Impact of ADC Loss in Different Hybrid Partial Product Shapes

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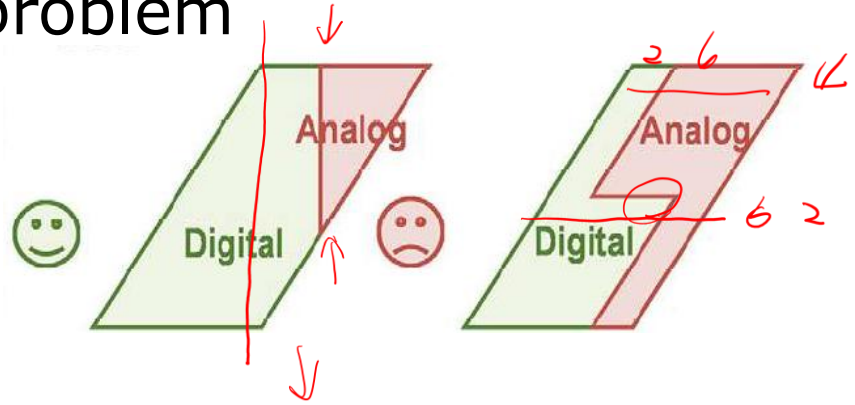
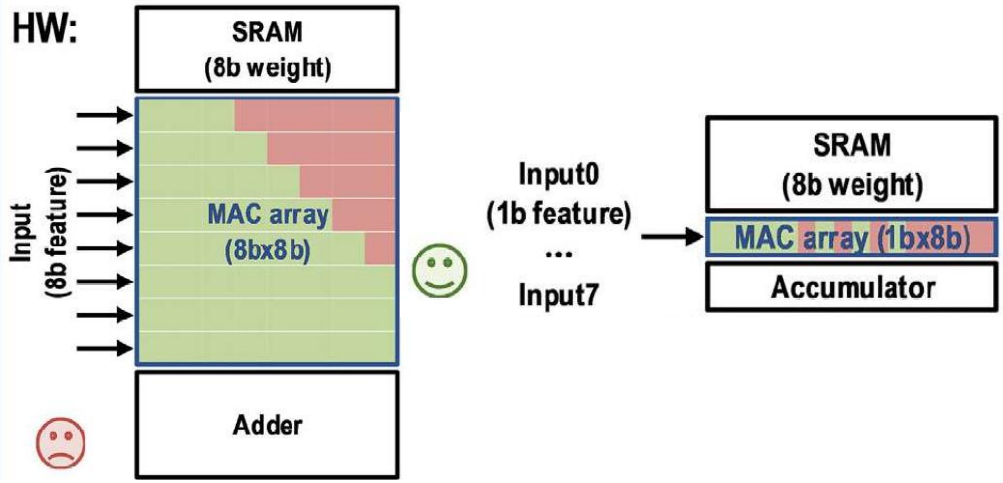
Recall

- The definition of boundary between analog and digital part is a problem

Digital Part : High precision
Analog Part : Low precision

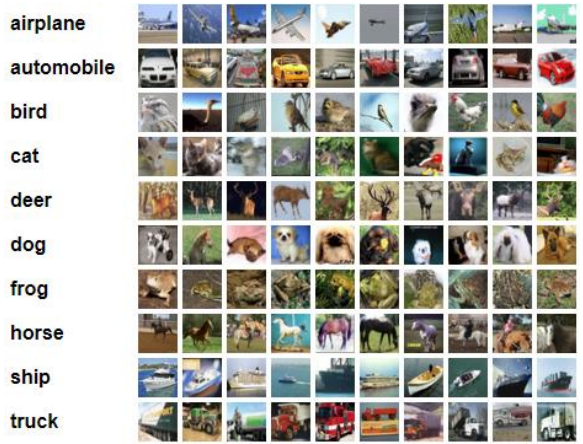


Digital Part : Bulky ckt
Analog Part : Less HW overhead



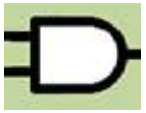
Flow

- Part A : Analyze the effect of different partition method of partial sum
  - Lightning / Big-triangle / small-triangle
- Part B : Use the result in part A to analyze the impact of analog loss on classification ML tasks
  - Analyze the characteristics of quantized CNN model
  - Apply the result in part A to the model
  - Resnet-18 on CIFAR-10

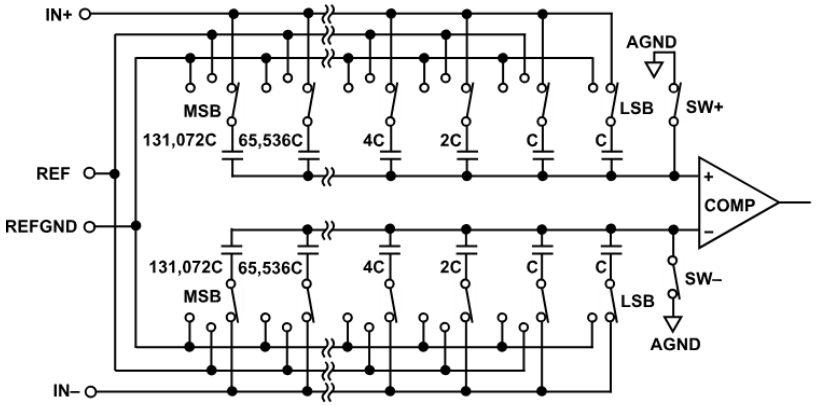


Part A : Shapes of Partial Sum

- Digital Sum
  - Using digital multiplier and adder tree
  - Easy to simulate and calculate area



- Analog Sum
  - Using analog multiplier and SAR ADC
  - SAR ADC implementation?



Part A : Shapes of Partial Sum

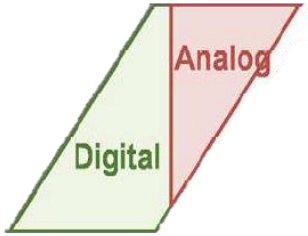
- Product = Digital sum + Analog Sum
  = Digital sum + Ideal Sum * loss

Part A : Shapes of Partial Sum

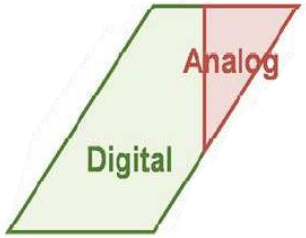
- Types of Shapes
  - Lightning : Bit-serial scheme
  - Big triangle : Bit-rotation scheme
  - Small triangle : Bit parallel scheme

Lightning

Big Triangle



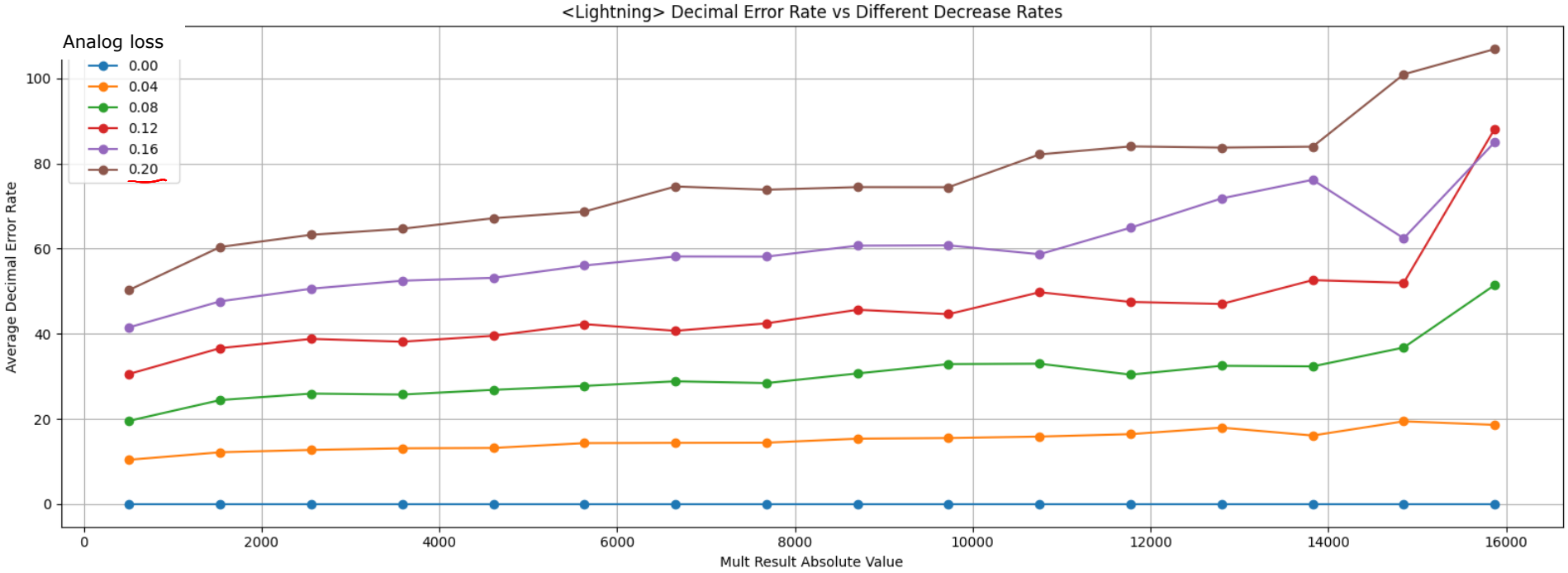
Small Triangle



Part A : Shapes of Partial Sum

- Error in ADC
  - Error of its value

Lightning



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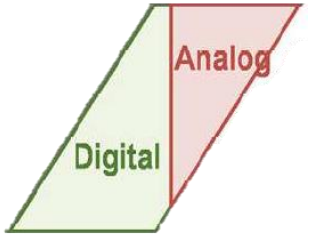
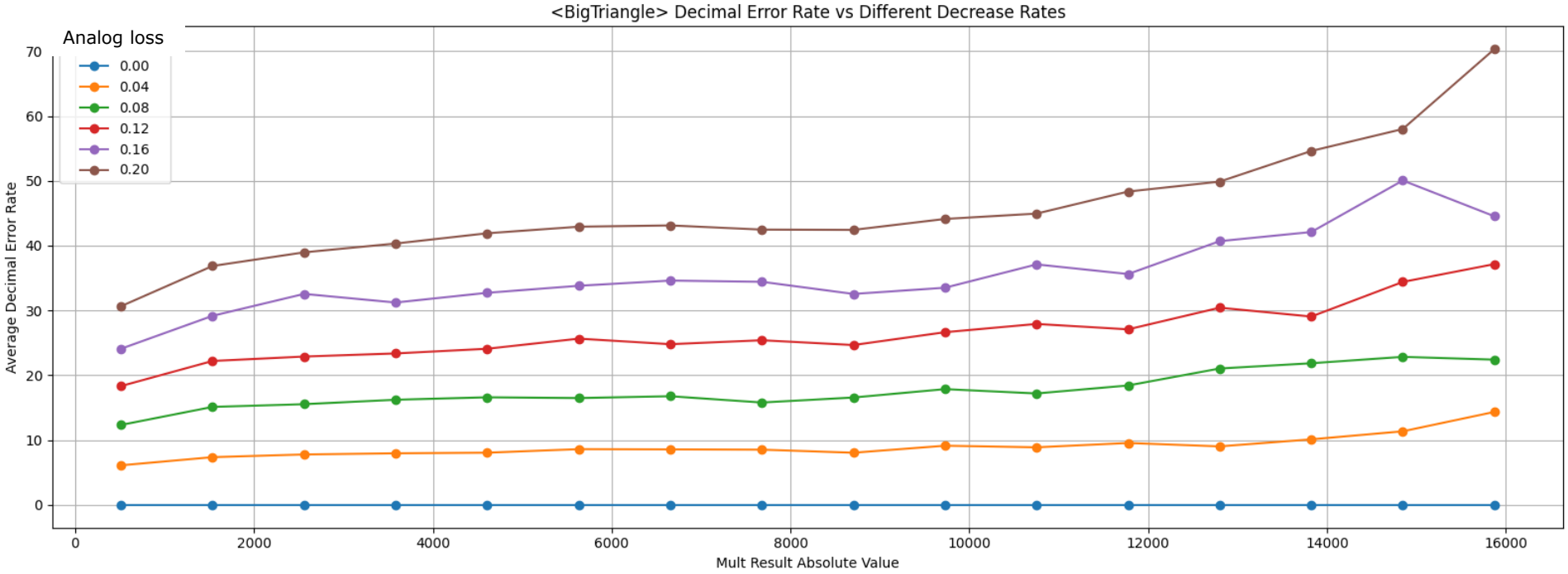
Big Triangle





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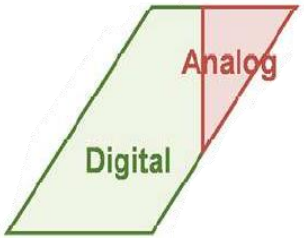
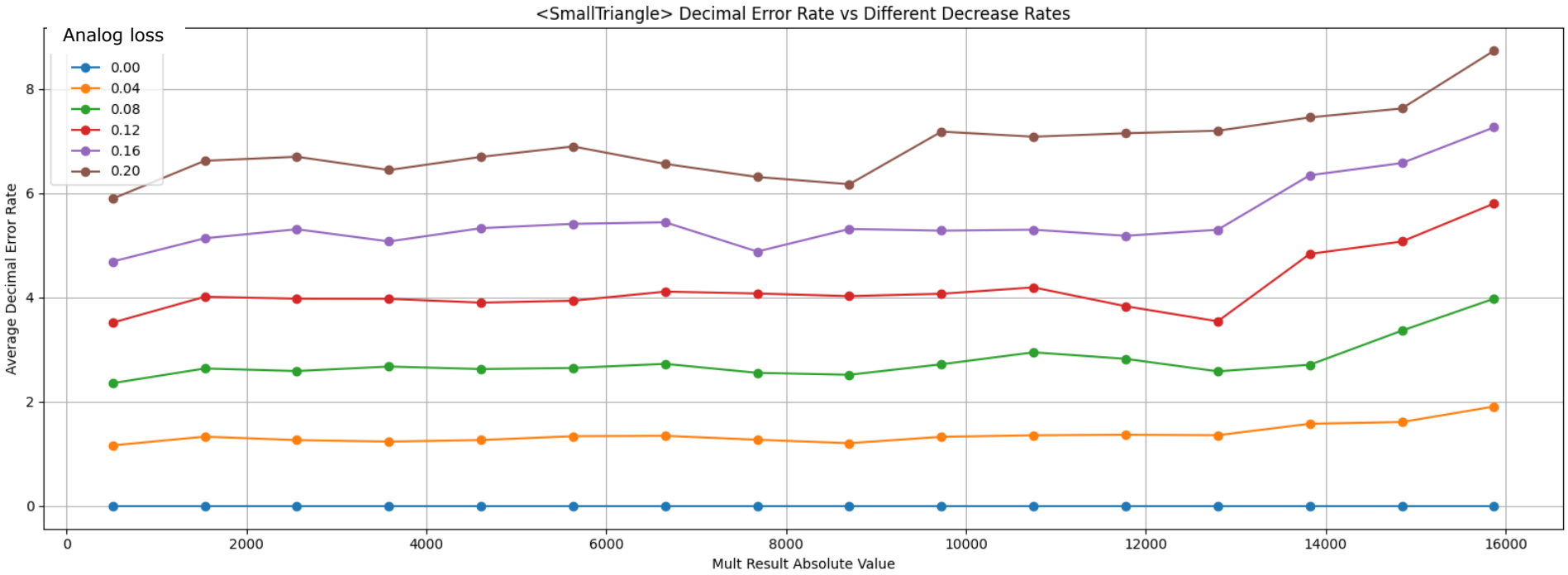
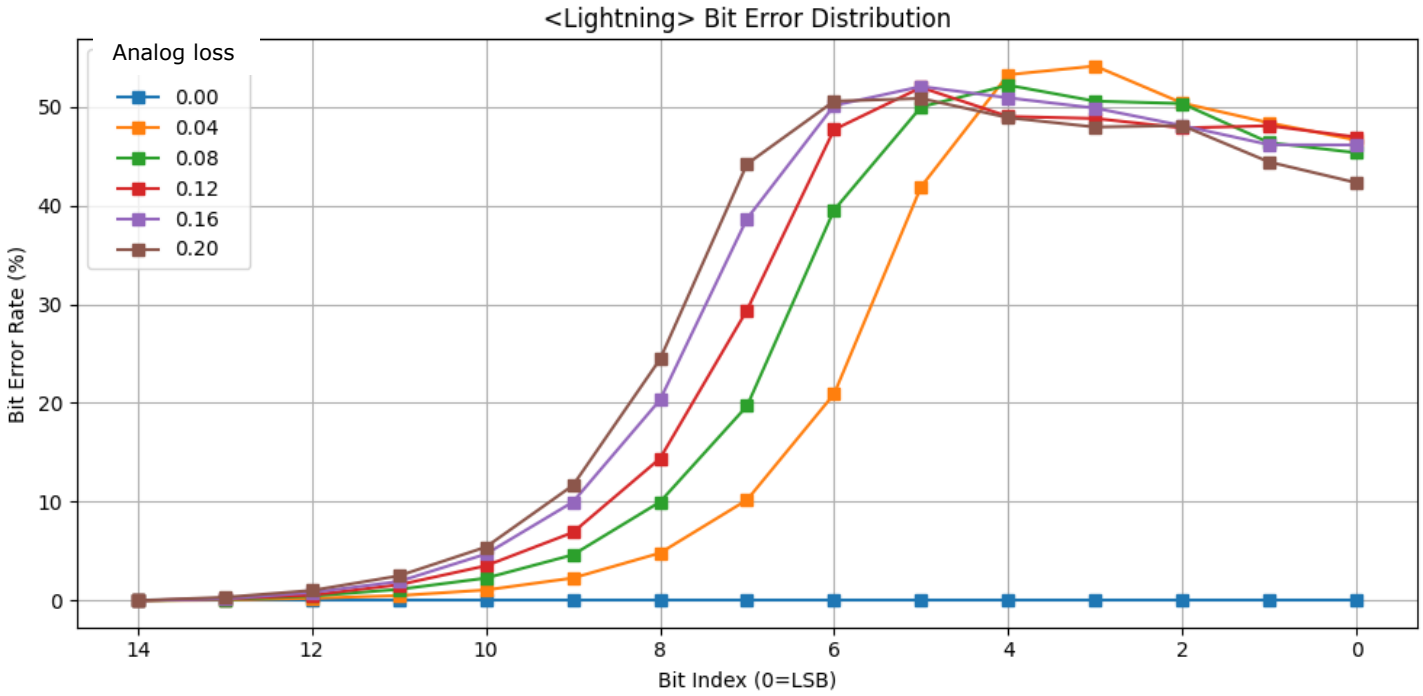




Part A : Shapes of Partial Sum

- Error in ADC
  - Error rate in bits

Lightning



Part A : Shapes of Partial Sum

- Error in ADC
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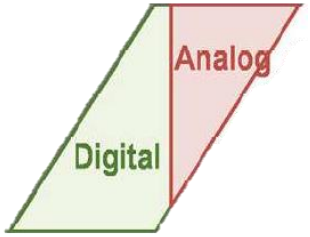
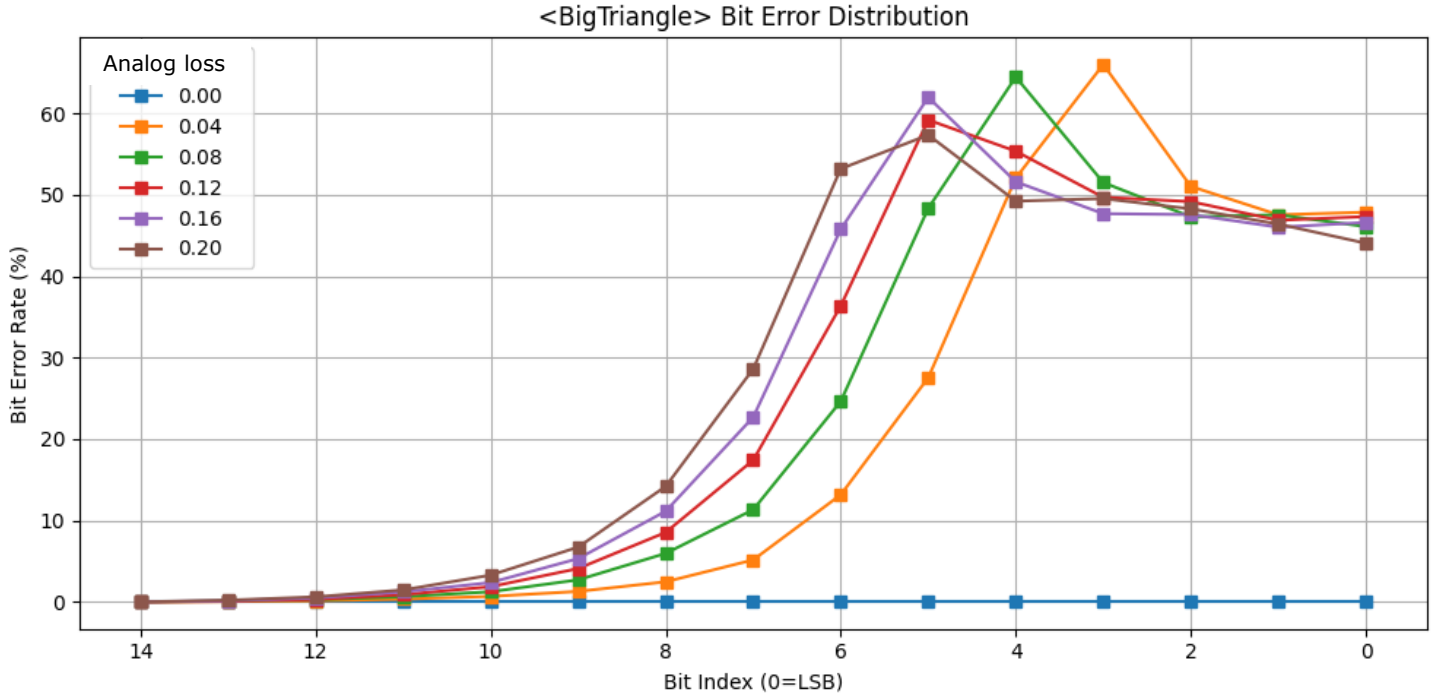
Big Triangle





Part A : Shapes of Partial Sum

- Error in ADC
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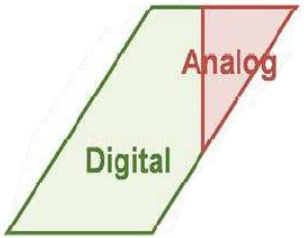
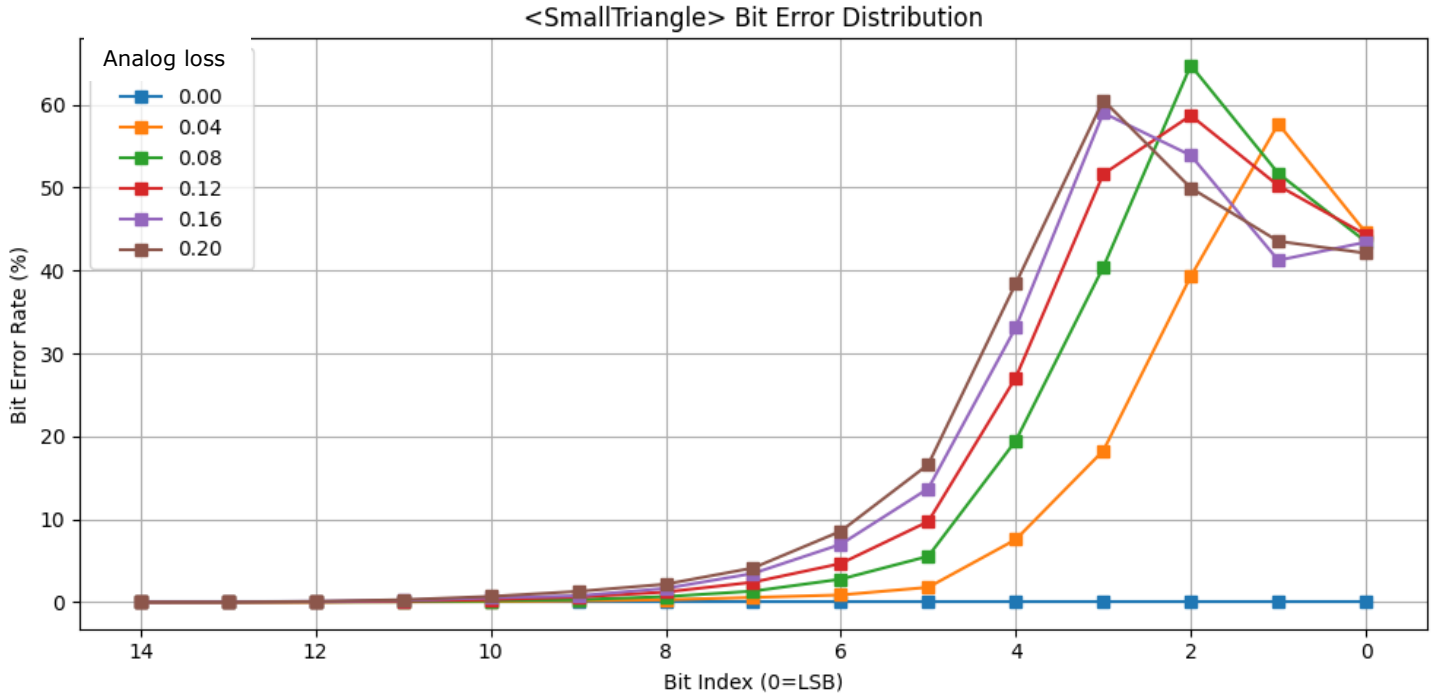
Small Triangle





Part B : Impact of Analog Loss

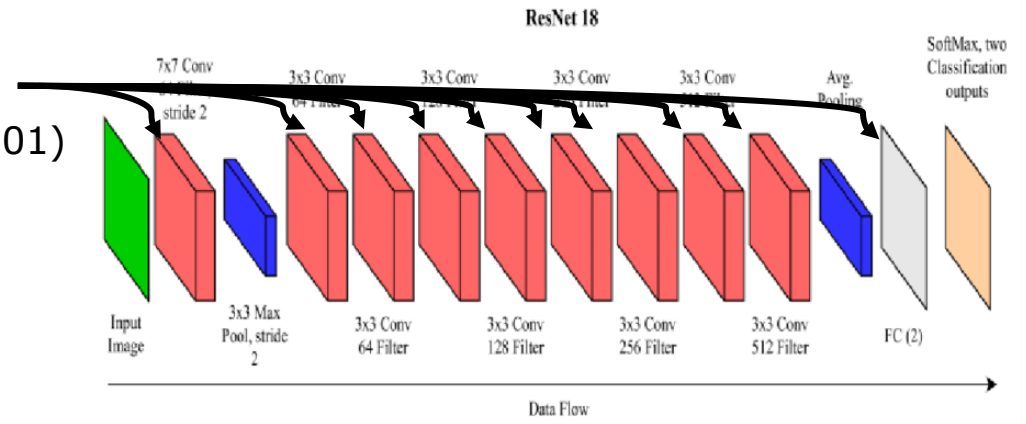
- The dataset used in the paper is ImageNet
  - ImageNet is not implemented in torch
  - Use a simpler dataset CIFAR-10

Model	ResNet-18
Dataset	ImageNet
Data precision	INT8
Task	Classification
Metric	Accuracy

- ResNet-18
  - Trained using fp precision
  - Quantize to int8 after training
  - Compute MAC result for each layer and apply loss

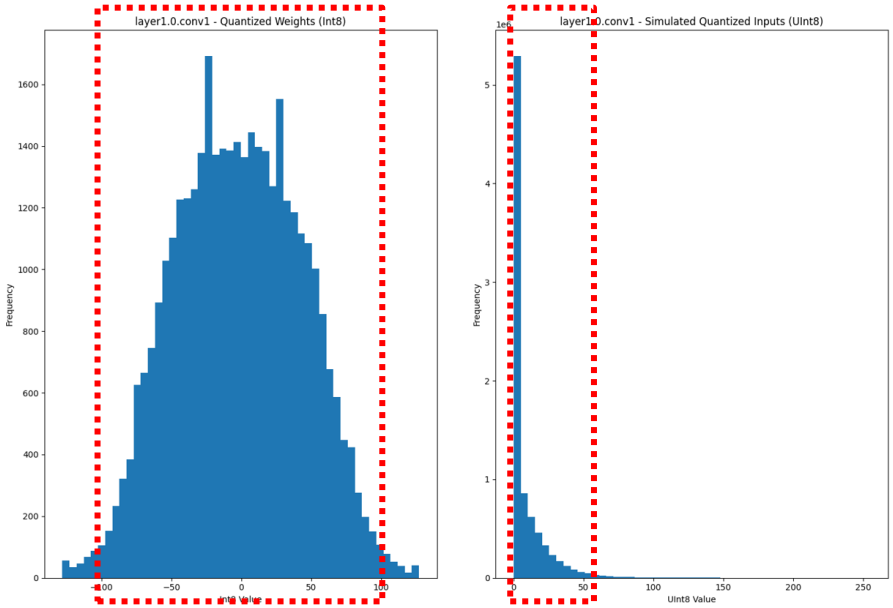
-LOSS

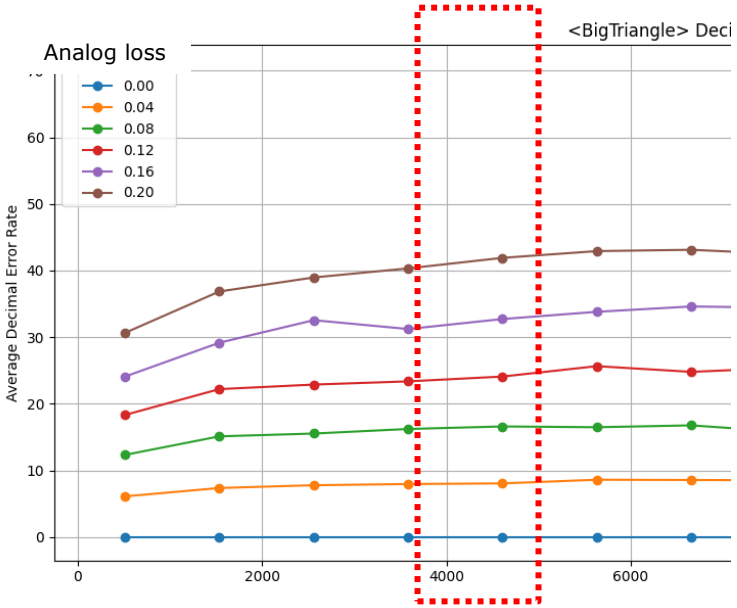
Gaussian(-Loss,0.01)



Part B : Impact of Analog Loss

- Analysis of the quantized model
  - Most of the quantized weight are within ± 100
  - Most of the quantized input activation < 50
  - MAC result are within ± 5000

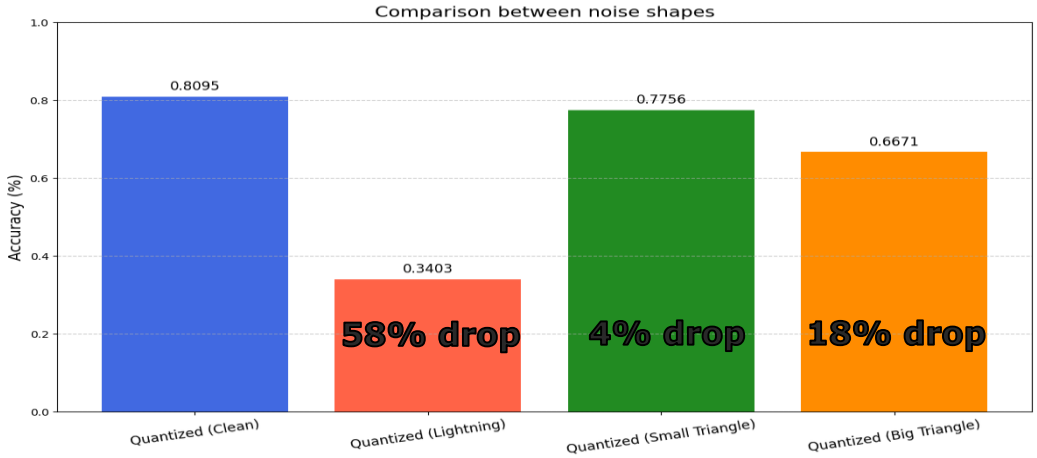


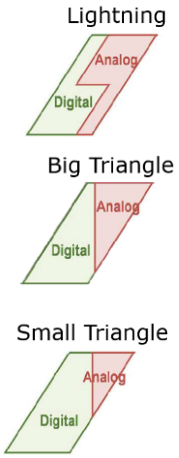


Use the result of this part

Part B : Impact of Analog Loss

- Accuracy drop of ResNet-18 if loss is applied



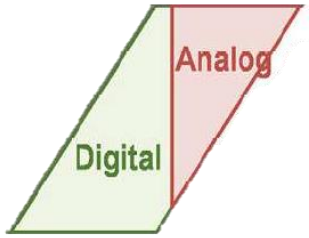
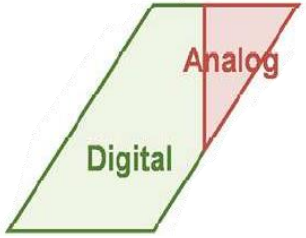


- What about area of ckt?
  - Lightning : bit-serial : 2x3 FA + 15 FA and 1 shift + 32C
  - Small Δ : bit-parallel : 49 FA + 130C
  - Big Δ : bit-rotate : 2x3 FA + 15 FA and 1 shift + 8C

Sign bit processing | Sum the product | Bit precision alignment | Analog Sum

Conclusion

- Comparison between different shapes

	Lightning	Big Triangle	Small Triangle
			
Decimal Loss (0.1 Loss)	36	20	3.5
Accuracy	Large drop (58%)	Acceptable drop (18%)	Low drop (4%)
Adder Area	21 FA	21 FA	49 FA
Capacitors Used	32 C	8 C	130 C