

Companion to article 4.4 of Block 4. Print on A4 or US Letter.

Frame types and typical bit budget

■ I-frame	Full picture. No references. Baseline = 100% of an I-frame.
■ P-frame	Predicts from past references. ~30-60% of I-frame.
■ B-frame	Predicts from past AND future. ~15-30% of I-frame.
■ IDR	I-frame that clears the reference buffer. Random-access point.

Open vs Closed GOP

Closed GOP	No reference crosses the boundary. REQUIRED for HLS, DASH, CMAF, ABR.
Open GOP	First B-frames look back across. Saves 1-3% bitrate. Archive masters only.

GOP length recipes (production presets)

Workflow	GOP length	Closed?	B-frames	Notes
HLS / DASH VOD 24 fps	48 frames / 2 s	Yes	B-pyramid	Apple-recommended
HLS / DASH VOD 30 fps	60 frames / 2 s	Yes	B-pyramid	Most common ladder
HLS / DASH VOD 60 fps	120 frames / 2 s	Yes	B-pyramid	Sports, gaming
LL-HLS / LL-DASH live	24-60 fr / 1 s	Yes	Off or 2-level	GOP = part size
WebRTC conference	30-1800 / 1-60 s	n/a	Off	PLI/FIR-driven
Surveillance / NVR	60-600 / 2-20 s	Yes	Off	Event-driven IDR
Broadcast contribution	12-30 / 0.5-1 s	Yes	Optional	SCTE-35 splice
Archive master	1 frame	n/a	n/a	All-intra (ProRes)

Encoder flags - force fixed closed GOP across the ladder

FFmpeg + libx264:

```
ffmpeg -i in.mov -c:v libx264 -g 48 -keyint_min 48 -sc_threshold 0 -bf 2 -b_strategy 1 out.mp4
```

FFmpeg + libx265:

```
ffmpeg -i in.mov -c:v libx265 -x265-params "keyint=48:min-keyint=48:no-open-gop=1:scenecut=0" out.mp4
```

FFmpeg + libaom-av1 (VOD):

```
ffmpeg -i in.mov -c:v libaom-av1 -g 48 -keyint_min 48 -aq-mode 1 -row-mt 1 out.mkv
```

Closed-GOP audit checklist for your ABR ladder

- Every rendition uses the same fixed GOP length in frames.
- GOP length divides evenly into segment length and frame rate.
- Source is CFR (constant frame rate) - VFR sources must be rewrapped first.
- Scene-cut keyframe insertion is OFF (sc_threshold=0).
- Open GOP is OFF (no-open-gop=1 on x265, default on libx264).
- Every segment boundary lands on an IDR, not a plain I-frame.
- Audio frame count per segment matches video segment length.
- ABR switch test: cycle 360p <-> 1080p every 2 s with no visible glitch.