

Companion to article 4.3 of Block 4. Print on A4 or US Letter.

## Frame types and typical bit budget

- **I-frame**     Intra-coded. No references. Baseline = 100% of an I-frame.
- **P-frame**     Predicts from past references. ~50% of I-frame size.
- **B-frame**     Predicts from past AND future. ~25% of I-frame size.

### Rule of thumb:

Disabling B-frames (low-latency live) typically costs 30-50% more bitrate at matched visual quality.

## Where the encoder spends its time

Motion estimation = 60-80% of total encoder time. Every preset is a motion-estimation knob.

## x264 / x265 motion-estimation presets

me=	Name	Speed	Quality	Use case
dia	Diamond	Fastest	Lowest	Live, ultrafast/superfast
hex	Hexagon	Fast	Good	Default; live and VOD fast
umh	Uneven Multi-Hex	Medium	+0.1 dB PSNR	VOD slow/slower/veryslow
esa	Exhaustive search	Slow	Marginal gain	Archive only; rarely worth it
tesa	Transformed exhaustive	Slowest	Placebo	Bragging rights only

## Settings that move bitrate and encode time

- Search range (merange)**     Wider = lower bitrate, quadratically slower. 16-24 live; 32-64 VOD.
- Sub-pixel depth**     1/2 pix gains ~1 dB; 1/4 pix gains another 0.5-0.8 dB. Cheap to enable.
- Reference frames**     More refs = lower bitrate, diminishing returns past 4-8.
- B-frame count**     0 for live; 2-3 for VOD; 16 for archival. Each costs decoder buffer.
- Affine / warped motion**     +5-15% encode time; big wins on pans, zooms, rotations.
- Rate-distortion optimisation**     Slower preset = more RDO = better quality at same bitrate.

## Live vs VOD - typical tuning

Setting	Live / low-latency	VOD / VOD-quality
<b>B-frames</b>	0	2 or 3
<b>ME pattern</b>	hex (or dia)	umh
<b>Search range</b>	16-24	32-64
<b>Reference frames</b>	1-3	4-8
<b>Sub-pixel</b>	1/4	1/4 or 1/8
<b>Preset</b>	veryfast / faster	slow / slower / veryslow

## Modern motion tools (by codec)

- H.264 (2003): variable blocks, multi-reference (up to 16), 1/4-pixel motion vectors
- HEVC (2013): quad-tree blocks, advanced motion-vector prediction, weighted prediction
- AV1 (2018): 7 references, global/warped motion, OBMC, compound prediction modes
- VVC (2020): affine motion model, BDOF, DMVR, decoder-side refinement
- AV2 (2025): extended reference buffer, learned modes, finer affine, improved compound