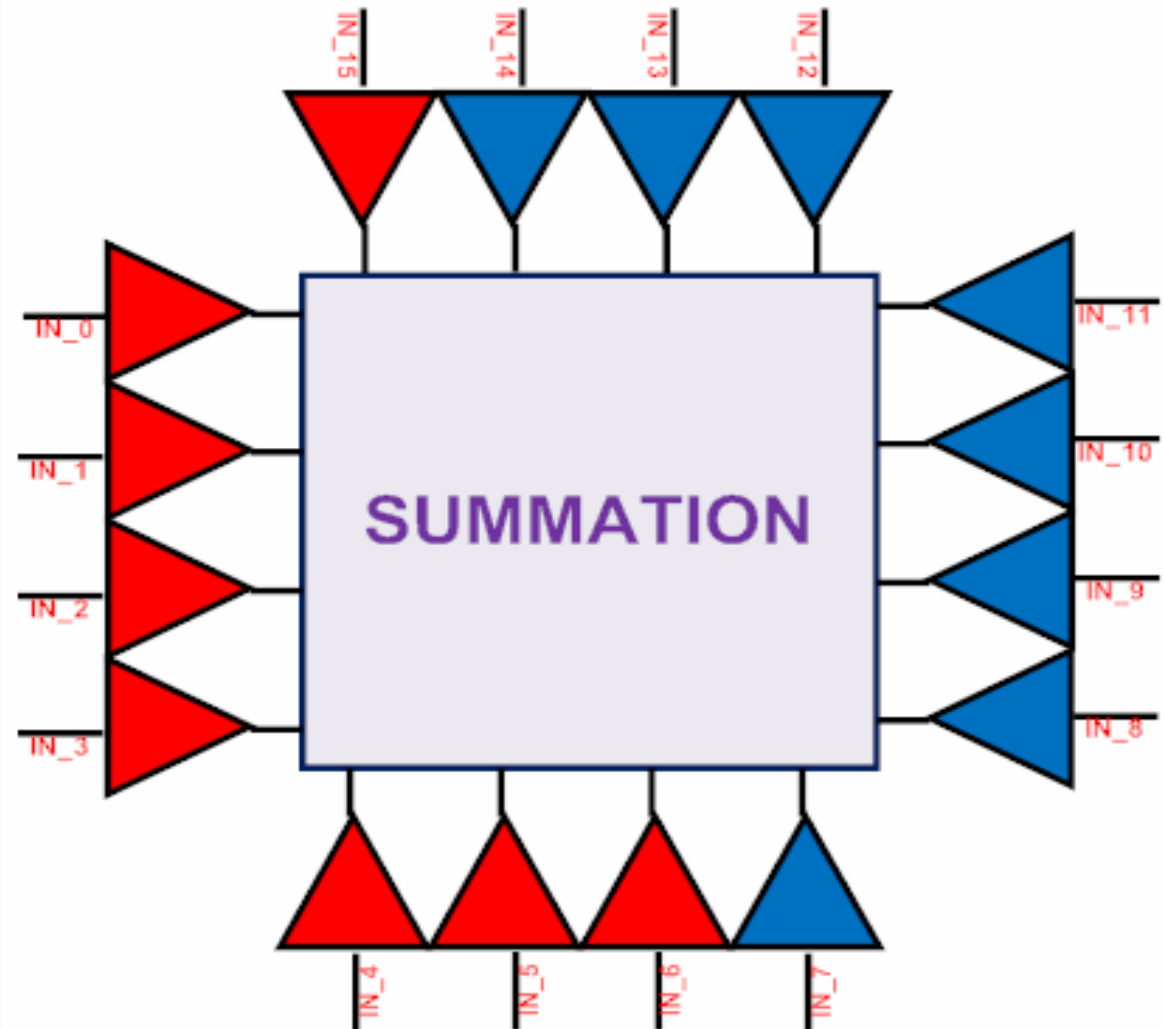
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DEM

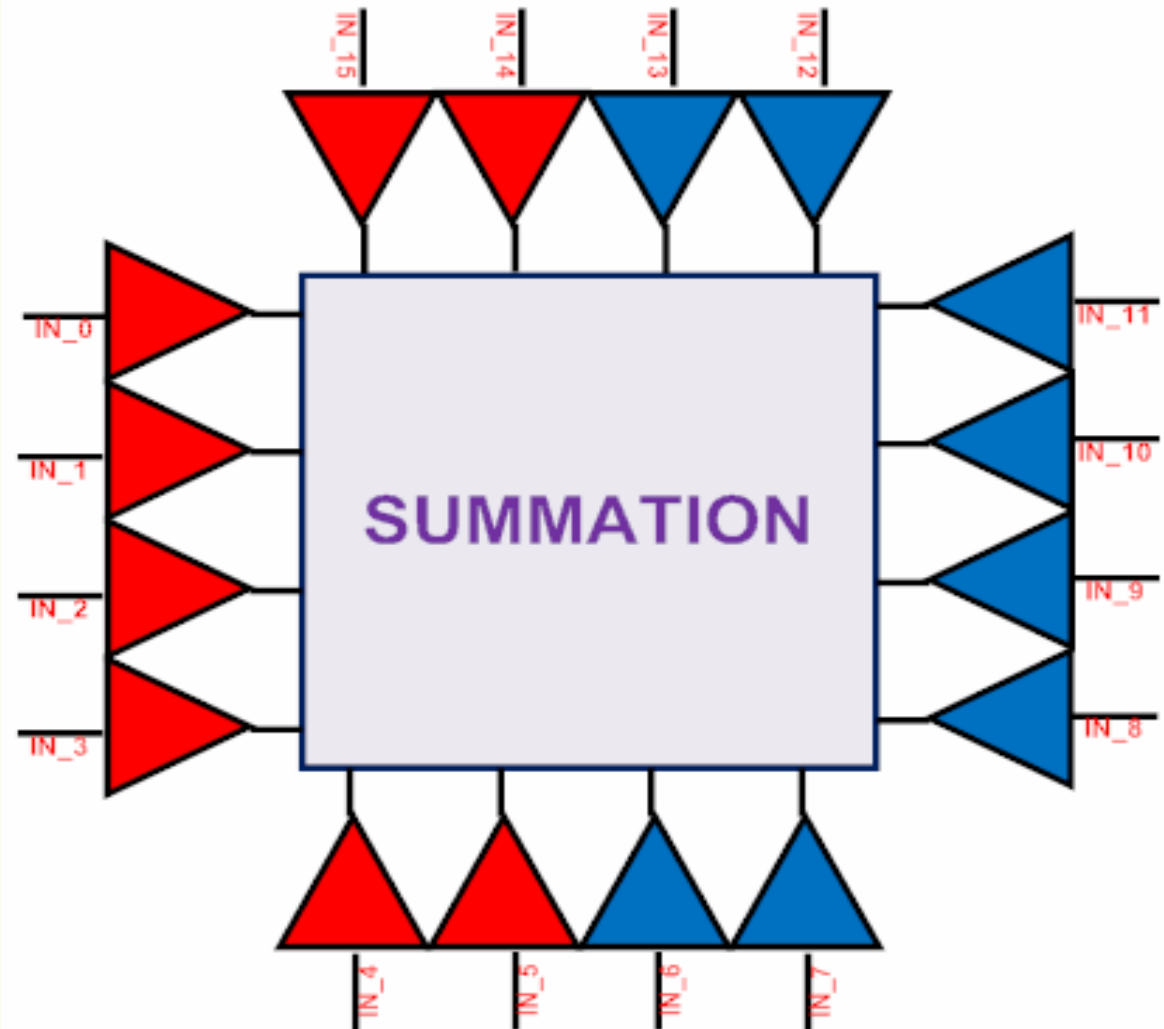
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DEM Scheme.





DEM

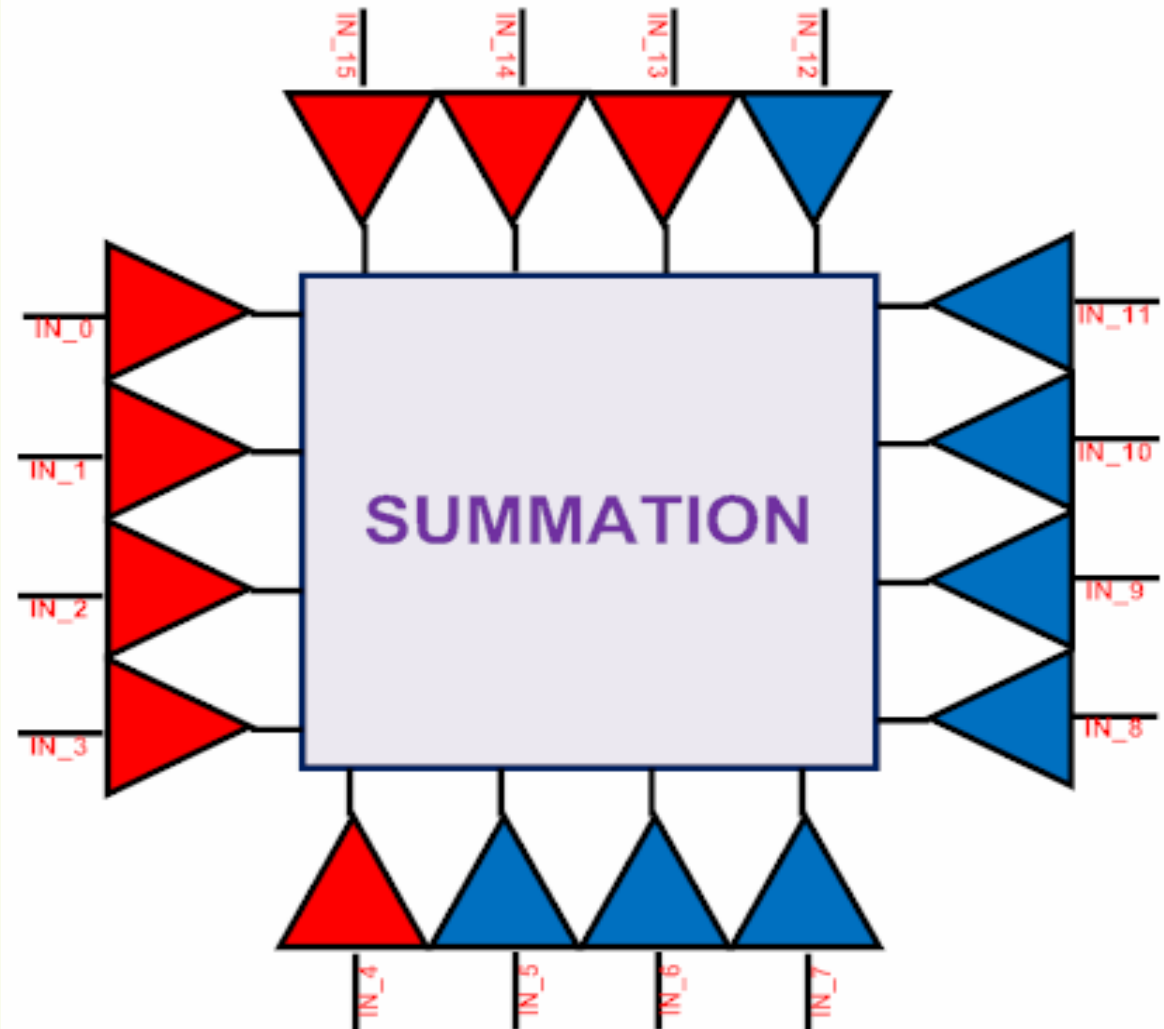
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DEM Scheme.





DEM

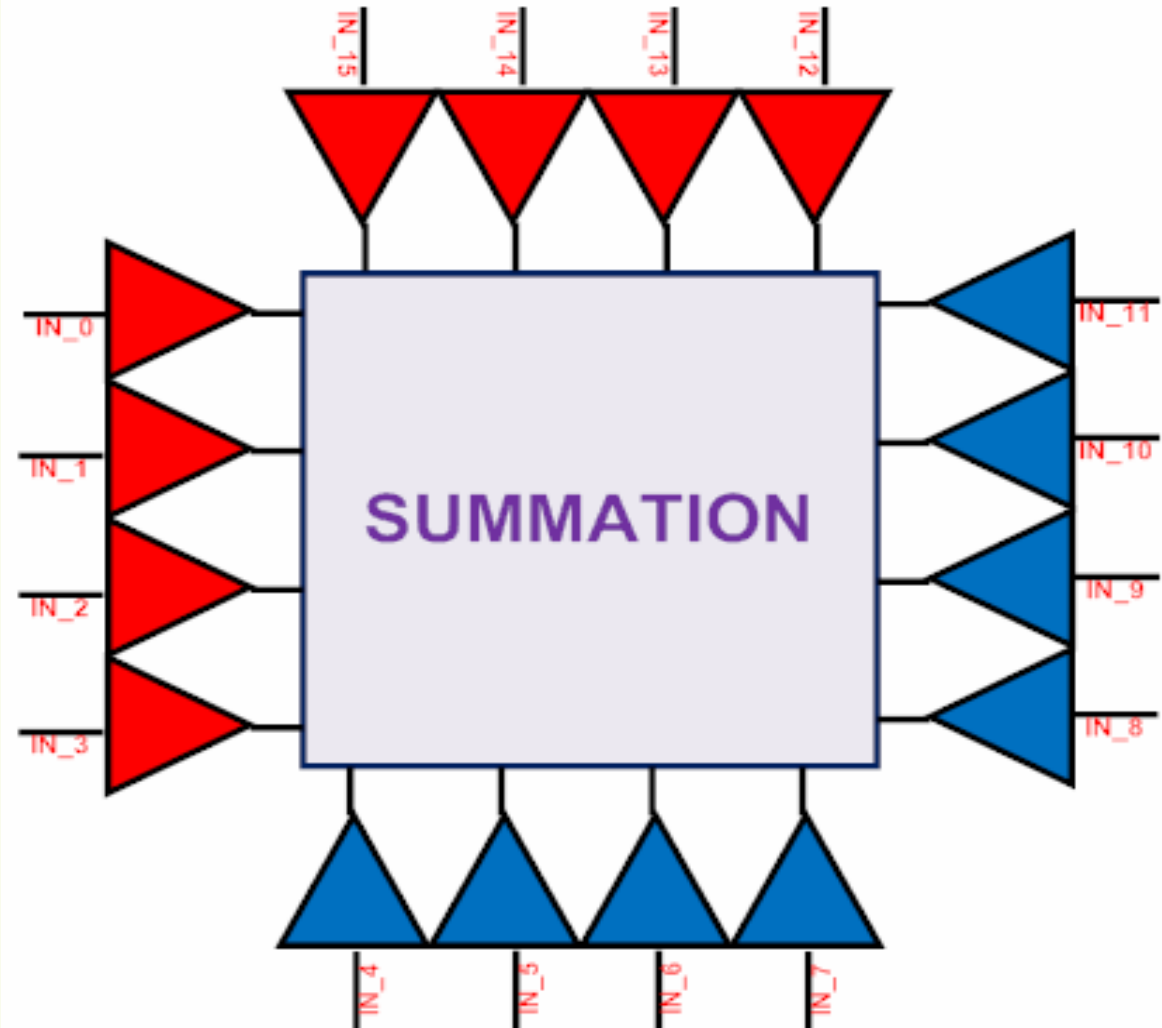
-Use Barrel Shifting
DEM Scheme.





DEM

- Use Barrel Shifting DEM Scheme.
- Mismatch Energy all located at Rotation Frequency.
- Modulation occurs and degrades in-band SNR.



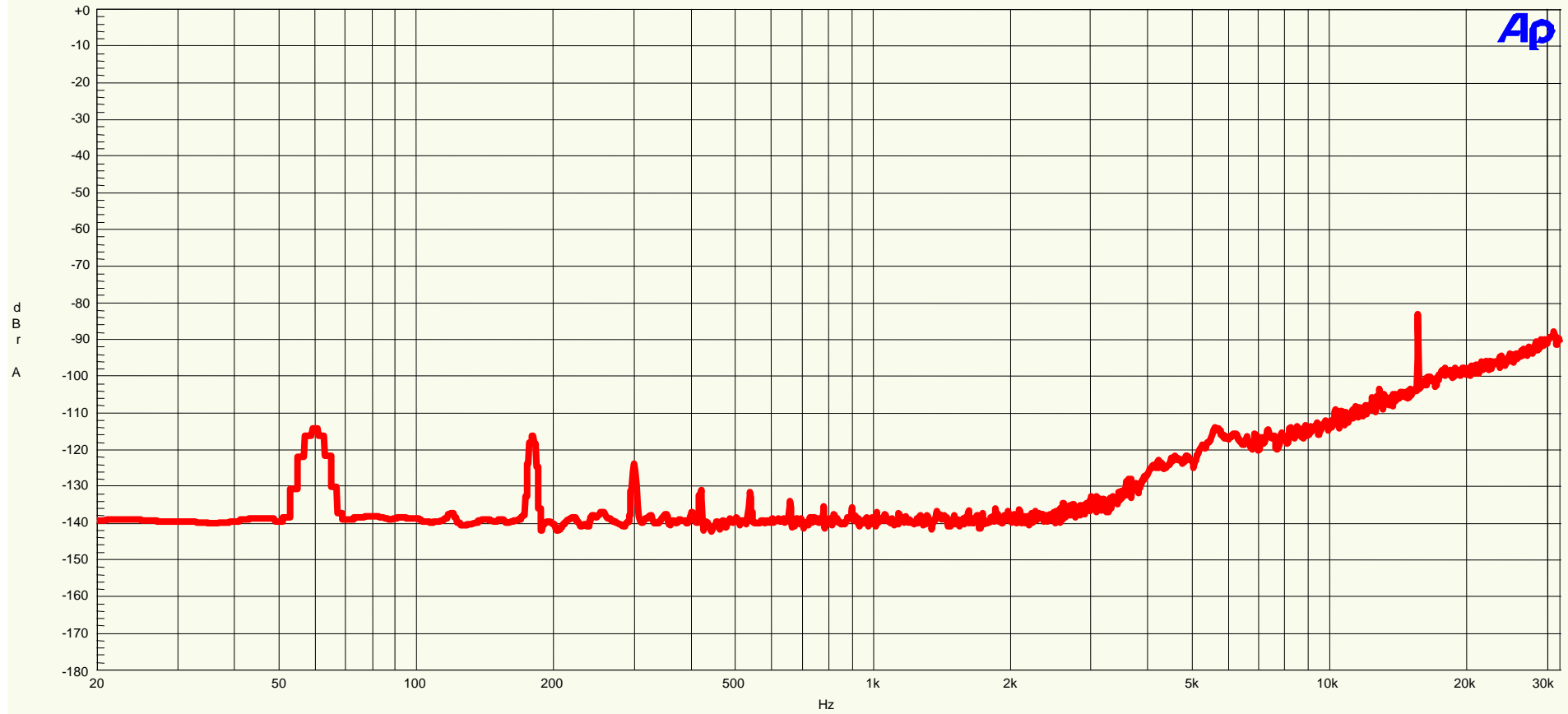


DEM ERROR FFT

ESS Technology

D-A FFT of Analog signal to 32kHz

06/26/07 16:03:20



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Green	Solid	1	Fft.Ch.1 Ampl	Left	

Sabre_DNR.at27



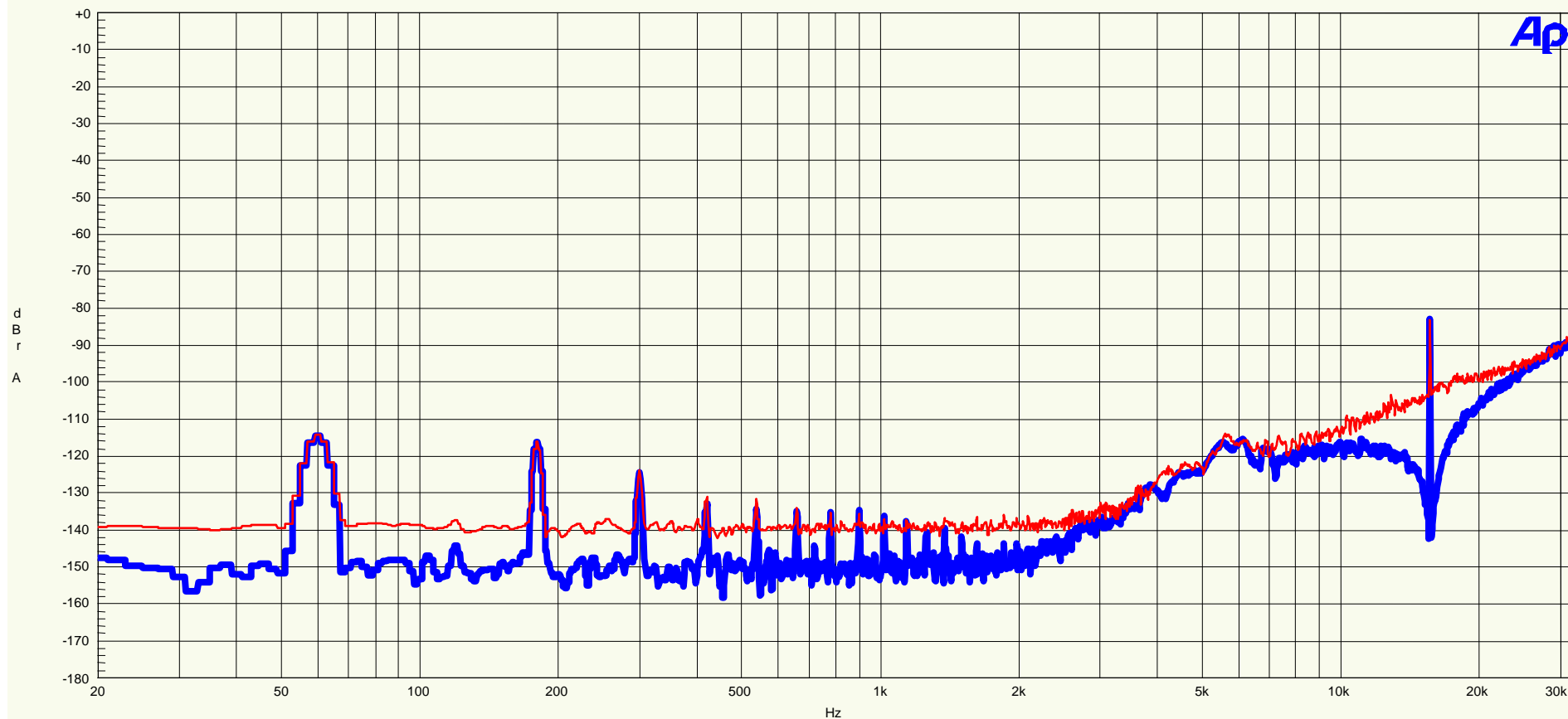


DEM NOTCH

ESS Technology

D-A FFT of Analog signal to 32kHz

06/26/07 16:03:20



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Green	Solid	1	Fft.Ch.1 Ampl	Left	

Sabre_DNR.at27





Conclusion

- DAC's must still implement De-emphasis.
- Popular topology today is “Multi-bit noise shaped”.
- Many single bit DAC cells are added up to get noise benefits.
- DEM is applied to the DAC cells to move the error out of band.
- Error is then “notched” out by filter before D/A interface.



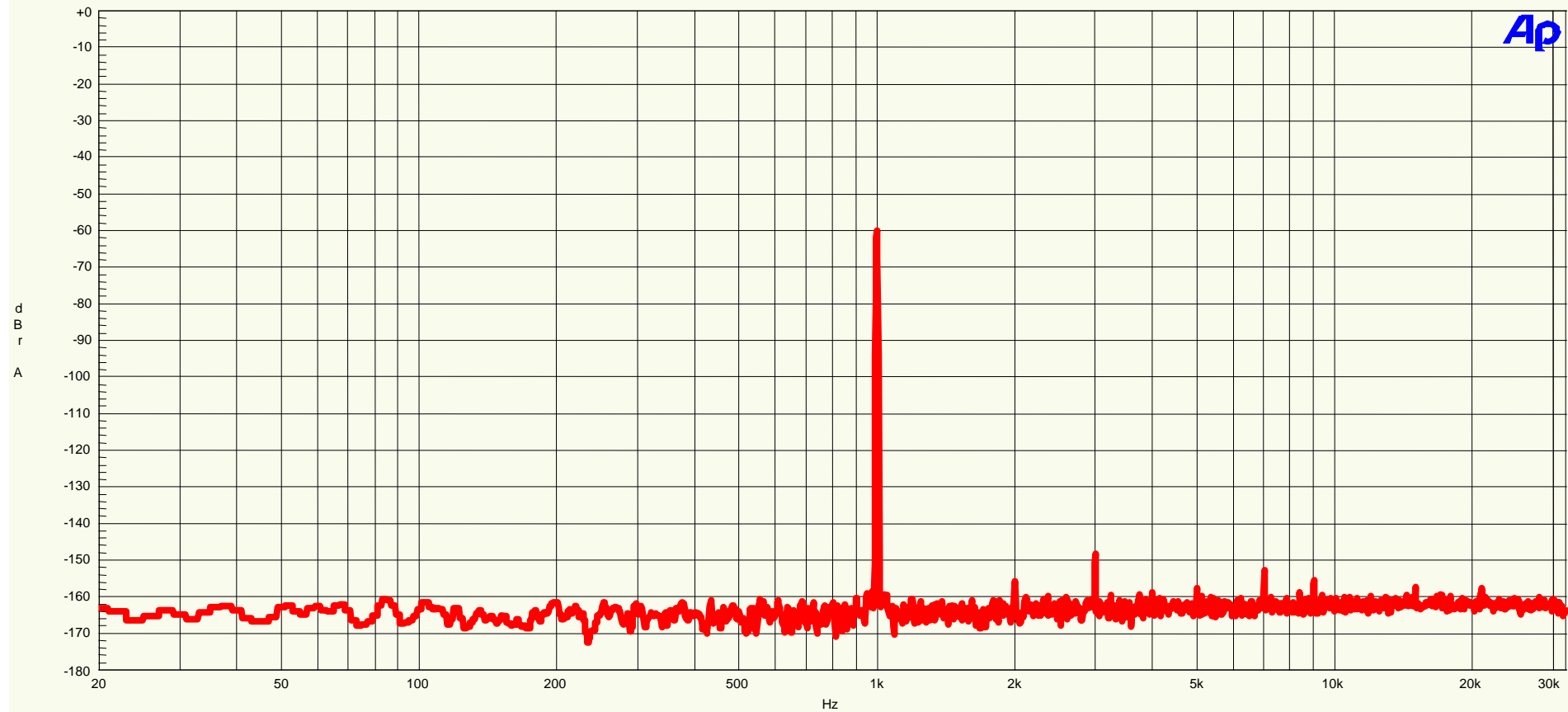


DAC PROTOTYPE DNR -131.5dB

ESS Technology

D-A FFT of Analog signal to 32kHz

07/09/07 13:45:47



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
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Sabre_DNR.at27



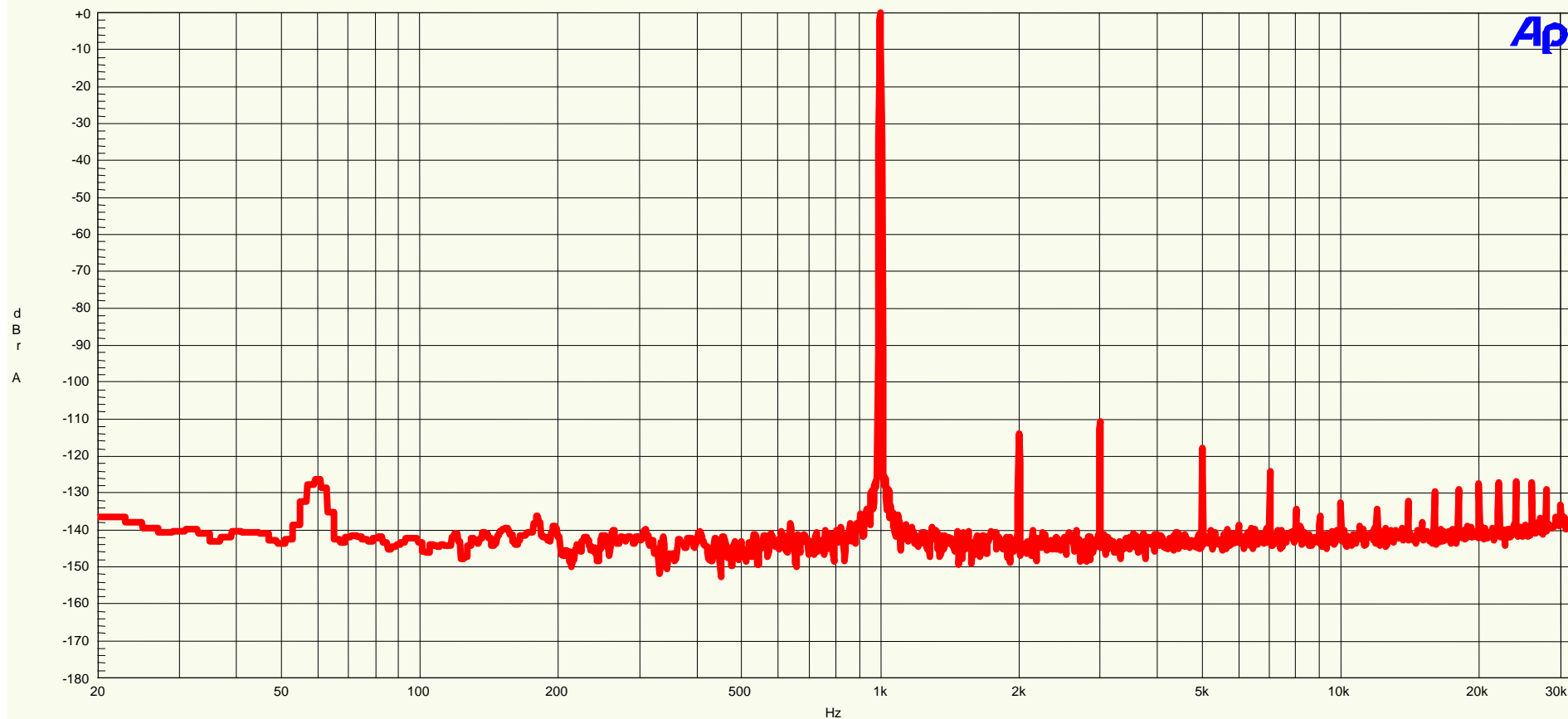


DAC PROTOTYPE THD+N -115dB

ESS Technology

D-A FFT of Analog signal to 32kHz

06/04/07 15:09:39



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Green	Solid	1	Fft.Ch.1 Ampl	Left	

Sabre_DNR.at27





THANK YOU

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