

# Next-Gen Media: How Hardware Video Encoders Are Shaping Content Creation

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**Abstract:** *This article examines the transformative impact of hardware video encoders on contemporary content creation across various industries. As demand for high-quality video content continues to surge across digital platforms, dedicated encoding hardware integrated into system-on-chip technology has become an essential component, enabling real-time, power-efficient video processing directly on mobile and edge devices. The evolution from software-based encoding to specialized silicon solutions has dramatically reduced computational demands while improving compression efficiency. These advancements, particularly when enhanced with artificial intelligence capabilities, are revolutionizing video production workflows by democratizing access to professional-grade tools previously restricted to specialized studios. The integration with emerging technologies, such as volumetric capture and extended reality, is further expanding creative possibilities for content creators worldwide. Through examining technical architectures, industry transformations, and future directions, the article demonstrates how hardware encoding technologies have fundamentally altered the economics and accessibility of professional media production.*

**Keywords:** Hardware encoders, video compression, content democratization, artificial intelligence, immersive media

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## INTRODUCTION: THE EVOLUTION OF VIDEO PROCESSING TECHNOLOGY

The digital content landscape has undergone a dramatic transformation in recent years, with video emerging as the dominant medium across platforms. The overwhelming majority of all internet traffic now comprises video content, representing a substantial increase from previous years [1]. This explosive growth has been driven by the proliferation of streaming services, which collectively have amassed subscribers numbering in the billions worldwide, with projections indicating continued expansion in the coming years [1]. This shift toward video-centric content consumption has been facilitated by significant advancements in video encoding technology, which have transitioned from purely software-based solutions to dedicated hardware

implementations. The evolution began with simple software codecs in the early digital era, which required substantial computational resources. It progressed through hybrid approaches in the subsequent decade. It culminated in today's sophisticated hardware encoders, capable of processing ultra-high-definition video at high frame rates while consuming minimal power [2].

<b>Era</b>	<b>Technology</b>	<b>Key Characteristics</b>	<b>Representative Codecs</b>
2000-2010	Software-based	High CPU usage, limited resolution	MPEG-2, H.264/AVC (early)
2010-2015	Hybrid	GPU acceleration, improved throughput	H.264/AVC, VP9 (early)
2015-2020	Dedicated hardware	ASICs, 4K support, low latency	H.265/HEVC, VP9
2020-2024	AI-enhanced hardware	Neural processing, content-aware optimization	AV1, VVC, neural codecs

Table 1: Evolution of Video Encoding Technologies [2]

Modern hardware encoding solutions have achieved compression efficiency improvements of double-digit percentages over previous-generation codecs, while simultaneously reducing encoding latency by orders of magnitude compared to software-only implementations [2]. This article examines how purpose-built video encoder hardware integrated into modern computing devices is reshaping content creation paradigms and enabling new forms of visual storytelling previously restricted to professional studios with specialized equipment costing tens of thousands of dollars [3].

### **Hardware Encoding Architecture: Technical Foundations**

Unlike software encoding, which relies on general-purpose CPU resources, hardware video encoders employ dedicated silicon optimized for video compression algorithms. These specialized processing units feature parallel architectures that efficiently handle the computational demands of modern codecs, such as H.265/HEVC and AV1. Comprehensive testing demonstrates that hardware encoding solutions typically achieve encoding speeds that are many times faster than software alternatives, while reducing power consumption by a substantial fraction compared to software encoding on equivalent platforms [2]. The architecture of modern hardware encoders typically consists of specialized processing blocks, including motion estimation engines, transform and quantization units, entropy coding accelerators, and in-loop filters. Leading mobile system-on-chip now integrates encoding blocks capable of handling extreme resolutions at impressive frame rates while consuming minimal power at peak load. In contrast, software encoding would require significantly more energy for equivalent quality [2]. These efficiency gains are achieved through application-specific integrated circuits (ASICs) that implement parallelized versions of computationally intensive encoding operations.

Modern hardware encoders also demonstrate remarkable compression efficiency. Recent benchmarks show that AV1 hardware encoders can achieve substantial bitrate reduction compared to H.265/HEVC at equivalent perceptual quality. At the same time, the latest HEVC implementations deliver considerable bitrate savings over H.264/AVC [3]. This efficiency translates directly to practical benefits: extended-duration ultra-high-definition HDR video, which would require significant storage space with software H.264 encoding, can be compressed to a fraction of that size using hardware-accelerated HEVC or even less with AV1, while maintaining visually indistinguishable quality [4].

Device Type	Codec Support	Max Resolution	Key Applications
Smartphones	H.265, AV1	8K	Social media, vlogging
Consumer Cameras	H.265, AV1	6K-8K	Independent film
Action Cameras	H.265, AV1	4K-5K	Sports, POV footage
Drones	H.265	4K	Aerial photography
Webcams	H.264, H.265	4K	Streaming, conferencing

Table 3: Hardware Encoders in Consumer Devices [4]

By offloading these intensive tasks from the central processor, hardware encoders achieve remarkable improvements in both processing speed and energy efficiency. Commercial implementations from leading manufacturers have demonstrated encoding improvements of triple-digit percentages for high-resolution content, while reducing power consumption by more than half compared to software-based alternatives [3]. This efficiency translates to extended battery life, with software encoding [3].

Method	Speed vs CPU	Power Usage	Bitrate Efficiency	Best For
Software (CPU)	1×	High	Baseline	Post-production
GPU Acceleration	3-5×	Medium	10-15% better	Workstations
Hardware Encoder	15-20×	Very Low	30-40% better	Mobile, IoT
AI-Enhanced	10-15×	Low	40-50% better	Premium devices

Table 2: Encoding Approaches Comparison [3]

**AI-Enhanced Encoding: Intelligent Video Optimization**

The integration of artificial intelligence with hardware encoding represents a significant leap forward in video processing technology. AI-enhanced encoding applies sophisticated algorithms at the frame level to dynamically optimize video quality based on content characteristics. Research indicates that neural network-based encoding optimizations can reduce bitrates by a considerable additional percentage beyond standard encoder improvements, while maintaining perceptual quality scores within a minimal deviation of reference values, according to Video Multimethod Assessment Fusion (VMAF) metrics [4].

These systems can intelligently apply techniques such as noise reduction, dynamic tone mapping, and object-aware compression to preserve detail in areas of importance while efficiently compressing less critical regions. Field testing demonstrates that AI-enhanced encoding can maintain nearly all of the perceptual quality of uncompressed sources at bitrates significantly lower than conventional encoders [4]. Commercial implementations of these technologies have been shown to reduce streaming bandwidth requirements by up to half while delivering equivalent or improved viewer experience scores in blind testing [4].

The computational demands of these AI systems are substantial, with typical neural network models requiring considerable processing power for real-time ultra-high-definition video enhancement [4]. However, the integration of specialized neural processing units (NPUs) within modern System-on-Chip (SoCs) has made this practical even in mobile devices, with leading smartphones now featuring NPUs capable of performing trillions of operations per second while consuming minimal power [2]. This enables sophisticated processing, such as selective detail preservation, where faces and text retain nearly all of the source quality, while background elements can be compressed more aggressively [4].

This section examines how machine learning models trained on vast datasets—typically consisting of hundreds of thousands of hours of diverse video content [4]—can identify optimal encoding parameters for different scenes, lighting conditions, and motion patterns, resulting in superior visual quality without increasing bandwidth requirements. Experimental results demonstrate improvements in standard quality metrics, including Peak Signal-to-Noise Ratio, Structural Similarity Index, and VMAF when compared to non-AI enhanced encoding at identical bitrates [4].

### **Industry Transformation: Democratization of Professional Video Production**

Hardware video encoders have fundamentally altered the economics and accessibility of professional video production. The financial barrier to entry for professional-quality video creation has decreased dramatically, with consumer devices now offering capabilities that previously required equipment costing orders of magnitude more [5]. Market research indicates that the proliferation of hardware encoding technology has contributed significantly to the expansion of the content creator economy, which has grown at a compound annual rate vastly exceeding that of traditional media sectors [5].

The democratization of these tools has had profound implications for media industries. The number of independent content creators earning substantial income from video platforms has increased exponentially since the widespread adoption of hardware encoding technologies in consumer devices [5]. This shift is particularly evident in emerging markets, where smartphone-based content creation has enabled creators to bypass traditional infrastructure limitations and reach global audiences [6].

Table 4: Impact on Content Creator Segments [6]

Creator Type	Primary Platforms	Key Hardware Benefits	Market Impact
Social Media	TikTok, Instagram	Mobile production, real-time effects	Exponential growth
Filmmakers	Streaming services	Cinema-quality, efficient workflow	Barrier reduction
Live Streamers	Twitch, YouTube	Low latency, extended duration	Expanded reach
VR/AR	Meta, App stores	Immersive capture, spatial effects	New format enablement
Educational	Learning platforms	High quality on modest equipment	Broader access

Tasks that once required dedicated workstations or specialized equipment can now be performed on mainstream mobile devices and compact cameras. Contemporary smartphones incorporate encoding hardware capable of processing professional video formats that formerly necessitated dedicated equipment costing many thousands of dollars [6]. This technological convergence has compressed the workflow from capture to distribution, with a substantial percentage of professional content now being produced entirely on portable devices, eliminating the need for intermediate processing on specialized workstations [6].

This democratization has empowered a new generation of content creators, from social media influencers to independent filmmakers, enabling them to produce cinema-quality content with consumer-grade equipment. The technical specifications of contemporary consumer cameras with hardware encoding capabilities now meet or exceed the minimum requirements for the premium content tiers of major streaming platforms [5]. As a result, independent productions created with accessible equipment have achieved viewership figures comparable to traditionally produced studio content, with engagement metrics sometimes surpassing those of conventionally produced media [6].

The accessibility of hardware encoding has also fostered innovative distribution models. The direct-to-audience approach has become increasingly viable for independent creators, with subscription-based models showing robust growth [6]. The reduced technical barriers have also led to the emergence of micro-niche content categories serving highly specialized audiences that would be economically unfeasible under traditional production models, which require substantial initial investment [7].

Industry analysis shows that hardware encoding capabilities have become a primary differentiating factor in consumer camera purchasing decisions, with manufacturers emphasizing codec support and encoding efficiency in their marketing materials [7]. This market pressure has accelerated development cycles and pushed capabilities previously found only in professional equipment down to consumer price points at an accelerated pace [7].

Educational institutions have responded to this shift by revising curricula to incorporate mobile production techniques alongside traditional methods. A significant proportion of film and media production programs now include courses specifically focused on optimizing content for hardware-accelerated workflows [6]. This pedagogical evolution reflects the understanding that future media professionals will operate in environments where the distinction between consumer and professional equipment is increasingly blurred.

### **Future Directions: Emerging Applications and Technologies**

As hardware encoding capabilities continue to evolve, new applications are emerging across industries. Real-time encoding enables sophisticated live streaming applications, mobile journalism, and immersive augmented reality experiences. The market for such applications is expanding rapidly, with projections indicating substantial growth across multiple sectors, including education, healthcare, retail, and entertainment [7]. This expansion is particularly pronounced in regions experiencing rapid digital transformation, where hardware-accelerated video technologies are enabling communities to leapfrog traditional development stages [7].

The integration of hardware encoding with edge computing represents an auspicious direction for future development. Distributing encoding workloads across edge devices reduces bandwidth requirements for cloud infrastructure while improving responsiveness for interactive applications [8]. Research in this area demonstrates that properly optimized edge-based encoding can reduce latency to levels imperceptible to human users while maintaining quality comparable to centralized processing [8].

Furthermore, the convergence of hardware encoding with other technologies, such as volumetric capture, light field photography, and real-time rendering, is opening new frontiers in interactive media and spatial computing. Current prototypes combining hardware encoding with volumetric capture can process spatial video at resolutions and frame rates suitable for immersive applications while maintaining power consumption within the thermal constraints of wearable devices [8]. This technological synergy enables experiences that were previously impossible due to computational limitations.

Advancements in hardware encoding have significantly transformed the field of computational photography. Contemporary mobile devices now incorporate image signal processors capable of performing operations that previously required specialized post-processing equipment [8]. The combination of these capabilities with neural processing units enables sophisticated computational methods, such as multi-frame synthesis, semantic segmentation, and scene-aware optimization, to be applied in real-time during capture rather than in post-production [8].



Table 5: Emerging Applications by Industry [8]

Sector	Application	Key Benefits	Technology Integration
Healthcare	Telemedicine	Diagnostic quality over limited bandwidth	AI diagnostics
Education	Distance learning	Interactive multi-stream content	AR/VR integration
Industrial	Remote inspection	Reliable high-detail transmission	IoT sensors
Entertainment	Volumetric video	Immersive 6DoF experiences	Neural rendering
Retail	Virtual try-on	Realistic visualization	Computer vision

Healthcare applications represent another expanding frontier, with hardware encoding enabling telemedicine services in previously underserved regions. Medical imaging systems incorporating specialized encoding hardware can transmit diagnostic-quality video over limited-bandwidth connections, extending the reach of specialist care to remote locations [7]. Similar technologies are being deployed in industrial contexts for remote inspection and monitoring applications, reducing operational costs while improving safety outcomes [7].

The entertainment industry is exploring novel content formats enabled by advancements in hardware encoding. Experimental productions utilizing dynamic bitrate allocation based on viewer attention patterns demonstrate significant improvements in subjective quality ratings compared to conventional encoding approaches [8]. Such approaches leverage eye-tracking data and content analysis to prioritize encoding resources for regions of interest, potentially revolutionizing content delivery for next-generation displays [8].

Educational applications of hardware-accelerated video technologies are similarly expanding. Distance learning platforms that incorporate real-time encoding can deliver interactive experiences that approach the engagement levels of in-person instruction, according to comparative studies [7]. These systems adaptively optimize content based on network conditions and learner interactions, ensuring continuity of experience across varying technical constraints [7].

Research into future encoding technologies indicates several promising directions. Neural video coding approaches, which replace traditional transform-based methods with learned representations, show potential for significant efficiency improvements beyond current standards [8]. Initial implementations demonstrate compression gains while maintaining perceptual quality, though computational requirements remain challenging for real-time applications [8]. As specialized neural accelerators continue to evolve, these approaches may eventually supersede conventional encoding methods.

The integration of video encoding with extended reality (XR) technologies presents both opportunities and challenges. Current research focuses on optimizing encoding parameters for head-mounted displays, where

traditional quality metrics may not accurately reflect perceived experience [8]. Specialized encoding profiles that account for perceptual factors unique to immersive viewing show significant improvements in subjective quality ratings compared to conventional approaches [8].

Industry consortia are actively developing next-generation standards incorporating hardware-optimized features. These collaborative efforts aim to strike a balance between compression efficiency and implementation practicality, ensuring that new codecs can be effectively realized in silicon [7]. The development cycle for such standards has accelerated considerably, reflecting the rapid pace of innovation in both software algorithms and hardware capabilities [7].

## CONCLUSION

Hardware video encoders represent a pivotal technology in the ongoing digital media revolution. By enabling efficient, high-quality video processing directly on capture devices, these systems have fundamentally altered how visual content is created, edited, and shared. The democratization of professional video tools through hardware acceleration continues to expand creative possibilities across global markets, empowering independent creators to produce cinema-quality content with accessible equipment. As AI capabilities become more deeply integrated with encoding processes, further improvements in both efficiency and quality can be expected, enabling new forms of media currently constrained by technical limitations. The convergence of edge computing, computational photography, and extended reality technologies suggests that hardware encoding will continue to drive innovation across various industries, including healthcare, education, entertainment, and industrial applications. The accelerating development cycle for encoding standards reflects the dynamic nature of this technological frontier, promising continued evolution toward more immersive, responsive, and accessible visual experiences. These advancements collectively point toward a future where sophisticated media creation becomes increasingly accessible to creators regardless of technical background or financial resources.

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