



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

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# CONTENT

1. Objectives
2. Overview of the VVC Real-time Encoder
3. Encoder Assessment of 4K-UHD Live Applications
  - Video Sequences
  - Video Encoders and Presets
  - Encoding Settings
  - Comparison Metrics
  - BD-rate and CPU Time
  - Selected Quality-bitrate Plots
  - Multithreaded Encoding Speed
4. UHD VVC Live Encoding and Streaming at IBC 2022
5. Conclusions
6. Future Work

# 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
<b>BasketballGame</b>	Netflix	Footage	4Kp59.94 HDR	112.6 (med)	152.2 (med)
<b>BerlinSeqs</b>	Fraunh. HHI	Footage	4Kp60 HDR	172.2 (med)	63.6 (low)
<b>DrivingPOV</b>	Netflix	Footage	4Kp59.94 HDR	150.0 (med)	147.4 (med)
<b>FollowCar</b>	PSNC	Footage	4Kp59.94 SDR	201.9 (high)	111.8 (med)
<b>MC2</b>	PSNC	Footage	4Kp59.94 SDR	280.5 (high)	82.5 (low)
<b>Meridian</b>	Netflix	Footage & CGI	4Kp59.94 HDR	89.8 (low)	23.6 (low)
<b>RollerCoaster</b>	Netflix	Footage	4Kp59.94 HDR	92.3 (low)	84.9 (low)
<b>SolLevante</b>	Netflix	Animation	4Kp24 HDR	237.5 (high)	269.4 (high)
<b>Superposition</b>	Unigine	CGI	4Kp60 SDR	226.5 (high)	82.9 (low)
<b>ToddlerFountain</b>	Netflix	Footage	4Kp59.94 HDR	170.2 (med)	79.3 (low)
<b>TunnelFlag</b>	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
<b>Standard</b>	AVC	HEVC	HEVC	HEVC	AV1	VVC	VVC
<b>Company</b>	VideoLAN	MulticoreWare	Intel	Spin Digital	Intel & Netflix	Fraunhofer HHI	Spin Digital
<b>Version</b>	r3094	3.5	1.5.1	1.2-dev	1.2.1	1.5.1	0.2
<b>Release date</b>	Apr. 2021	Apr. 2022	June 2021	Sep. 2022	Aug. 2022	July. 2022	Sep. 2022
<b>Presets</b>	slower, medium, veryfast	slower, medium, ultrafast	3, 5, 7, 9, 11	default	4, 6, 7,, 8 9, 10, 12	fast, faster	default



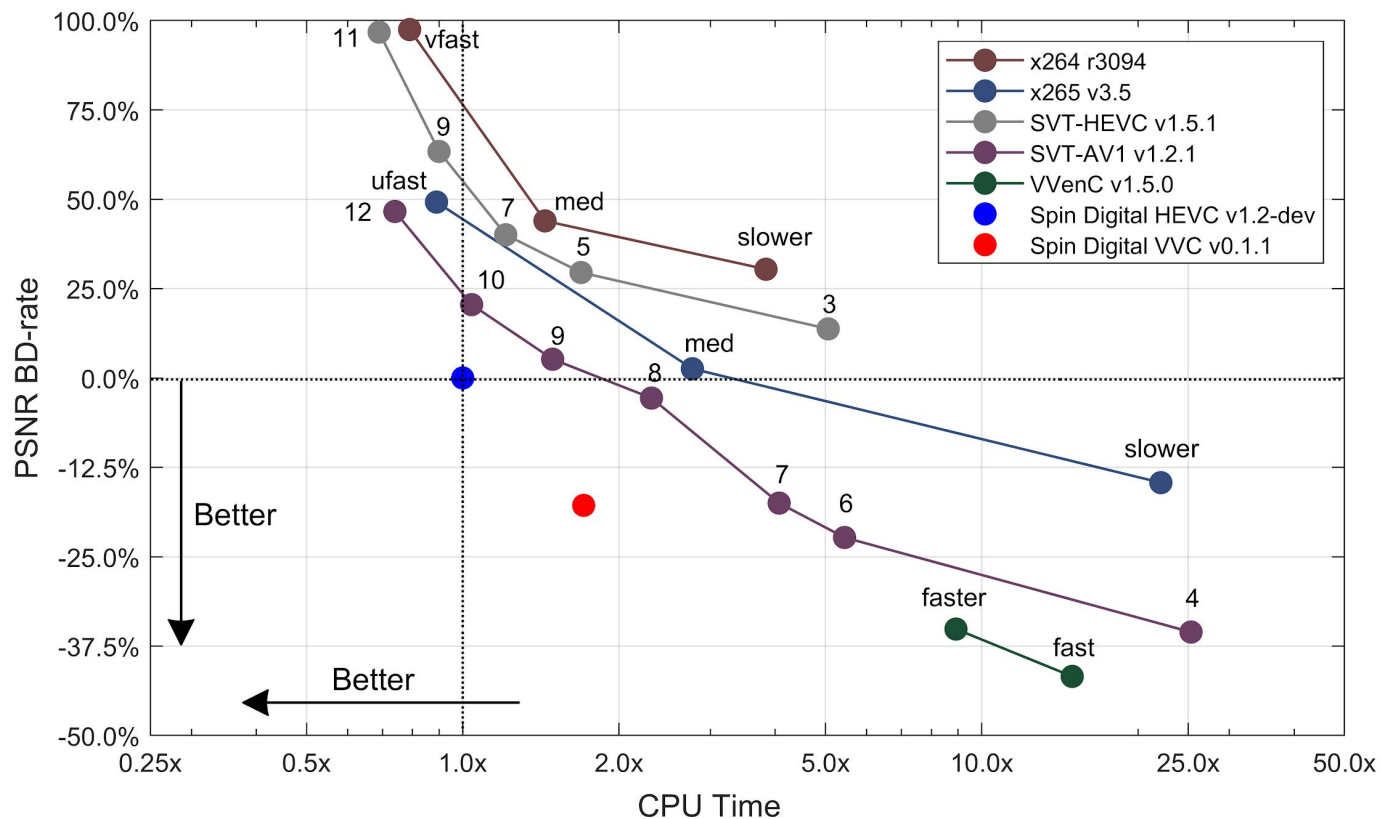
# Comparison Metrics - 1

- 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

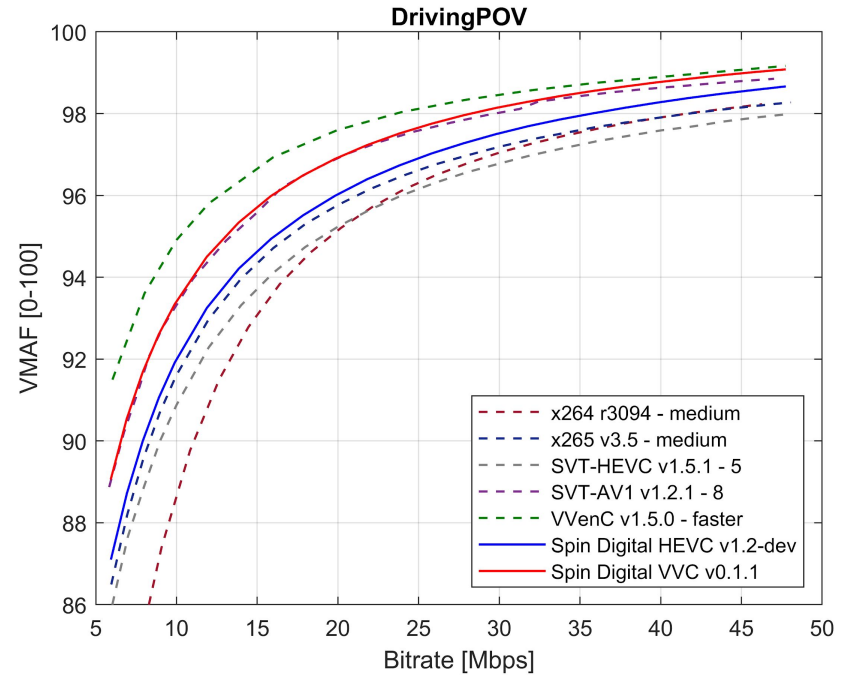
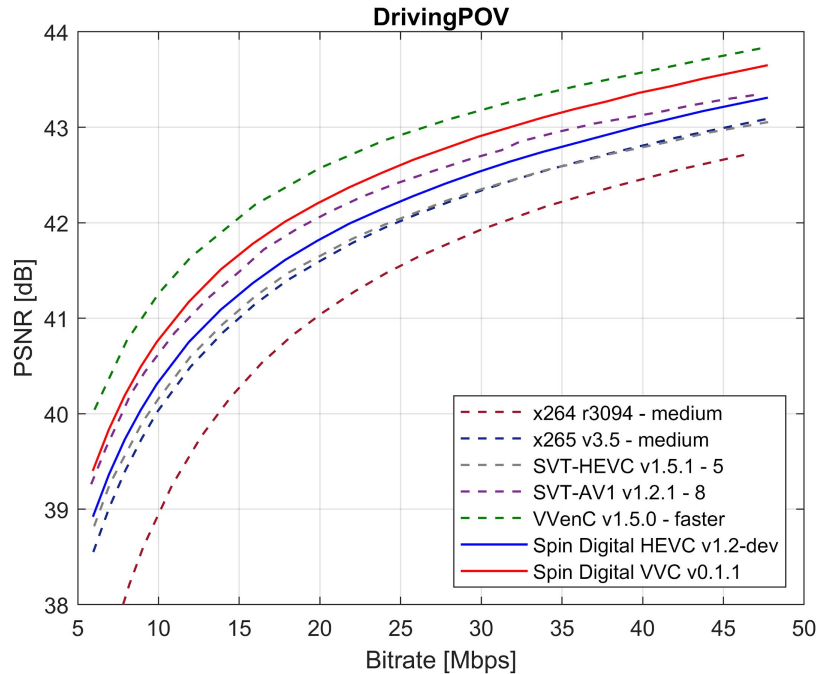
# BD-rate and CPU Time



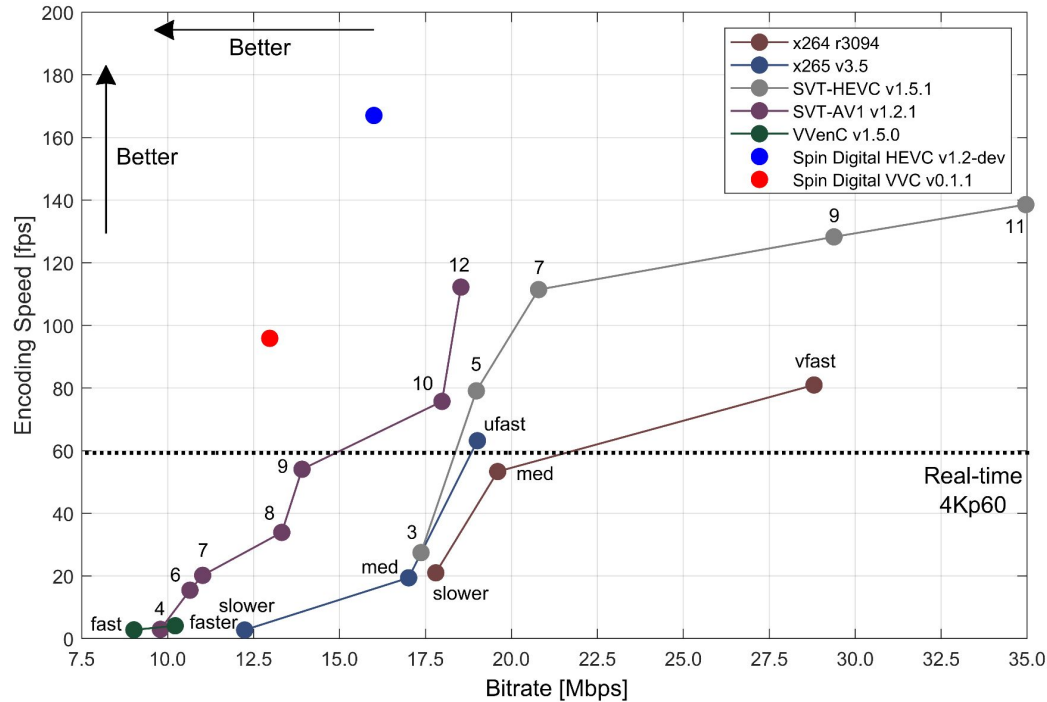
# BD-rate and CPU Time

- 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



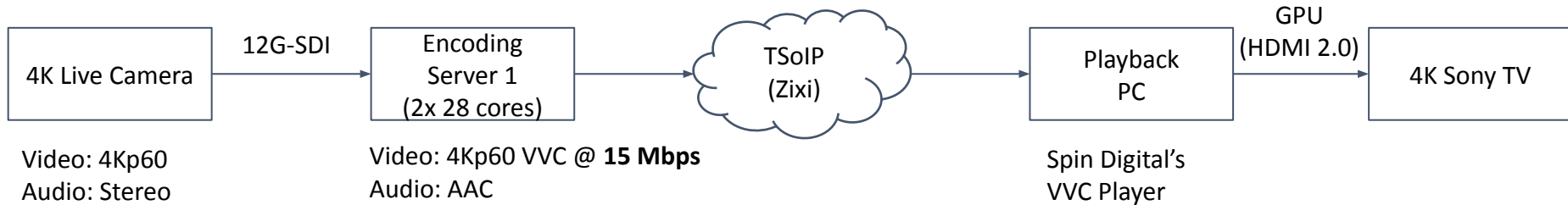
Video: DrivingPOV (Netflix) - Config: Bitrate that produces the same quality (VMAF 95)

# 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

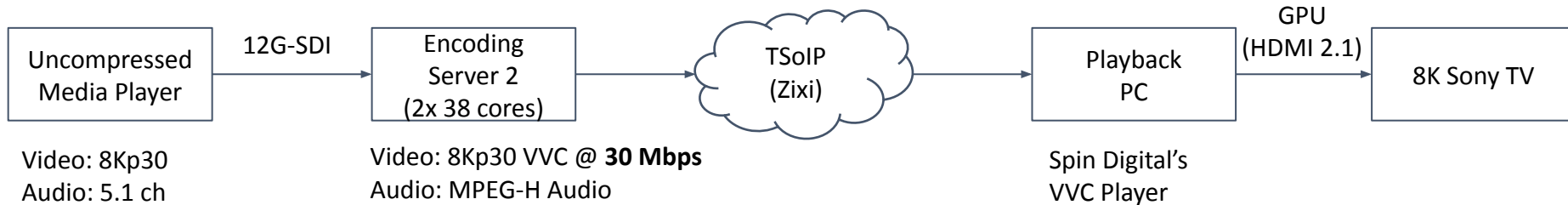
## 4Kp60 VVC Live





# 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!

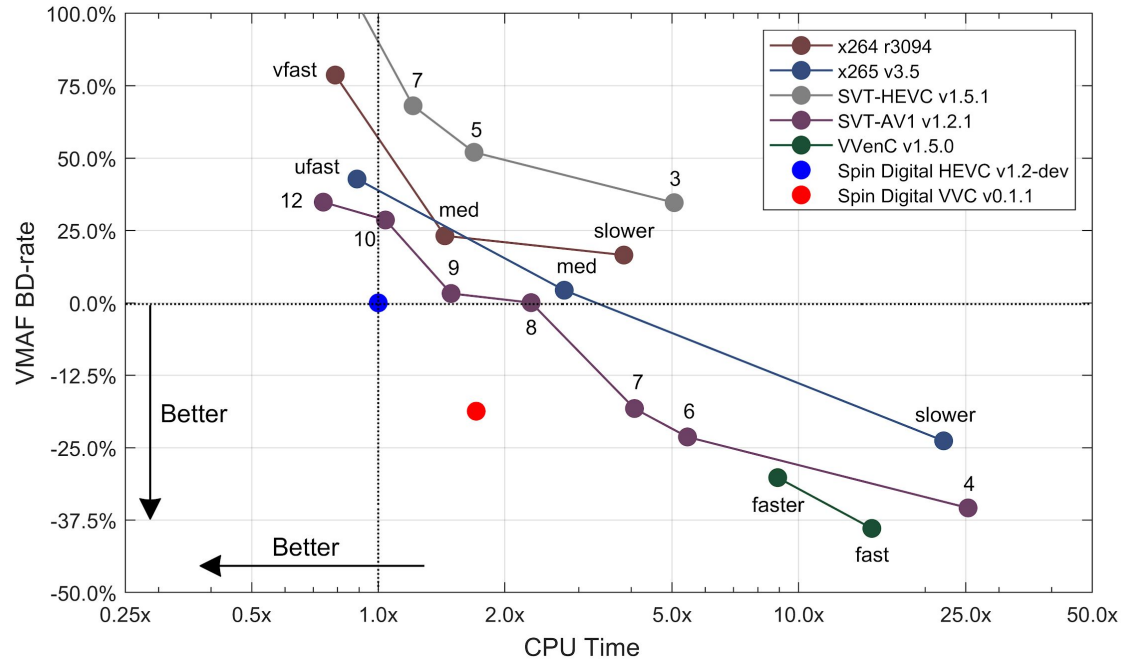
## Time for questions

HIGH PERFORMANCE VIDEO CODECS

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# Backup Slides

# BD-rate VMAF and CPU Time



# BD-rate and CPU Time

Encoder - preset	PSNR	XPSNR	MS-SSIM	VMAF	CPU Time [times]
	BD-rate [%]	BD-rate [%]	BD-rate [%]	BD-rate [%]	
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

