The Datatypes Zoo

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sampl

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OF COMPUTER SCIENCE & ENGINEERING

tvm.ai

By “datatypes”, we mean **numerical datatypes:** how the hardware represents and operates on real numbers.

IEEE 754 Floating Point

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Single precision (32 bit) 

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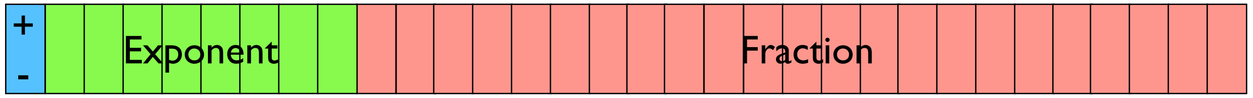
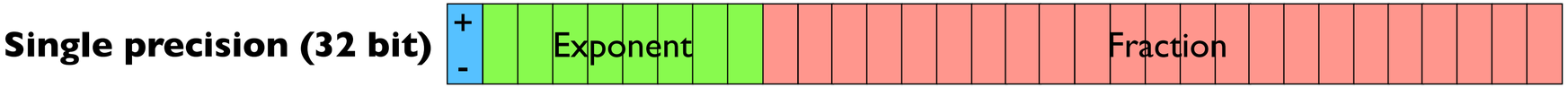
Single precision (32 bit)



IEEE 754 Floating Point



$$\text{value} \approx \text{sign}$$

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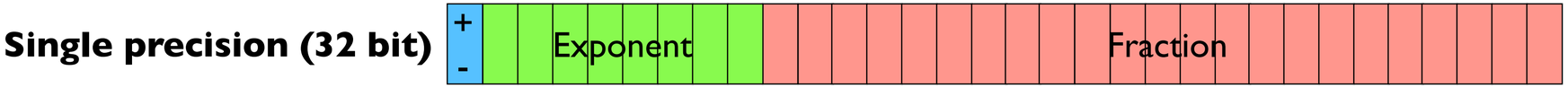

$$\text{value} \approx \text{sign} * 2^{\text{exponent}}$$

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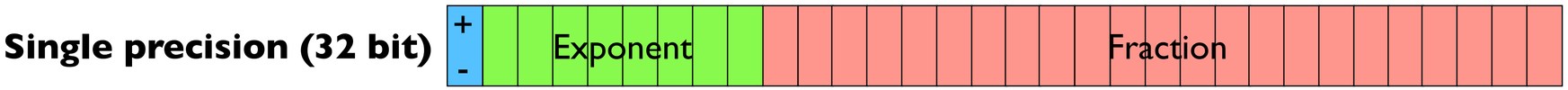

$$\text{value} \approx \text{sign} * 2^{\text{exponent}} * 1.\text{fraction}$$

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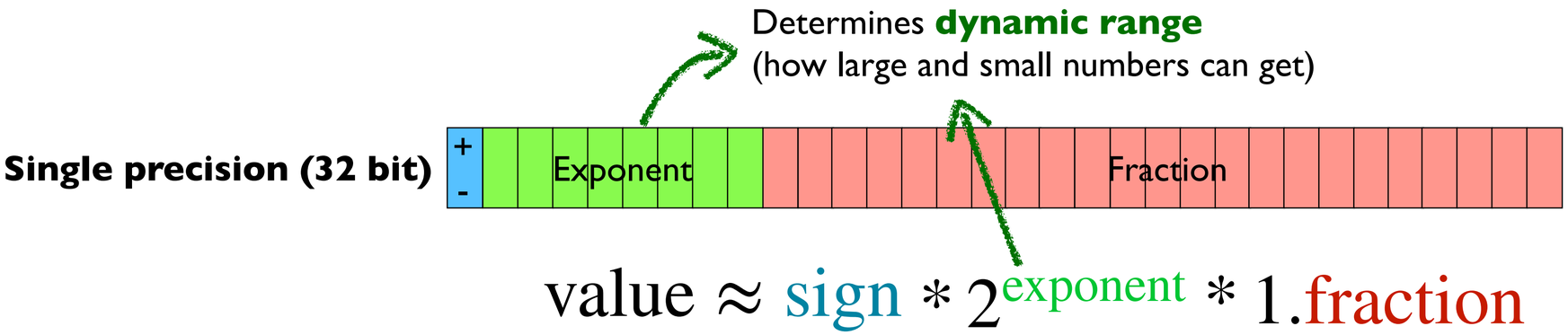

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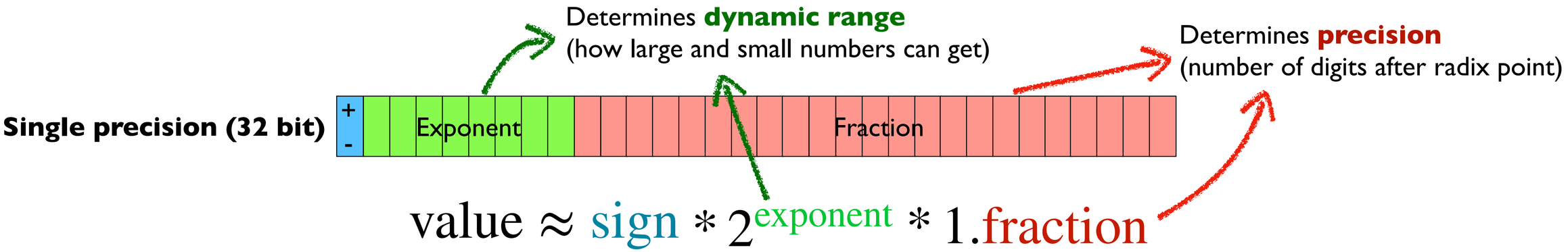

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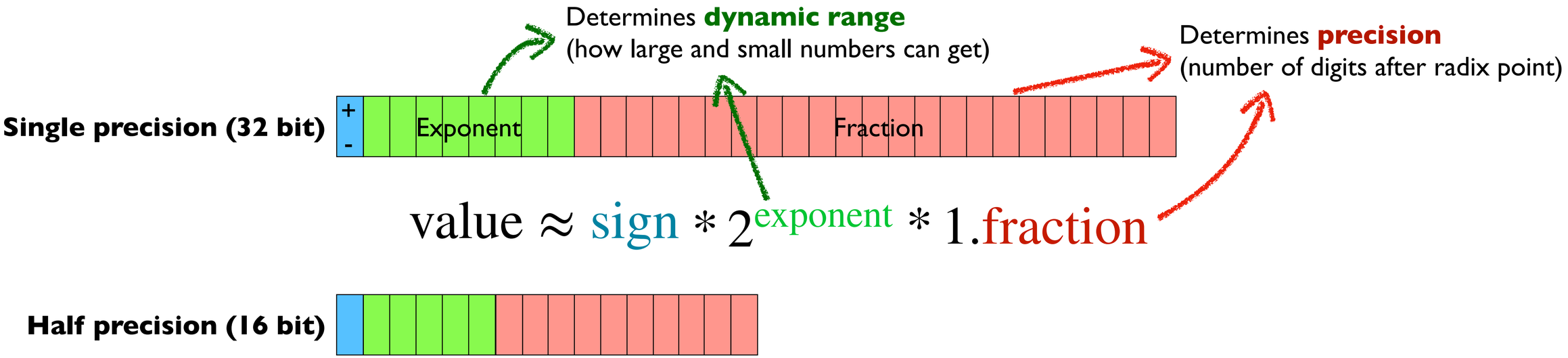

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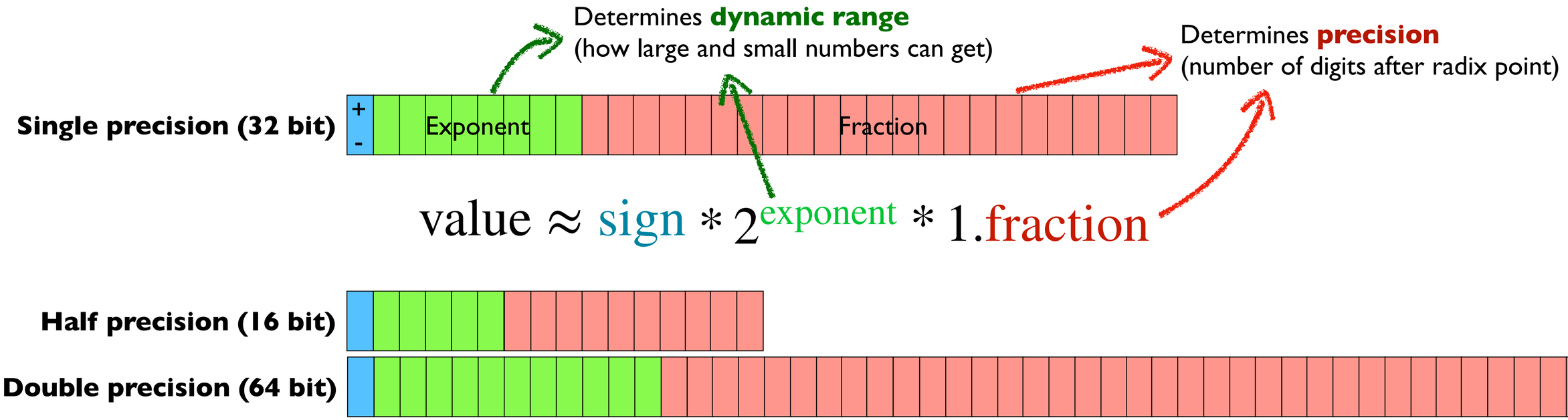

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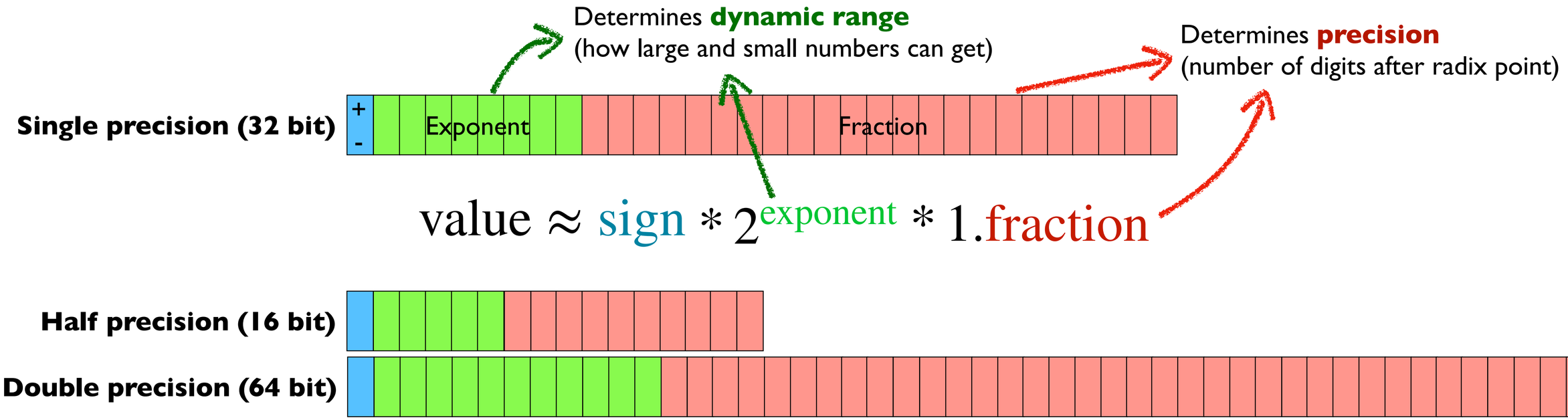
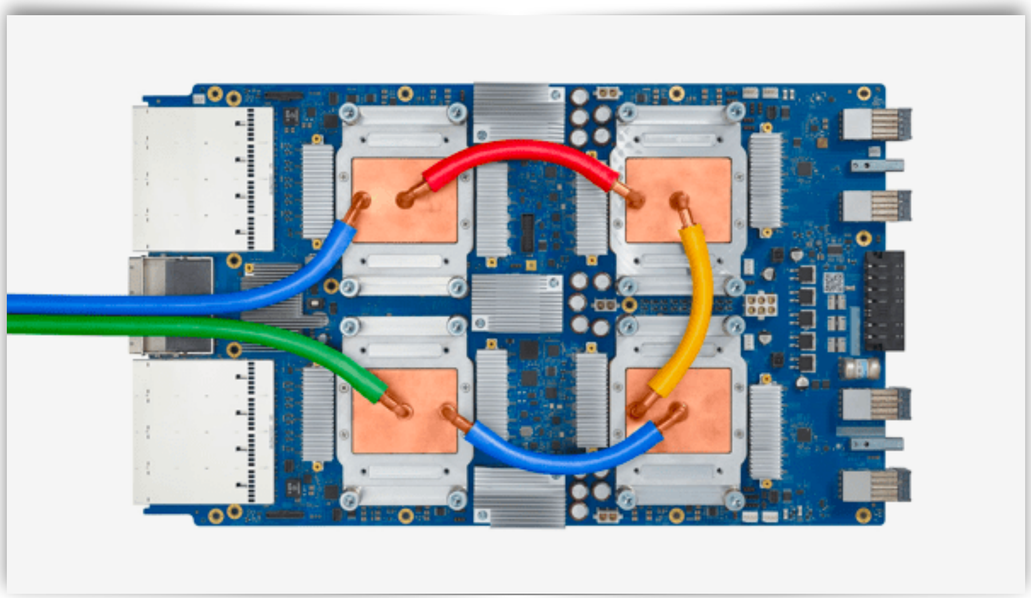
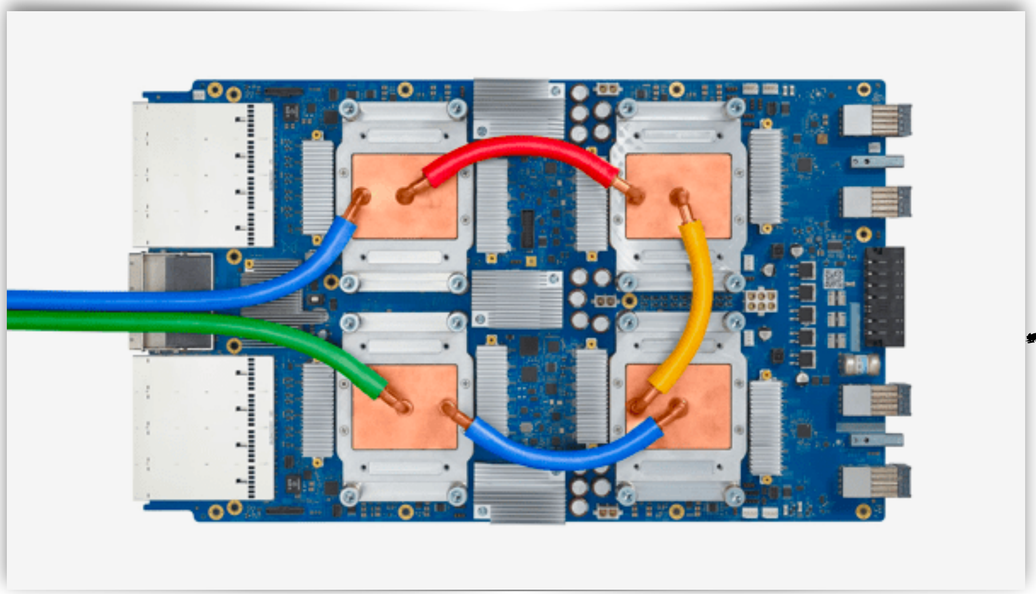
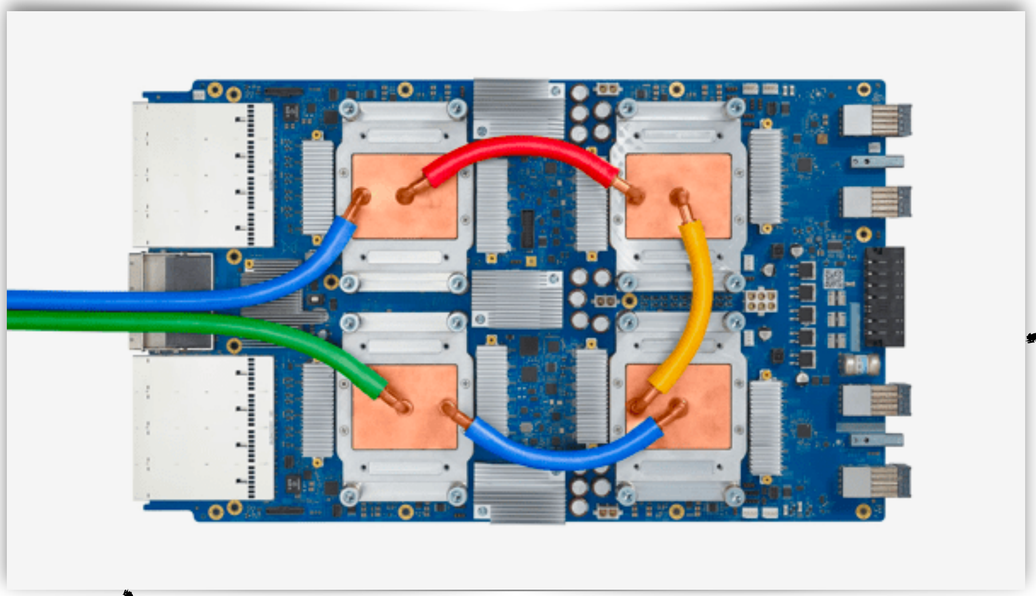


Has remained an industry standard for more than thirty years!





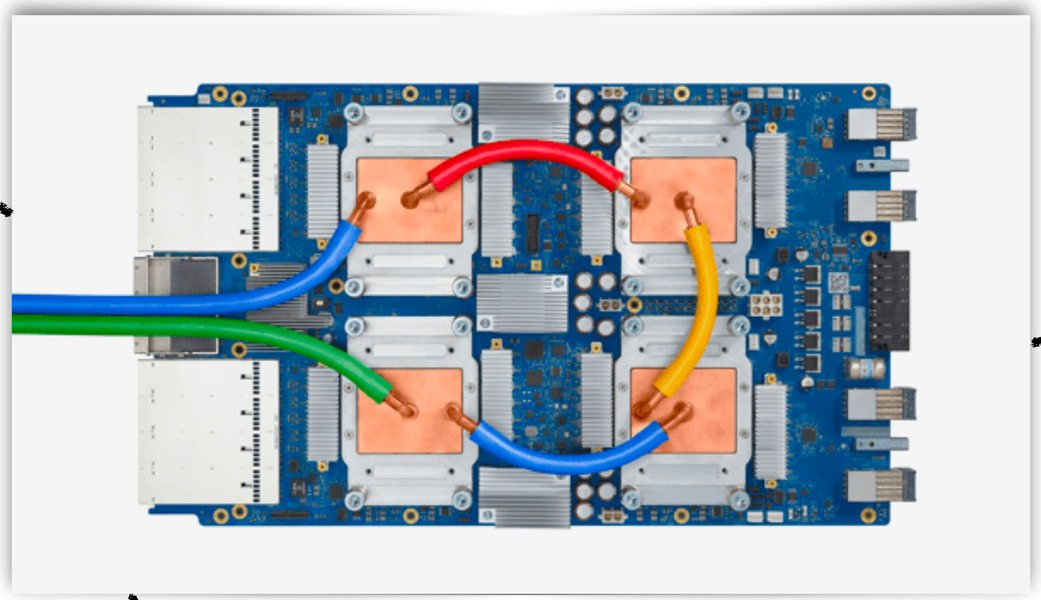
Should be fast and power-efficient



Should be fast and power-efficient

Needs small weights and activations
to maximize usage of chip area

Only needs to represent a specific range of values:
Weights and activations cluster (e.g. around [-1, 1])



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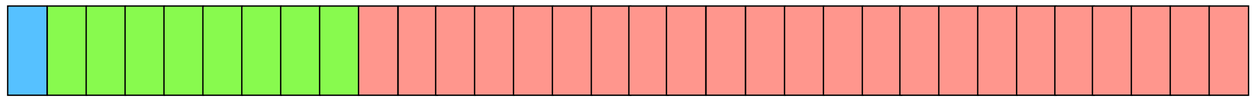
The Datatypes Zoo

What do new datatypes look like?



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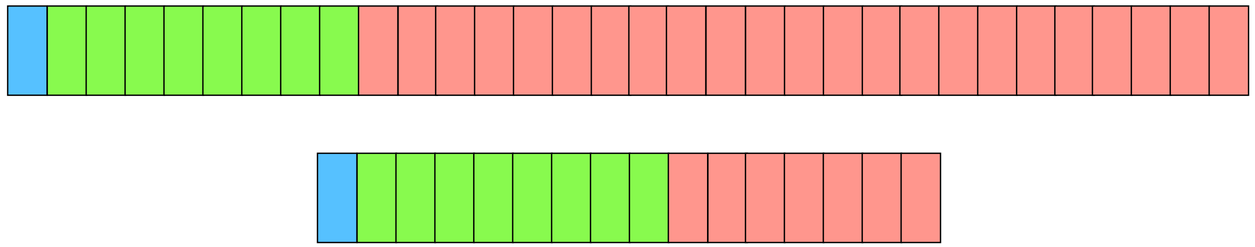

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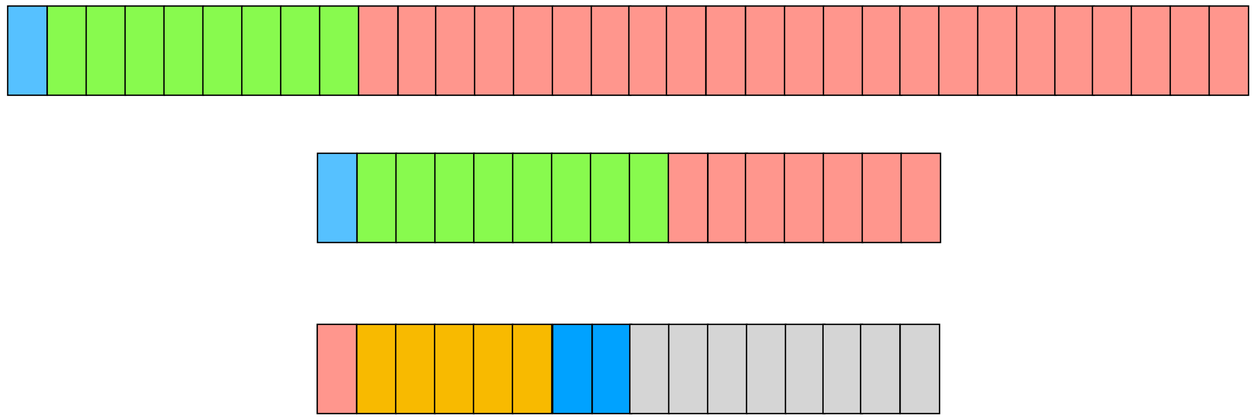

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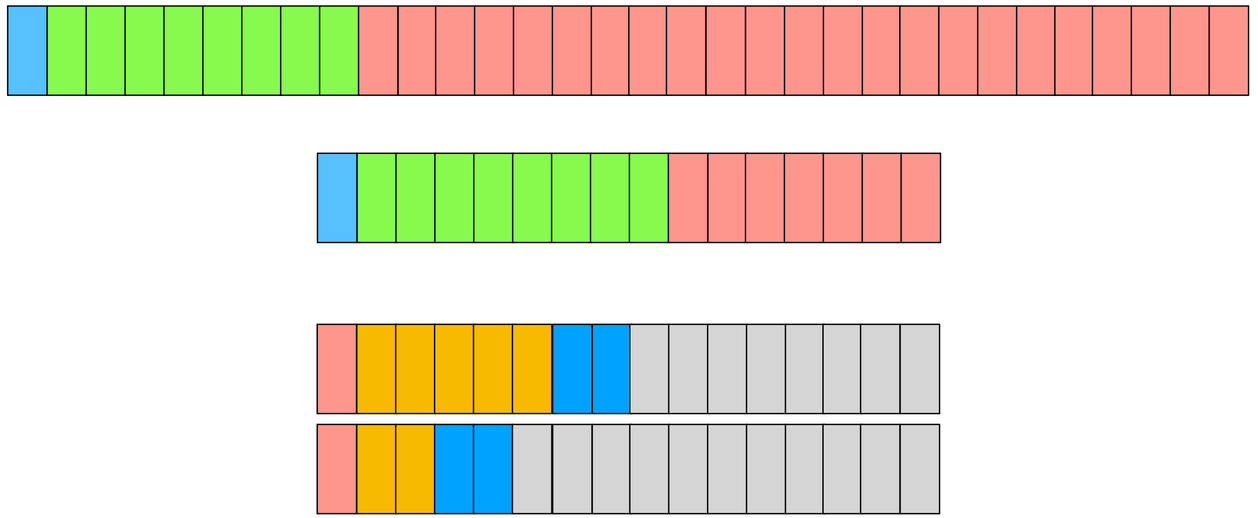

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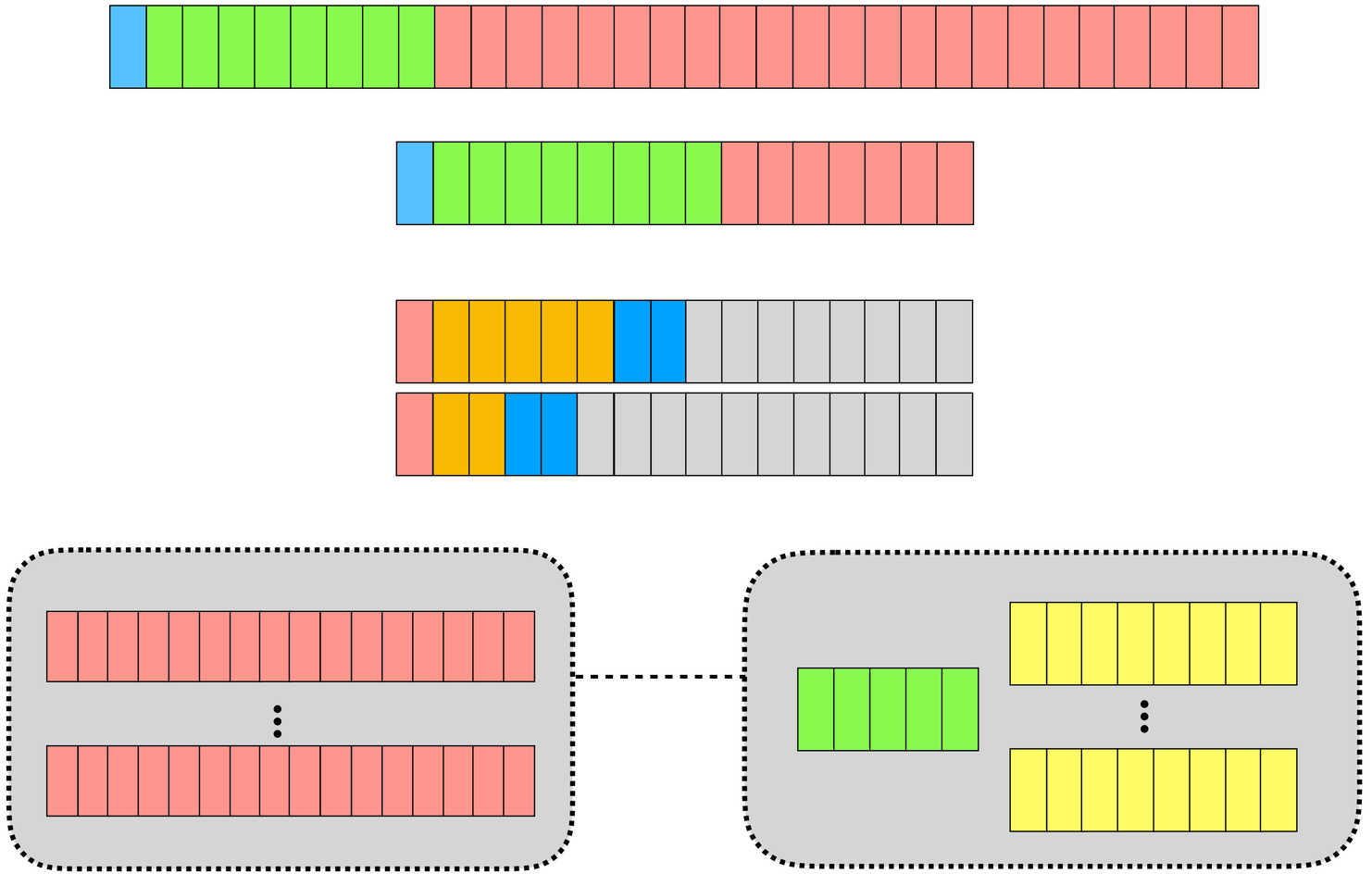

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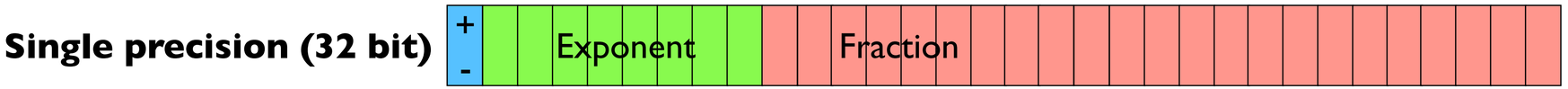
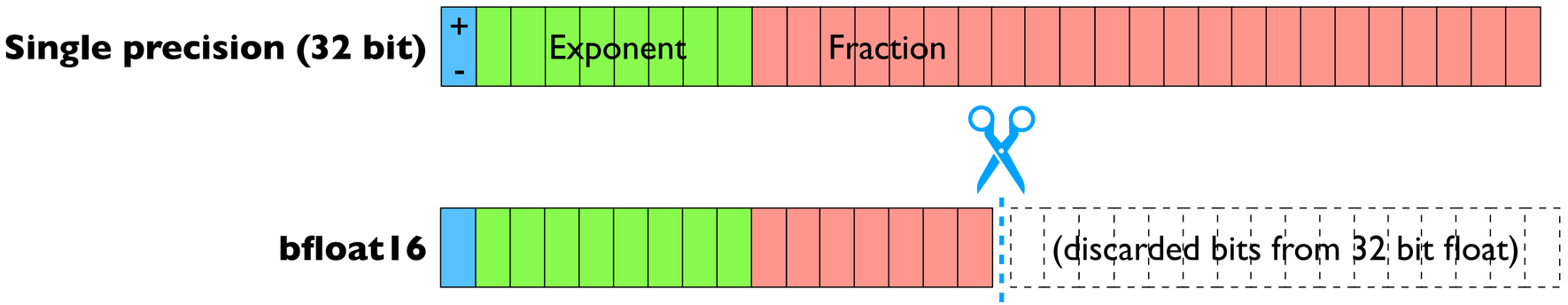


See https://cloud.google.com/tpu/docs/bfloat16

bfloat16



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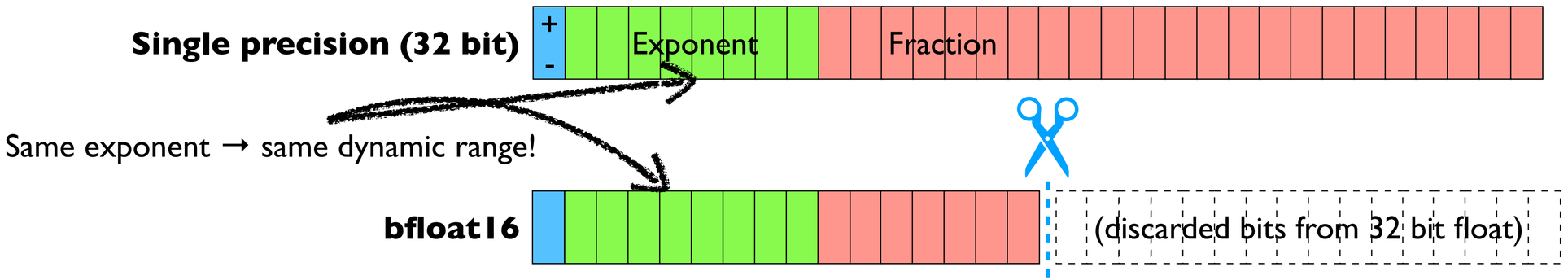

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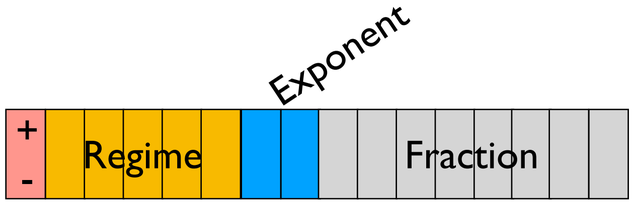
Posits



See www.johngustafson.net/pdfs/BeatingFloatingPoint.pdf

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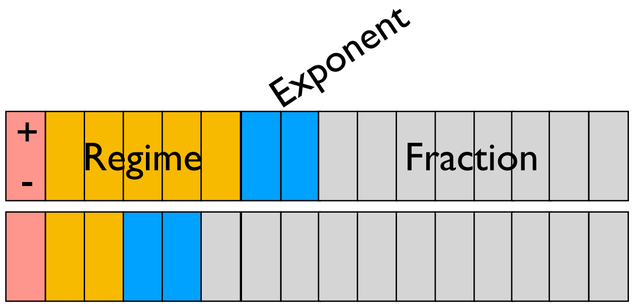

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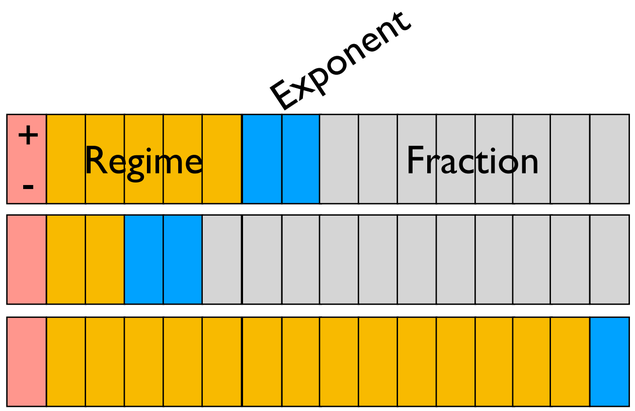

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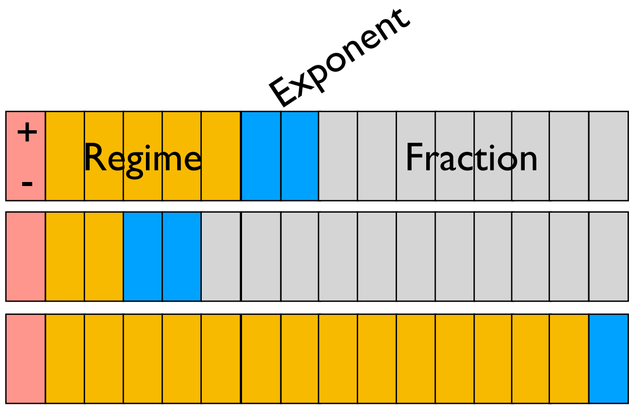

Close to ±1, more precision and accuracy!

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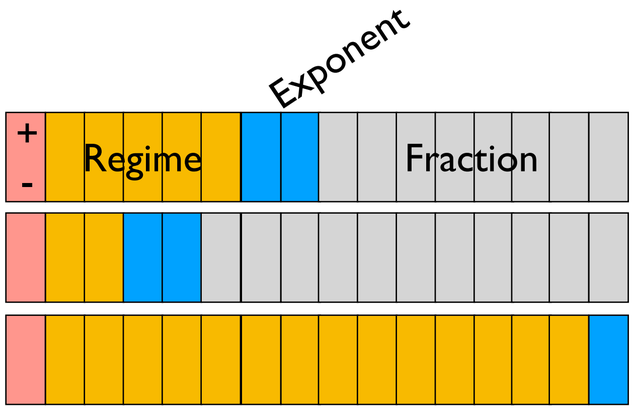

Close to ±1, more precision and accuracy!

Close to extremes, less precision and accuracy!

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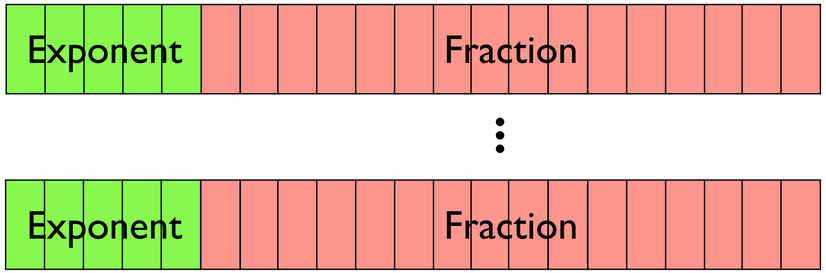
Flexpoint



See Köster et. al., "An Adaptive Numerical Format for Efficient Training of Deep Neural Networks"

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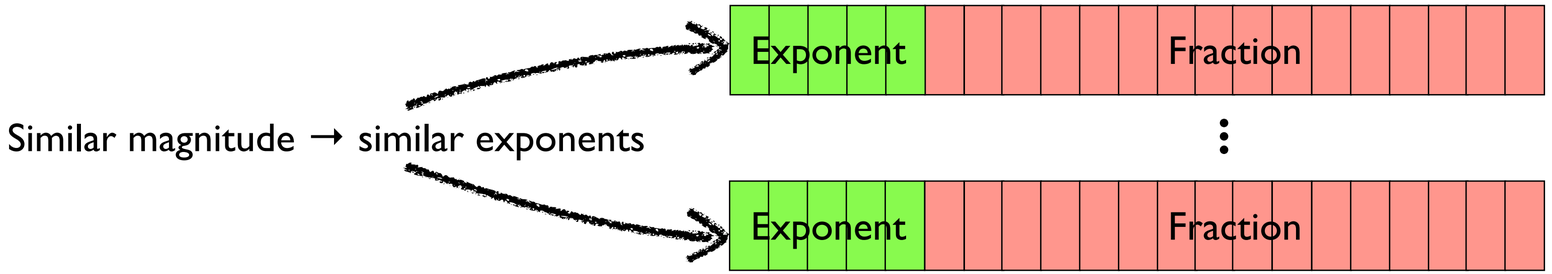

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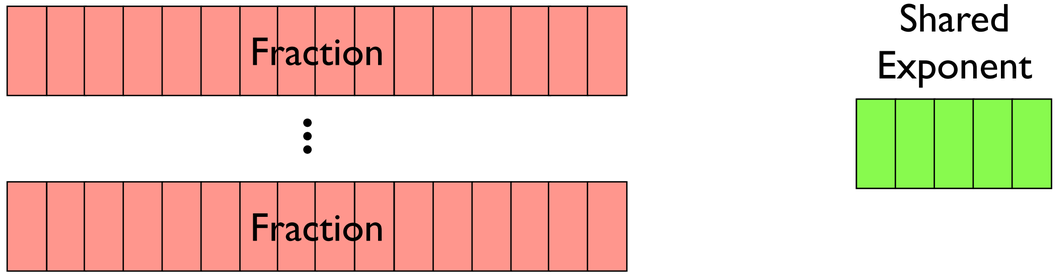

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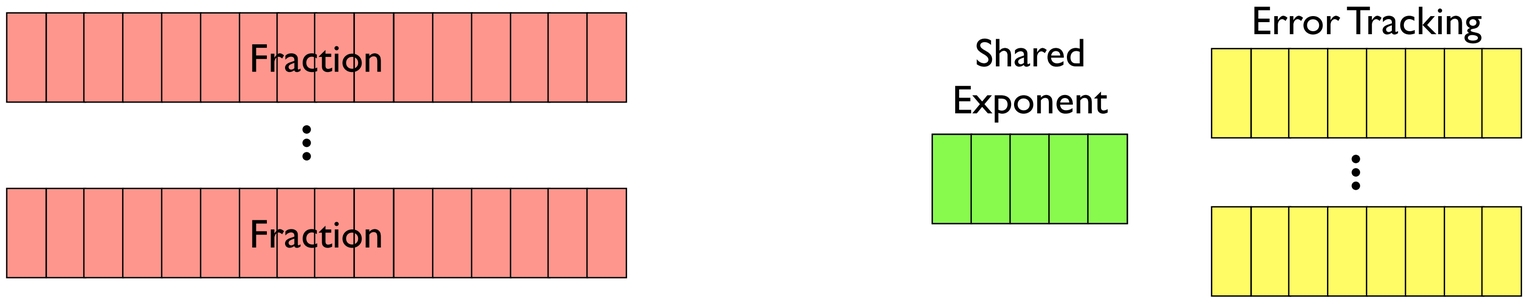

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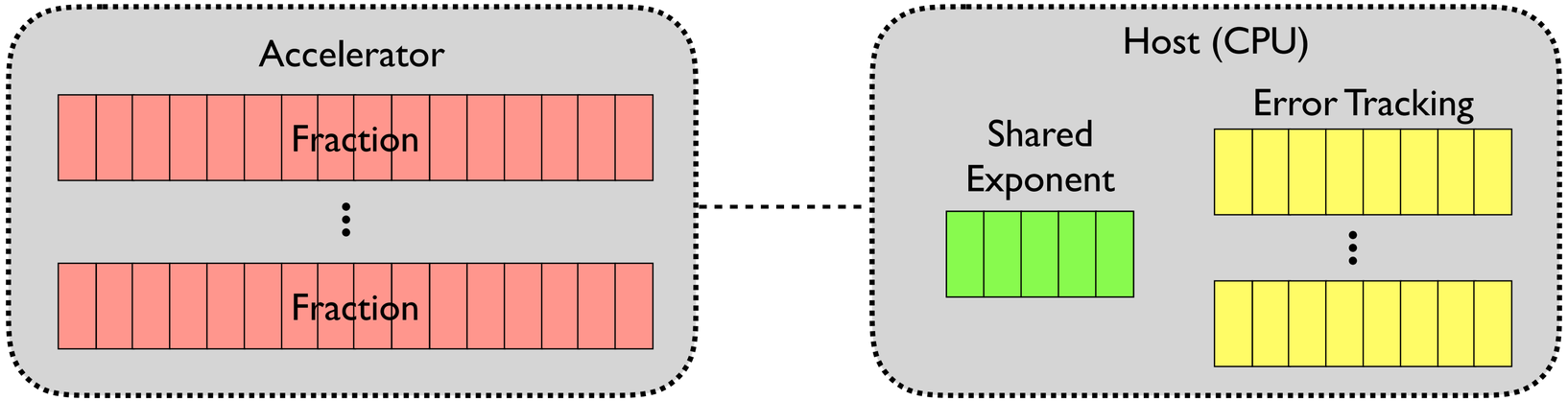

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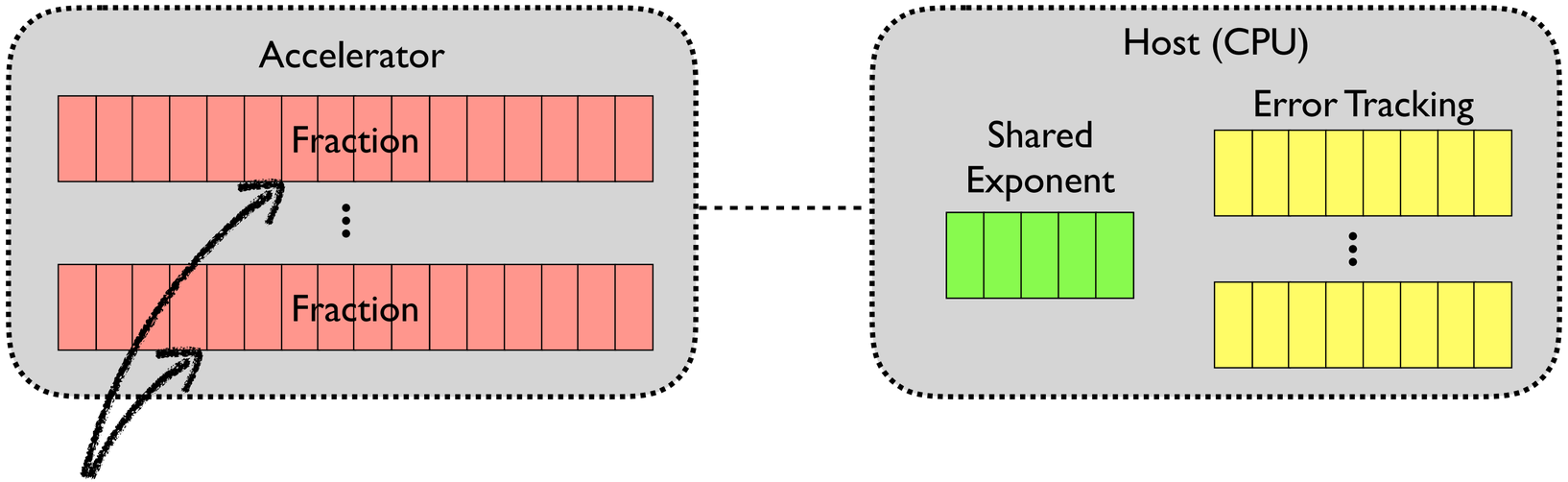

Just integers! We can use integer hardware!

See Köster et. al., "An Adaptive Numerical Format for Efficient Training of Deep Neural Networks"

In conclusion,

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- Representing real numbers in hardware is an ongoing challenge

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- There are many interesting solutions out there, beyond IEEE floats!

Thank you!