Coefficient reordering & RLE - cheat sheet

Scan patterns, run-length packaging, and last-coefficient signalling across MPEG-2, H.264, HEVC, AV1, VVC. Companion to article 4.9 of Block 4. Print on A4.

1. Scan pattern per codec

Codec	Block sizes	Scan pattern	Last-coef signal	Sub-block flag
MPEG-2	8x8	zig-zag + alt. (field)	no - read until EOB	no
H.264 / AVC	4x4, 8x8	zig-zag + field scan	inside CAVLC / CABAC	no
HEVC	4x4 to 32x32	4x4 diagonal (H/V/D)	`last_sig_coeff_x, _y`	`coded_sub_block_flag`
AV1	4x4 to 64x64 + 1-D	per-shape table	eob index first	implicit via eob
VVC	4x4 to 64x64	diagonal + dep-Q ctx	`last_sig_coeff_x, _y`	`coded_sub_block_flag`

2. Run-length packaging - the (run, level) anatomy

After the scan flattens the block, the encoder emits pairs of (run, level) plus EOB:

- **run** = number of leading zeros before the next non-zero coefficient
- **level** = the non-zero coefficient itself (signed)
- **EOB** = 'everything else in this block is zero'

Sparse 8x8 block with 3 non-zeros: 3 pairs + EOB = ~15-20 bits in the bitstream. DC is coded separately by DPCM (difference from the neighbour's DC), in its own VLC table.

3. HEVC: two-level diagonal scan + skip flag

A 32x32 transform block becomes a grid of 4x4 sub-blocks. Two scans run nested:

- **outer:** sub-blocks visited along the main diagonal (top-right to bottom-left)
- **inner:** cells inside each sub-block visited in the same diagonal direction

Sub-blocks with `coded_sub_block_flag` = 0 are skipped wholesale - one bit each. The position of the last non-zero coefficient is signalled up front, so the decoder knows in advance how many cells of the scan to read. No 'walk until EOB' cost.

4. AV1 and VVC - what changed after HEVC

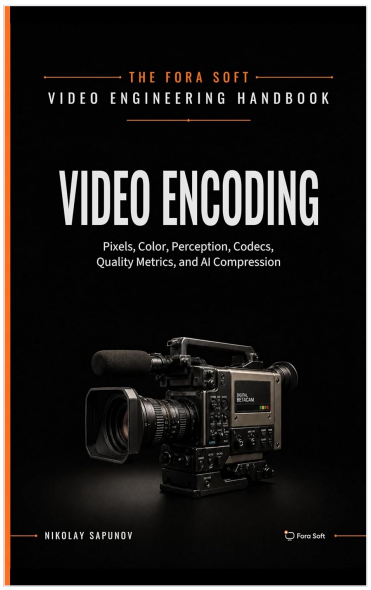
- **AV1:** scan tables per transform shape (square, rectangular, 1-D). 4x4 keeps zig-zag.
- **AV1:** coefficients coded in REVERSE scan order from the last non-zero back to the DC.
- **AV1:** lower magnitude bits in one pass; sign and higher magnitude bits in a second pass.
- **VVC:** same diagonal scan as HEVC, but context depends on dependent-quantization state.
- **VVC:** sign data hiding - sign of first non-zero in each sub-block inferred from parity.

5. Debugging quick reference

Symptom	Cause
Blocky garbage from one point to the slice end (H.264 / MPEG-2)	mis-parsed EOB.
Blocky garbage localised to a 4x4 region (HEVC / VVC)	bit error inside a sub-block.
Whole block wrong but next block correct (HEVC / AV1 / VVC)	last-coef position contained it.
Slow decode on dense blocks	VVC dependent-Q forces sequential context updates.

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Companion to: 'Reordering, Zig-Zag Scan, and Run-Length Coding'
www.forasoft.com/learn/video-encoding/articles/reordering-zigzag-rle



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This sheet compares scan patterns, run-length packaging and last-coefficient signalling across MPEG-2, H.264, HEVC, AV1 and VVC. Volume 1 covers the whole compression pipeline around this step: transforms and quantization, entropy coding, how H.264, HEVC and AV1 differ, and the quality metrics that show the result.

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