



A VVC/H.266 Real-time Software Encoder for UHD Live Video Applications

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Objectives

- Present Spin Digital's VVC live software encoder for UHD broadcasting and streaming applications
- Compare the new encoder with optimized implementations of H.264/AVC, H.265/HEVC, AV1, and H.266/VVC

Overview of the VVC Real-time Encoder

- Software encoder optimized for latest-generation CPU architectures
- Optimizations and main features:
 - Advanced coding-tool decision algorithms
 - Pre-processing, pre-analysis, CBR and VBR RC, HRD
 - Perceptually-optimized encoding mode
 - SIMD instructions
 - Memory optimizations
 - Multi-level parallelization
- Real-time encoding
 - 4K at 60 fps and 8K at 30 fps
 - using current dual-socket servers

Encoder Assessment for 4K-UHD Live Applications

- Spin Digital VVC has been compared to five open-source optimized software encoders of different coding standards
- The encoders were configured assuming a **4K-UHD live streaming and broadcasting scenario**
 - Rate control (CBR if possible)
 - Random-access mode (long GOP)

Encoding Settings

- Random-access mode (long GOP)
- Open GOP
- 1-second intra period
- 1-pass CBR rate control
 - Exceptions: 1-pass VBR for SVT-AV1 and VVenC
- 1-second HRD buffer
- Target bitrates: 8 to 44 Mbps in steps of 4 Mbps
- Tuned to maximize the PSNR
- Other parameters (e.g. GOP pattern, lookahead window) are kept at the default values

Video Sequences

- 11 representative 4K-UHDTV seqs. of 1 minute

| | Producer | Type | Format | SI | TI |
|------------------------|-------------|---------------|--------------|--------------|--------------|
| BasketballGame | Netflix | Footage | 4Kp59.94 HDR | 112.6 (med) | 152.2 (med) |
| BerlinSeqs | Fraunh. HHI | Footage | 4Kp60 HDR | 172.2 (med) | 63.6 (low) |
| DrivingPOV | Netflix | Footage | 4Kp59.94 HDR | 150.0 (med) | 147.4 (med) |
| FollowCar | PSNC | Footage | 4Kp59.94 SDR | 201.9 (high) | 111.8 (med) |
| MC2 | PSNC | Footage | 4Kp59.94 SDR | 280.5 (high) | 82.5 (low) |
| Meridian | Netflix | Footage & CGI | 4Kp59.94 HDR | 89.8 (low) | 23.6 (low) |
| RollerCoaster | Netflix | Footage | 4Kp59.94 HDR | 92.3 (low) | 84.9 (low) |
| SolLevante | Netflix | Animation | 4Kp24 HDR | 237.5 (high) | 269.4 (high) |
| Superposition | Unigine | CGI | 4Kp60 SDR | 226.5 (high) | 82.9 (low) |
| ToddlerFountain | Netflix | Footage | 4Kp59.94 HDR | 170.2 (med) | 79.3 (low) |
| TunnelFlag | Netflix | Footage | 4Kp59.94 SDR | 211.6 (high) | 206.8 (high) |

Video Encoders and Presets

| | x264 | x265 | SVT-HEVC | Spin Digital HEVC | SVT-AV1 | VVenC | Spin Digital VVC |
|---------------------|--------------------------------|---------------------------------|----------------|----------------------|-------------------------|----------------|---------------------|
| Standard | AVC | HEVC | HEVC | HEVC | AV1 | VVC | VVC |
| Company | VideoLAN | MulticoreWare | Intel | Spin Digital | Intel & Netflix | Fraunhofer HHI | Spin Digital |
| Version | r3094 | 3.5 | 1.5.1 | 1.2-dev | 1.2.1 | 1.5.1 | 0.2 |
| Release date | Apr. 2021 | Apr. 2022 | June 2021 | Sep. 2022 | Aug. 2022 | July. 2022 | Sep. 2022 |
| Presets | slower, medium, veryfast | slower, medium, ultrafast | 3, 5, 7, 9, 11 | default | 4, 6, 7, 8 9, 10, 12 | fast, faster | default |

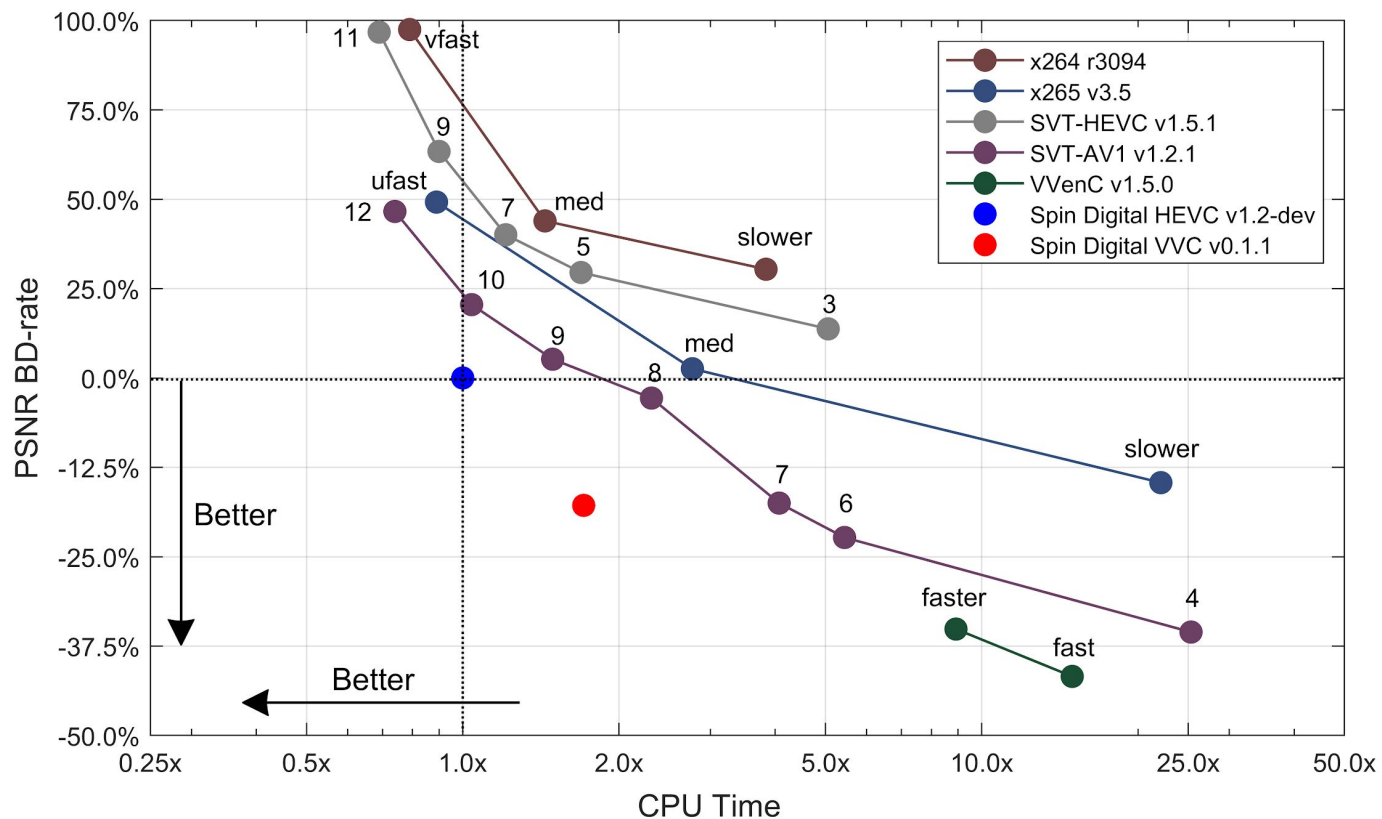
Comparison Metrics - 1

- Compression efficiency: BD-rate
 - Metrics: PSNR, XPSNR, MS-SSIM, VMAF
 - Baseline: Spin Digital HEVC
- Encoding complexity: CPU time
 - Single-threaded CPU time compared to baseline
 - Baseline: Spin Digital HEVC
- Platform
 - CPU: 4x Intel Xeon Platinum 8176 (4x 28 cores)
 - DRAM: 24x 16 GB DDR4 2666 MHz
 - OS: Ubuntu 20.4

Comparison Metrics - 2

- Maximum performance
 - Multithreaded encoding speed measured in frames per second (fps)
- Platform
 - CPU: 2x Intel Xeon Platinum 8378 (2x 38 cores)
 - DRAM: 16x 16 GB DDR4 3200 MHz
 - OS: RedHat 8.5

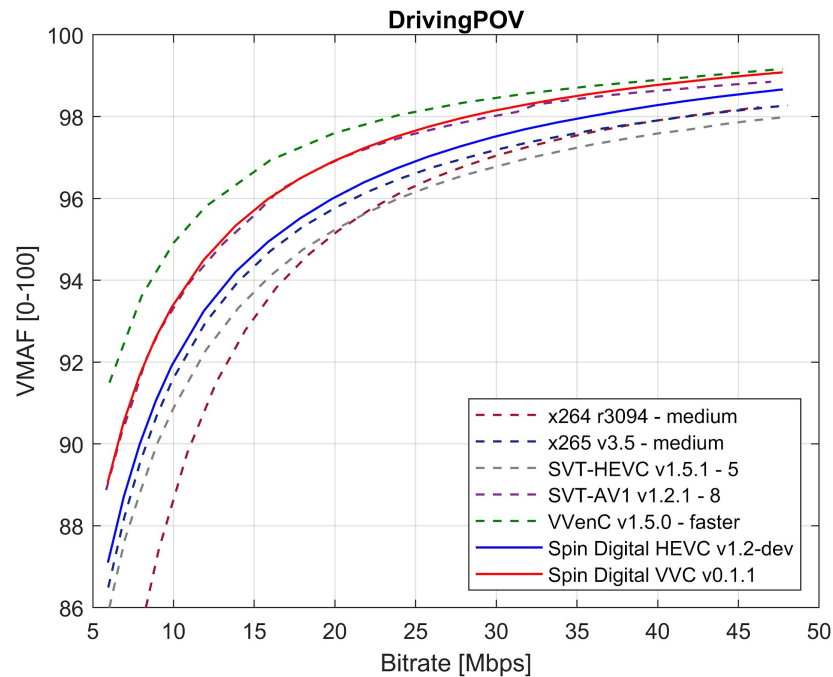
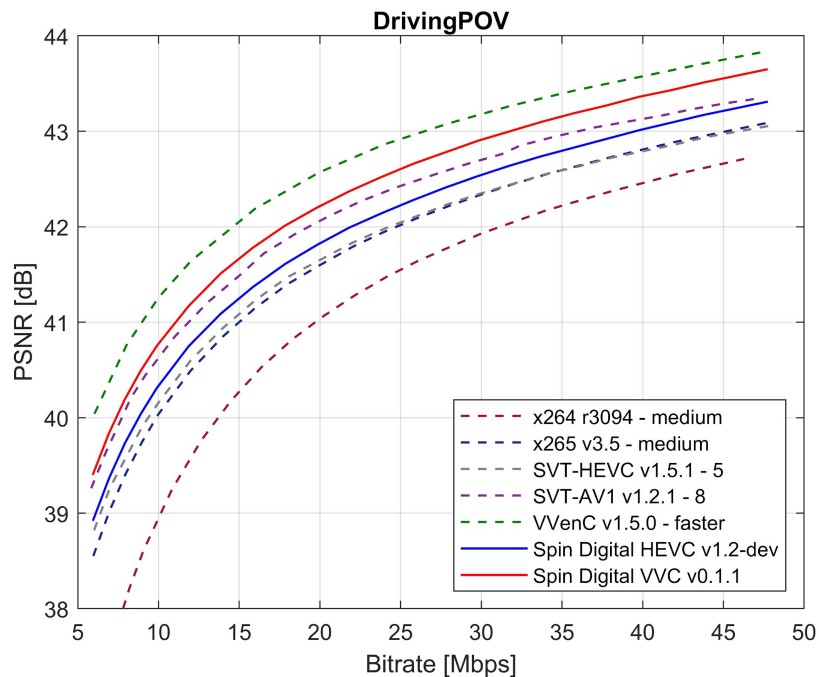
BD-rate and CPU Time



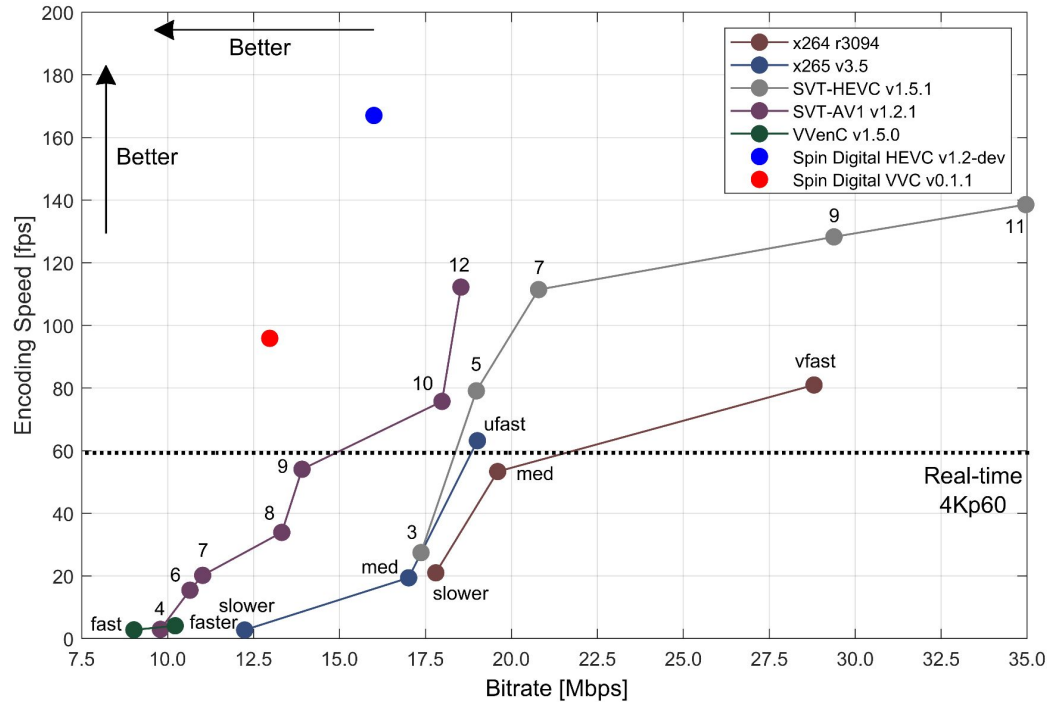
BD-rate and CPU Time

- Spin Digital VVC achieves
 - BD-rate savings of 17.8%, 19.7%, 17.3%, and 18.7% based on PSNR, XPSNR, MS-SSIM and VMAF, respectively,
 - At 1.7 times the computational cost with respect to Spin Digital HEVC
- At a comparable complexity, Spin Digital VVC has higher compression eff. than others (e.g. SVT-AV1)
- At a comparable compression efficiency, Spin Digital VVC is less complex than SVT-AV1 and x265
- VVenC has higher compression efficiency (-21%) but higher complexity (5.2x) than Spin Digital VVC (different use case)

Selected Quality-bitrate Plots



Multithreaded Encoding Speed



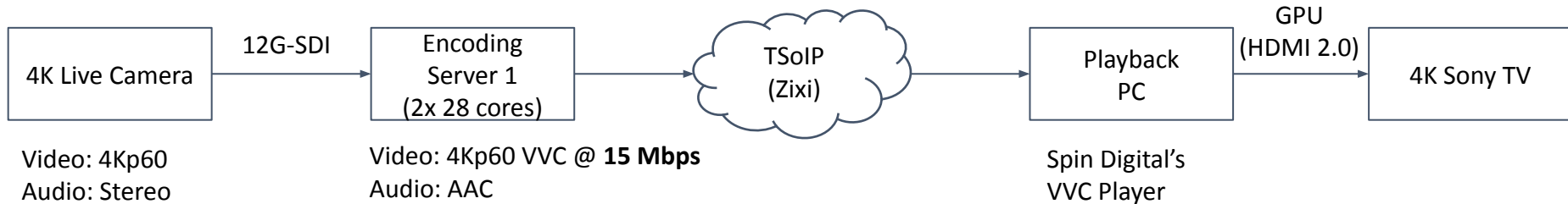
Video: DrivingPOV (Netflix) - Config: Bitrate that produces the same quality (VMAF 95)

Multithreaded Encoding Speed

- Spin Digital VVC achieves a performance beyond real-time 4Kp60 video (96 fps)
- Spin Digital VVC produces the lowest bitrate for a given quality under real-time conditions (13 Mbps)
- Other encoders (SVT-AV1, SVT-HEVC, x264, x265) can achieve real-time performance but at significantly higher bitrates (e.g. 38.6% higher for SVT-AV1)

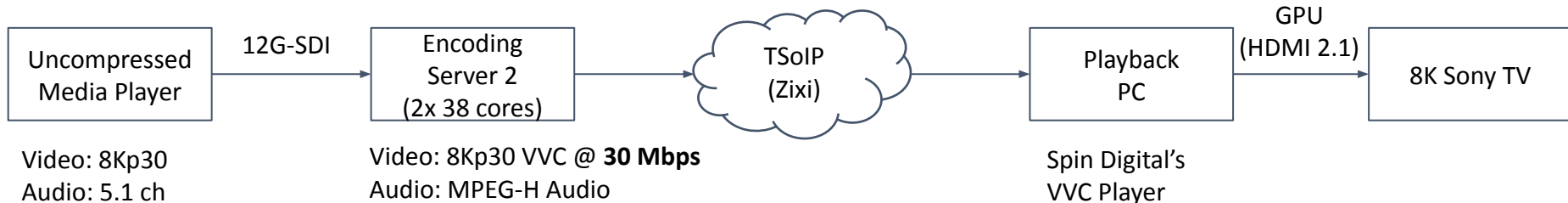
UHD VVC Live Encoding and Streaming at IBC 2022

4Kp60 VVC Live



UHD VVC Live Encoding and Streaming at IBC 2022

8Kp30 VVC Live



Conclusions

- Live VVC encoder 18.7% bitrate savings relative to a state-of-the-art HEVC live encoder at the cost of 1.7 times the computational complexity
- Real-time 4Kp60 and 8Kp30 video encoding on a current dual-socket server with 2x 38 cores
- Higher compression efficiency than open-source HEVC and AV1 encoders under real-time conditions
- Ready for 4K/8K live streaming and broadcasting

Future Work

- Improve the encoder for delivering UHD live video at higher quality with lower bitrates
- Performance optimizations for next-generation CPU architectures to compress with VVC 8Kp60 10-bit HDR video in real-time
- Evaluate the encoders with the perceptual encoding modes enabled



Thanks for your attention!

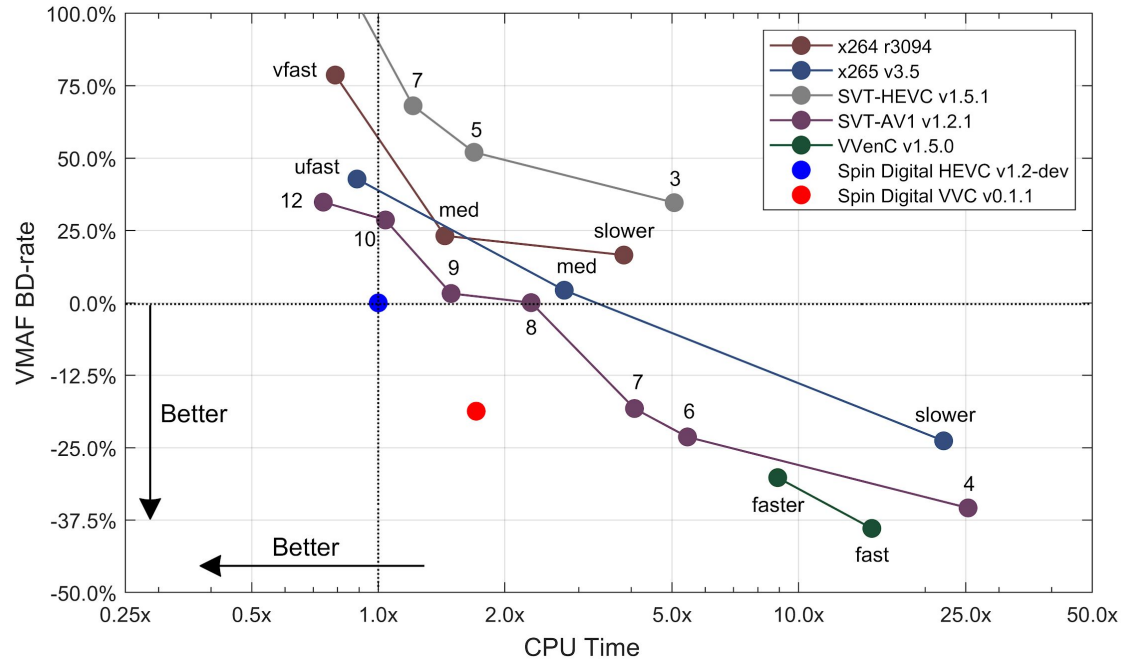
Time for questions

HIGH PERFORMANCE VIDEO CODECS

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Backup Slides

BD-rate VMAF and CPU Time



BD-rate and CPU Time

| Encoder - preset | PSNR BD-rate [%] | XPSNR BD-rate [%] | MS-SSIM BD-rate [%] | VMAF BD-rate [%] | CPU Time [times] |
|-----------------------|---------------------|----------------------|------------------------|---------------------|---------------------|
| x264 r3094 - slower | 30.42 | 51.44 | 47.34 | 16.52 | 3.84 |
| x264 r3094 - medium | 43.94 | 67.96 | 62.01 | 23.18 | 1.44 |
| x264 r3094 - veryfast | 97.48 | 153.88 | 113.13 | 78.69 | 0.79 |
| x265 v3.5 - slower | -14.64 | -11.66 | -6.94 | -23.82 | 22.14 |
| x265 v3.5 - medium | 2.59 | 6.10 | 10.66 | 4.38 | 2.77 |
| x265 v3.5 - ultrafast | 49.20 | 55.23 | 52.38 | 42.78 | 0.89 |
| SVT-HEVC v1.5.1 - 3 | 13.74 | 15.19 | 14.89 | 34.61 | 5.06 |
| SVT-HEVC v1.5.1 - 5 | 29.51 | 30.84 | 30.19 | 52.01 | 1.69 |
| SVT-HEVC v1.5.1 - 7 | 40.07 | 40.08 | 37.88 | 68.07 | 1.21 |
| SVT-HEVC v1.5.1 - 9 | 63.37 | 64.38 | 57.37 | 102.36 | 0.90 |
| SVT-HEVC v1.5.1 - 11 | 96.74 | 99.79 | 85.98 | 133.49 | 0.69 |

BD-rate and CPU Time

| Encoder - preset | PSNR BD-rate [%] | XPSNR BD-rate [%] | MS-SSIM BD-rate [%] | VMAF BD-rate [%] | CPU Time [times] |
|----------------------------|---------------------|----------------------|------------------------|---------------------|---------------------|
| SVT-AV1 v1.2.1 - 4 | -35.54 | -37.43 | -34.08 | -35.40 | 25.31 |
| SVT-AV1 v1.2.1 - 6 | -22.31 | -23.87 | -21.30 | -23.15 | 5.44 |
| SVT-AV1 v1.2.1 - 7 | -17.50 | -19.40 | -16.65 | -18.24 | 4.07 |
| SVT-AV1 v1.2.1 - 8 | -2.81 | -2.37 | -3.70 | 0.08 | 2.31 |
| SVT-AV1 v1.2.1 - 9 | 5.26 | 5.39 | 4.38 | 3.25 | 1.49 |
| SVT-AV1 v1.2.1 - 10 | 20.52 | 20.92 | 13.56 | 28.62 | 1.04 |
| SVT-AV1 v1.2.1 - 12 | 46.58 | 49.33 | 35.48 | 34.79 | 0.74 |
| VVenC v1.5.0 - fast | -41.74 | -44.66 | -41.76 | -38.94 | 14.94 |
| VVenC v1.5.0 - faster | -35.12 | -37.60 | -35.01 | -30.17 | 8.92 |
| Spin Digital HEVC v1.2-dev | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 |
| Spin Digital VVC v0.1.1 | -17.82 | -19.66 | -17.34 | -18.70 | 1.71 |

Multithreaded Encoding Speed

| Encoder - preset | Bitrate [Mbps] | Encoding speed [fps] | Encoding time [spf] | CPU utilization [CPU cores] |
|-----------------------|-------------------|-------------------------|------------------------|--------------------------------|
| x264 r3094 - slower | 17.80 | 21.00 | 0.048 | 24.51 |
| x264 r3094 - medium | 19.60 | 53.33 | 0.019 | 26.01 |
| x264 r3094 - veryfast | 28.80 | 80.97 | 0.012 | 26.52 |
| x265 v3.5 - slower | 12.24 | 2.74 | 0.365 | 23.14 |
| x265 v3.5 - medium | 17.01 | 19.41 | 0.052 | 22.78 |
| x265 v3.5 - ultrafast | 19.01 | 63.18 | 0.016 | 28.23 |
| SVT-HEVC v1.5.1 - 3 | 17.37 | 27.46 | 0.036 | 144.44 |
| SVT-HEVC v1.5.1 - 5 | 18.98 | 79.10 | 0.013 | 125.29 |
| SVT-HEVC v1.5.1 - 7 | 20.79 | 111.43 | 0.009 | 64.17 |
| SVT-HEVC v1.5.1 - 9 | 29.38 | 128.26 | 0.008 | 42.77 |
| SVT-HEVC v1.5.1 - 11 | 34.96 | 138.57 | 0.007 | 29.94 |

Multithreaded Encoding Speed

| Encoder - preset | Bitrate [Mbps] | Encoding speed [fps] | Encoding time [spf] | CPU utilization [CPU cores] |
|----------------------------|-------------------|-------------------------|------------------------|--------------------------------|
| SVT-AV1 v1.2.1 - 4 | 9.79 | 2.94 | 0.340 | 28.58 |
| SVT-AV1 v1.2.1 - 6 | 10.65 | 15.45 | 0.065 | 34.05 |
| SVT-AV1 v1.2.1 - 7 | 11.02 | 20.19 | 0.050 | 31.86 |
| SVT-AV1 v1.2.1 - 8 | 13.32 | 33.90 | 0.029 | 29.74 |
| SVT-AV1 v1.2.1 - 9 | 13.91 | 54.06 | 0.018 | 31.37 |
| SVT-AV1 v1.2.1 - 10 | 17.98 | 75.73 | 0.013 | 28.49 |
| SVT-AV1 v1.2.1 - 12 | 18.53 | 112.22 | 0.009 | 30.81 |
| VVenC v1.5.0 - fast | 9.02 | 2.78 | 0.360 | 18.26 |
| VVenC v1.5.0 - faster | 10.22 | 4.10 | 0.244 | 17.24 |
| Spin Digital HEVC v1.2-dev | 16.00 | 167.02 | 0.006 | 68.03 |
| Spin Digital VVC v0.1.1 | 12.97 | 95.86 | 0.010 | 76.23 |

Recommended Bitrate for 4K Live Video

- Use case: UHDTV (4Kp60 4:2:0 10-bit) live broadcast and streaming
- Real-time encoders: Spin Digital's HEVC and VVC
- VMAF-based criterion

| Percentage of videos | VMAF score | Equivalent MOS | Quality description |
|----------------------|------------|----------------|----------------------|
| ≥75% | ≥90 | ≥4.5 | "good" - "excellent" |
| 100% | ≥70 | ≥3.5 | "fair" - "good" |

- 20 1-min 4Kp60 sequences

Recommended Bitrate for 4K Live Video

