

Core Transform Property for Practical Throughput Hardware

JCTVC-G265

Mehul Tikekar, Chao-Tsung Huang,
Chiraag Juvekar, Anantha Chandrakasan

MIT



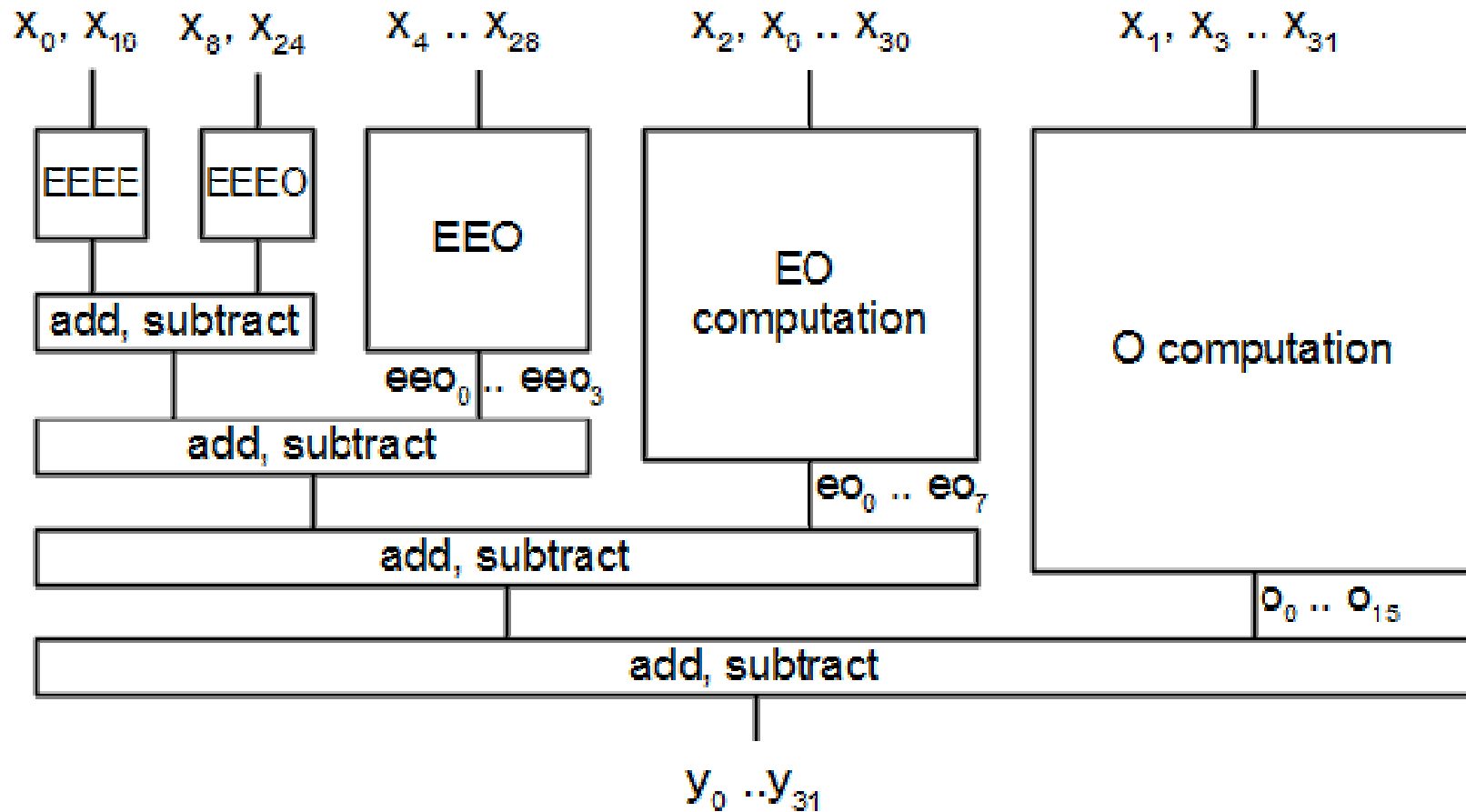
Massachusetts Institute of Technology

Key Idea

- The number of unique operations is better metric for hardware area than computational complexity
- HM-4.0 2D 32-pt transform takes 21888 multiplications
- In practical hardware implementations, the 21888 multiplies are distributed over hundreds of cycles
- Fewer unique multiplies enable more hardware sharing
- This useful property of HM-4.0 enables 25% area reduction



HM-4.0 Butterfly Structure



Example

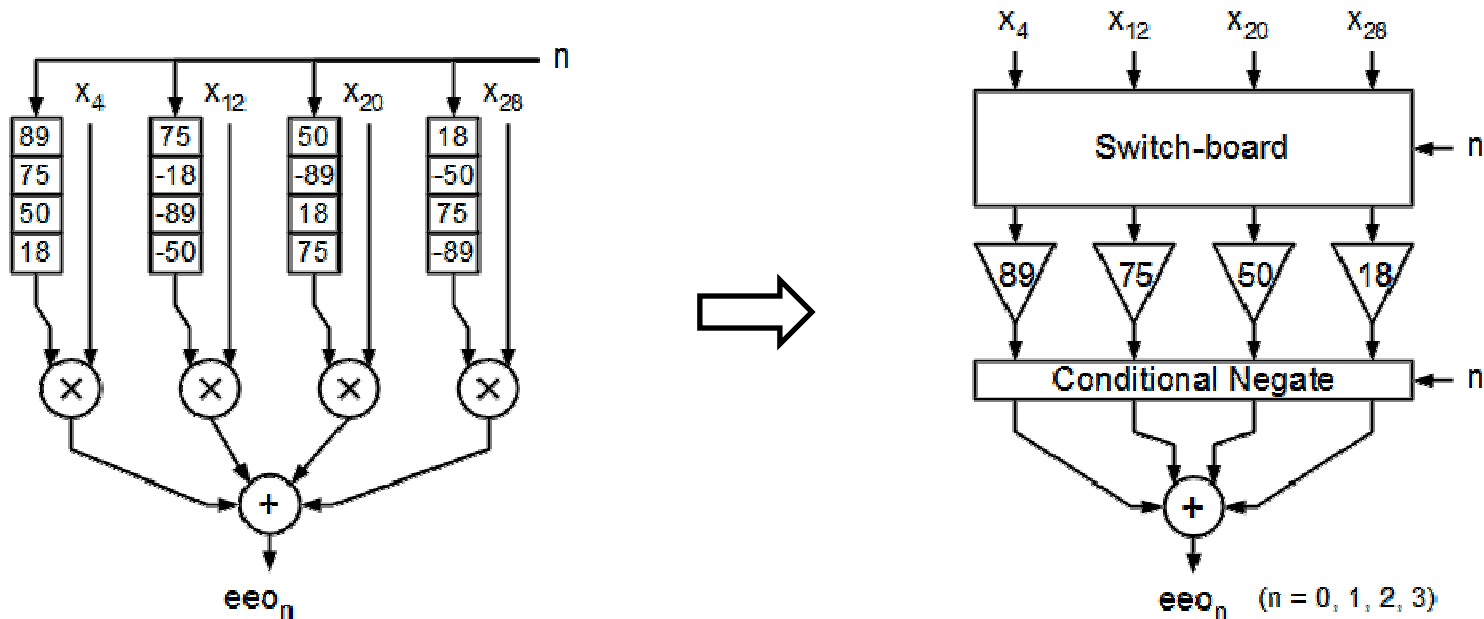
- EEO computation in HM-4.0 partial butterfly

$$\begin{bmatrix} eeo_0 \\ eeo_1 \\ eeo_2 \\ eeo_3 \end{bmatrix} = \begin{bmatrix} 89 & 75 & 50 & 18 \\ 75 & -18 & -89 & -50 \\ 50 & -89 & 18 & 75 \\ 18 & -50 & 75 & -89 \end{bmatrix} \begin{bmatrix} x_4 \\ x_{12} \\ x_{20} \\ x_{28} \end{bmatrix}$$

- Total 16 multiplications
- Only 4 unique multiply operations
 - $\times 89$, $\times 75$, $\times 50$ and $\times 18$
- 1-pixel/cycle processing requires only 4 multiply-by-constant modules



Exploiting the useful property



- 4 general multipliers and look-up tables replaced by constant multipliers and multiplexing logic
- Works for EO and O matrix multiplications as well

HM-4.0 core transform hardware

Module	Area with general multipliers (kgates)	Area with constant multipliers (kgates)
EEO Matrix Multiplication	10.5	7
EO Matrix Multiplication	23	13.5
O Matrix Multiplication	47	34
Miscellaneous	23	23
Complete 1-D Transform	103.5	77.5

- Design throughput: 4-pixels/cycle of 1D transform
- Supports 4Kx2K @ 30fps decoding at 200MHz clock
- 25% area reduction
- Complete area includes DST, DCT of all lengths and logic to switch between them



Conclusion

- Number of unique operations impacts hardware complexity
- This, in turn, depends on the number of unique coefficients in the transform matrix
- Suggestion to consider this property when comparing transform proposals for HEVC

