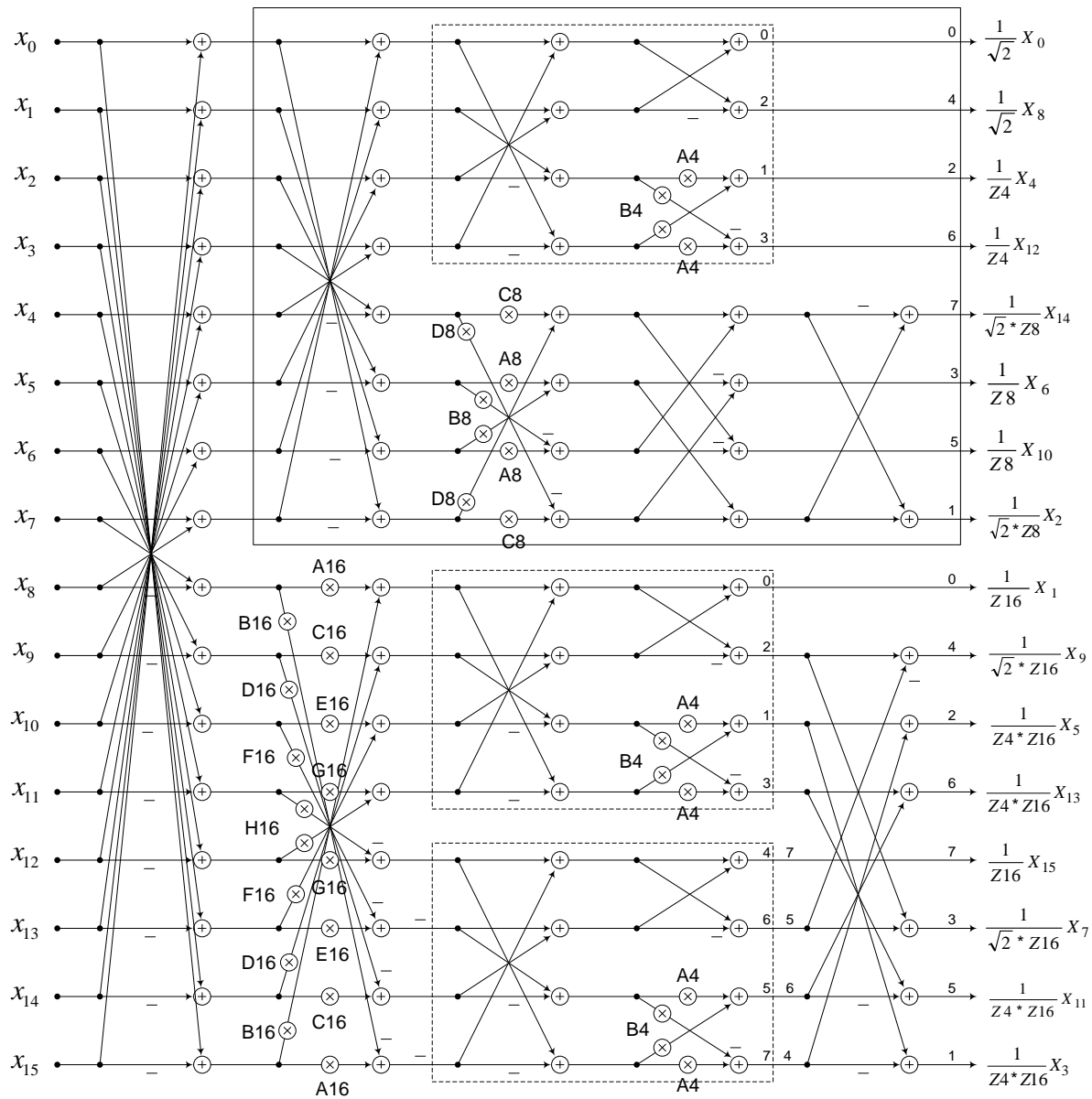# Recursive factorization for 16 and 32-point transforms using 4 and 8-point HM 3.0 core transforms
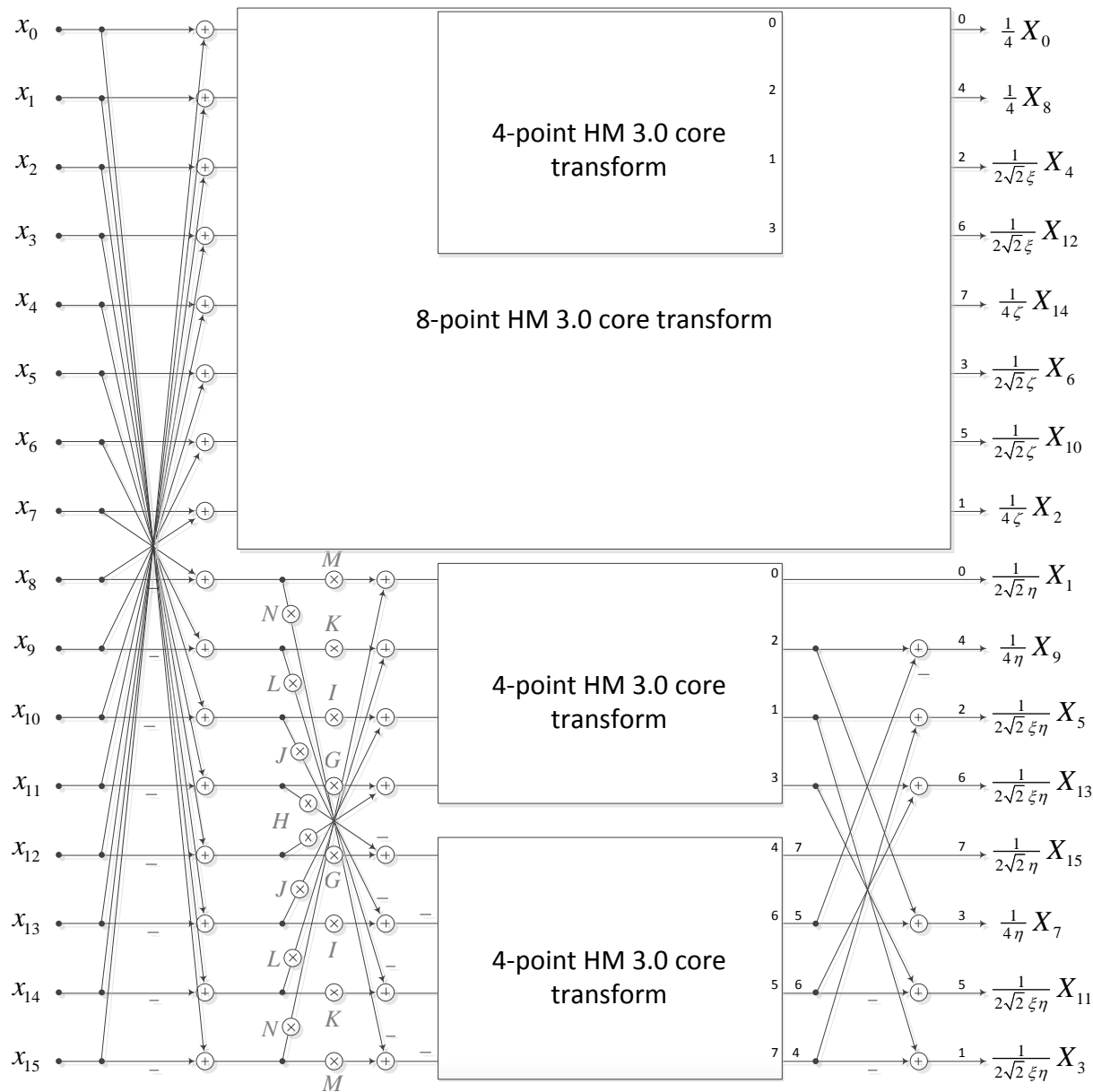
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# Motivation

- HM 3.0 core transforms: Partial Butterfly
  - N/2 x N/2 matrix multiply in the lower (odd) part of the transform.
  - 8 x 8 transform: Only 4 x 4 matrix multiply needed.
- Matrix multiplication vs full factorization
  - Trade-off between number of multiplies and number of sequential operations.

$x_0$   $\frac{1}{\sqrt{2}} X_0$

$x_1$   $\frac{1}{\sqrt{2}} X_8$

$x_2$   $\frac{1}{Z4} X_4$

$x_3$   $\frac{1}{Z4} X_{12}$

$x_4$   $\frac{1}{\sqrt{2} * Z8} X_{14}$

$x_5$   $\frac{1}{Z8} X_6$

$x_6$   $\frac{1}{Z8} X_{10}$

$x_7$   $\frac{1}{\sqrt{2} * Z8} X_2$

$x_8$   $\frac{1}{Z16} X_1$

$x_9$   $\frac{1}{\sqrt{2} * Z16} X_9$

$x_{10}$   $\frac{1}{Z4 * Z16} X_5$

$x_{11}$   $\frac{1}{Z4 * Z16} X_{13}$

$x_{12}$   $\frac{1}{Z16} X_{15}$

$x_{13}$   $\frac{1}{\sqrt{2} * Z16} X_7$

$x_{14}$   $\frac{1}{Z4 * Z16} X_{11}$

$x_{15}$   $\frac{1}{Z4 * Z16} X_3$

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$x_0$

$x_1$

$x_2$

$x_3$

$x_4$

$x_5$

$x_6$

$x_7$

$x_8$

$x_9$

$x_{10}$

$x_{11}$

$x_{12}$

$x_{13}$

$x_{14}$

$x_{15}$

0

2

4-point HM 3.0 core transform

1

3

8-point HM 3.0 core transform

0 $\frac{1}{4}X_0$

4 $\frac{1}{4}X_8$

2 $\frac{1}{2\sqrt{2}\,\xi}X_4$

6 $\frac{1}{2\sqrt{2}\,\xi}X_{12}$

7 $\frac{1}{4\,\zeta}X_{14}$

3 $\frac{1}{2\sqrt{2}\,\zeta}X_6$

5 $\frac{1}{2\sqrt{2}\,\zeta}X_{10}$

1 $\frac{1}{4\,\zeta}X_2$

$M$

$N$ $K$

$L$ $I$

$J$ $G$

$H$

$J$ $G$

$L$ $I$

$N$ $K$

$M$

4-point HM 3.0 core transform

4-point HM 3.0 core transform

0 $\frac{1}{2\sqrt{2}\,\eta}X_1$

4 $\frac{1}{4\,\eta}X_9$

2 $\frac{1}{2\sqrt{2}\,\xi\eta}X_5$

6 $\frac{1}{2\sqrt{2}\,\xi\eta}X_{13}$

7 $\frac{1}{2\sqrt{2}\,\eta}X_{15}$

3 $\frac{1}{4\,\eta}X_7$

5 $\frac{1}{2\sqrt{2}\,\xi\eta}X_{11}$

1 $\frac{1}{2\sqrt{2}\,\xi\eta}X_3$

Proposed transform

# Arithmetic complexity

|  | HM 3.0 core transforms | Proposed transforms | Transforms proposed in JCTVC-352 |
|---|---|---|---|
| 16 point | 86 | 50 | 36 |
| 32 point | 342 | 126 | 92 |

# Storage of dequantization matrices

- 32-point transform
  - Only 5 distinct scale factors (5×5 matrix) instead of 12x12 in F352.
  - Scale factors for 16-point transform embedded in this matrix.

# Conclusion

- Proposed 16 and 32-point transforms
  - Desirable tradeoff between number of multiplies and number of sequential operations.

- 4 and 8-point transforms unchanged from HM 3.0