

Show Me the Next-Generation HDMI

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Author Introduction

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With an install base of over 1.1 billion devices worldwide, HDMI has become the de facto multimedia interface for all digital home and mobile/portable multimedia devices. The recently introduced HDMI 1.4 specification further reinforces the HDMI message of performance, reliability and simplicity. Features like the HDMI Ethernet and Audio Return Channel (HEAC), introduced in version 1.4, further simplify digital home theater wiring while adding new and innovative features. In addition, the HDMI 1.4 specification supports advanced media capabilities such as enhanced color spaces for digital still cameras, 3D modes and ultra-high resolution display formats (up to 4x higher than 1080p) that will be key features in the next-generation of premium multimedia entertainment consumer electronic products.

The first part of this white paper explores the basic concepts behind HDMI, the markets it serves and its leadership role in multimedia interfaces. This is followed by a tutorial on the new capabilities of HDMI 1.4 and their role in providing a richer, more straightforward user experience. Next, we'll explore a series of user case scenarios that illustrate how the HEAC feature can simplify cabling requirements between digital home multimedia devices. The last portion of this paper discusses the architectural considerations and technical details involved with incorporating the Ethernet and Sony/Philips Digital Interconnect Format (S/PDIF) standards into the HDMI system-on-chips (SoCs) to support the HEAC feature.

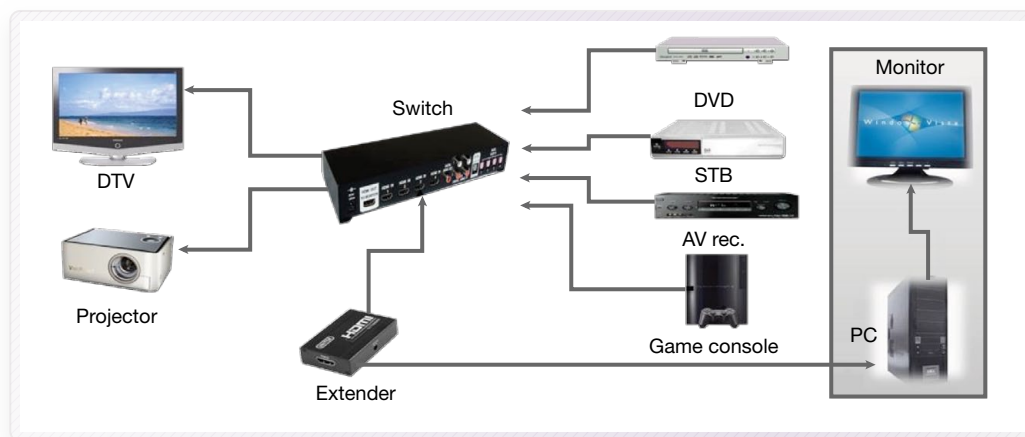


Figure 1: HDMI connectivity in a digital home theater

HDMI Overview

HDMI's global acceptance as the connectivity technology of choice for consumer electronics and PC multimedia products is largely due to its ability to deliver the highest quality audio/video signal over a single cable. Developed as a backwards-compatible enhancement of the Digital Visual Interface (DVI) standard, the HDMI electrical interface transports its data using three Transition Minimized Differential Signaling (TMDS) serial data channels which are logically interleaved to form a single serial data stream.

Early versions of HDMI (version 1.2 and below) clocked their serial links at 165 MHz, giving the connection a total capacity of 4.95 Gbps. When the HDMI 1.3 specification was introduced in 2006, its optional 340 MHz system clock rate doubled the link's maximum capacity to 10.2 Gbps. To put some perspective on this enormous bandwidth, it only takes 2.23 Gbps to support a 1080i, 8 bits/color HDTV display running at a 60 Hz frame refresh rate.

| Application | Resolution | Color Depth | Frame Rate | Bandwidth |
|-------------|------------|-------------|------------|-----------|
| 480p TV | 480p | 8-Bit | 60 Hz | 0.81 Gbps |
| HD STB | 720p | 8-Bit | 60 Hz | 2.23 Gbps |
| HD STB | 1080i | 8-Bit | 60 Hz | 2.23 Gbps |
| PS3/Blu-ray | 1080p | 8-Bit | 60 Hz | 4.46 Gbps |
| PS3/Blu-ray | 1080p | 12-Bit | 60 Hz | 6.68 Gbps |
| WQXGA | 2560x1600p | 8-Bit | 60 Hz | 8.06 Gbps |
| 4K x 2K | 4096 | 8-Bit | 24 Hz | 8.91 Gbps |
| 3D Mode | 1920x1080p | 16-Bit | 24 Hz | 8.91 Gbps |

Figure 2: Bandwidth requirement of commonly used frame formats

The HDMI serial data stream is segmented into packets that allow it to encapsulate nearly any digital media format including standard, enhanced, or high-definition video, multi-channel digital audio and control information on a single cable. Video data is always transmitted in an uncompressed format, complete with horizontal and vertical blanking intervals. The video blanking intervals (Data Island Periods) are used to transmit audio data, which can consist of any compressed, non-compressed, PCM, single or multi-channel formats and control information. The audio formats include the new DTS-HD Master Audio and Dolby TrueHD formats used by Blu-ray media players.

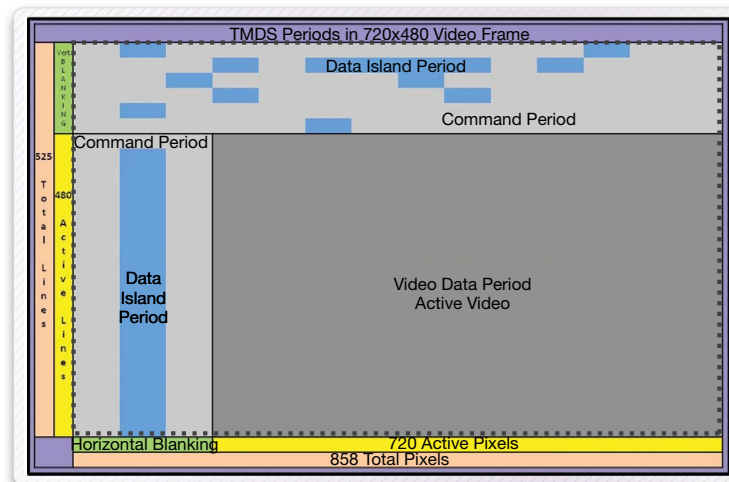


Figure 3: TMDS periods in 720x480p video frame

HDMI Markets

Although it was originally developed as a connection between digital home devices like set-top boxes, Digital TVs (DTV), Blu-ray players, A/V receivers and game consoles, HDMI has also gained acceptance in many other applications that were not anticipated when this versatile interface was first defined. The explosive growth of multimedia capabilities in laptop computers, media players, cell phones and nearly every category of mobile/handheld products has created a nearly insatiable demand for high-speed connectivity. Manufacturers are discovering that the bandwidth required to move high-definition video between their electronic products has outstripped the capacity of most other common interfaces, leaving HDMI as an attractive candidate for the next-generation universal multimedia interconnect.

The HDMI market can be divided into four key segments:

- ▶ **Digital Home:** This established, stable market is HDMI's "home turf", where it enjoys 90-95% penetration in audio/video recorders, DTVs, set-top boxes, game consoles and home entertainment devices.
- ▶ **Portable Multimedia:** This growing market includes cameras (still and video) and portable media players where the number of ports shipped per year is currently at a 33% CAGR. Much of HDMI's success in this market is due to the smaller Type C connectors introduced by the HDMI 1.3 specification. Now, the Type D micro HDMI connector introduced with the 1.4 specification is making it an attractive option for media-enabled mobile phones.
- ▶ **Industrial Applications:** HDMI's high bandwidth and ability to support virtually any audio or video protocol has helped it earn a dominant position in digital signage, as well as high-end video projectors used in business/commercial and even so-called "prosumer" applications.
- ▶ **PC/Laptop Equipment:** HDMI has penetrated into the laptop and graphic cards market, but its adoption in this market is slowed somewhat due to competition from the DisplayPort interface.

Much of HDMI's near-universal acceptance in the home multimedia market has been due to the Consortium's diligent efforts at recruiting support from all the stakeholders – equipment manufacturers, content providers, service providers and semiconductor manufacturers. It remains to be seen whether DisplayPort's advocates will be able to duplicate HDMI's success within the PC market ecosystem. In this transitional period, it is certain that the stakes are high as the distinction between PCs and DTVs becomes increasingly blurry.

HDMI Evolution

From its inception, HDMI was designed to be a very future-proof standard that could keep pace with the rapidly evolving requirements of consumer electronics. It has done an excellent job of anticipating next-generation features in digital home and portable multimedia devices. Typically a new wave of change is led by content providers, service providers and consumer electronics manufacturing giants. But in this case, HDMI has taken a leadership position by blazing a path that allows the rest of the players in the ecosystem to expedite the introduction of new and innovative features such as 3D mode, Ethernet channel and the ultra-high 4K resolution (4K x 2K pixel) mode.

Figure 4 below illustrates how each revision has brought improvements to HDMI's speed, capability and versatility that have helped HDMI reach beyond digital home applications.

While HDMI 1.3 made some giant leaps by doubling the data rate, providing up to 2.8 trillion colors, lossless audio formats, 120 Hz frame rates and 1440p resolution modes, HDMI 1.4 has further added some subtle but highly innovative features that will reinforce consumers' perception that HDMI equates to simplicity, reliability and performance.

| Specification/Version | 1.0 | 1.1 | 1.2 (a) | 1.3 (a-c) | 1.4 |
|-------------------------------------|-------|-------|---------|-----------|-------|
| Maximum signal bandwidth (MHz) | 165 | 165 | 165 | 340 | 340 |
| Maximum TMDS bandwidth (Gbps) | 4.95 | 4.95 | 4.95 | 10.2 | 10.2 |
| Maximum video bandwidth (Gbps) | 3.96 | 3.96 | 3.96 | 8.16 | 8.16 |
| Maximum audio bandwidth (Mbps) | 36.86 | 36.86 | 36.86 | 36.86 | 36.86 |
| Maximum Color Depth (bit/pixel) | 24 | 24 | 24 | 48 | 48 |
| sRGB | Y | Y | Y | Y | Y |
| YCbCr | Y | Y | Y | Y | Y |
| 8-CH LPCM/192 kHz/24-bit Audio | Y | Y | Y | Y | Y |
| Blu-ray Disc A/V at full resolution | Y | Y | Y | Y | Y |
| CEC | Y | Y | Y | Y | Y |
| DVD-Audio | N | Y | Y | Y | Y |
| Super Audio CD (DSD) support | N | N | Y | Y | Y |
| Deep Color | N | N | N | Y | Y |
| xvYCC | N | N | N | Y | Y |
| Auto lip-sync | N | N | N | Y | Y |
| Dolby True HD bit stream | N | N | N | Y | Y |
| DTS-HD Master Audio bit stream | N | N | N | Y | Y |
| Updated list of CEC commands | N | N | N | Y | Y |
| Ethernet Channel | N | N | N | N | Y |
| Audio Return Channel | N | N | N | N | Y |
| 3D Over HDMI | N | N | N | N | Y |
| 4K x 2K Resolution Support | N | N | N | N | Y |

Figure 4: Evolution of HDMI

HDMI 1.4

Introduced in June, 2009, the HDMI 1.4 specification contains many important capabilities that have further revolutionized the home theater system. The remainder of this paper will review the new additions in the HDMI 1.4 specification, use cases and implementation challenges for SoC and system designers.

HDMI Ethernet and Audio Return Channel (HEAC)

According to an In-Stat report, 24% of all consumer devices will require an Ethernet connection.* Furthermore, 100% of game consoles and digital media adapters, 80% of Blu-ray and 72% of Professional Video Recorders (PVR)/Digital Video Recorders (DVR) will have network capabilities. This is the reason why the most important feature introduced in HDMI 1.4 is the HEAC functional block. HEAC is a compound acronym which combines the HEC (HDMI Ethernet Channel) and its companion ARC (Audio Return Channel) function. This block simplifies the connectivity between internet-enabled digital home devices by incorporating a bi-directional 100 Mbps Ethernet connection and a uni-directional audio return channel within the HDMI cable. By eliminating the need for separate Ethernet/audio cables and connectors, the HEAC feature helps tame the tangle of wiring that was previously required to connect a modern home theater system.

HEAC User Cases

The HDMI 1.4 specification added capabilities that give both consumers and seasoned A/V professionals many new ways to get the best out of their multimedia equipment. At the same time, the complex matrix of functions, features and possible configurations raises an even greater number of questions about how different system elements play together. To reduce the confusion a bit, the following typical user scenarios were created. The equipment and configurations used in these examples should help clarify how various HEAC-enabled multimedia devices will interact to produce a superior user experience.

User Case #1 (HEC)

The Home Entertainment System with DTV and Blu-Ray Player

In today's home entertainment systems, more and more devices are internet-enabled but each one must access the internet via its own external Ethernet or WiFi connection. For example, the Netflix receiver inside a Blu-ray player gets its streamed IP video through an Ethernet cable or a WiFi (802.11 wireless data) connection coming from the home router. After decoding the video stream, the player transmits it to a flat-screen display or DTV via an HDMI interface. The DTV also requires its own internet connection to access web-based features like the Yahoo widgets. Without HEAC, both the Blu-ray player and DTV must use separate Ethernet cables or 802.11 connections from the home router to obtain their own web-based content.

* In-stat report, No. IN080088RC, November 2008

Adding HEAC capability to the DTV and Blu-ray player will allow these devices to share a single Ethernet connection. Assuming that the DTV retains its internet connection, the Blu-ray player can now obtain the Netflix IP stream via the TV's internet connection through the HEC feature. In this case, IP data packets containing encoded media to be processed by the Blu-ray player are physically transferred through the additional twisted shielded pair embedded in the HDMI cable. After the player is done with its processing, the resulting audio/video/control information is sent back to the TV for display via the TMDS channels of the same HDMI cable. Using a single cable to carry internet, digital video and audio simplifies the home theater wiring and reduces the overall system cost for the consumer.



Figure 5: HEC User Case #1 (DTV and Blu-ray Player)

User Case #2 (HEC)

The Home Entertainment System with DTV and Game Console

For this example, the Blu-ray player has been replaced by a gaming console equipped with built-in WiFi capability and the HDMI 1.4 interface. Without HDMI's new HEAC capabilities, the DTV would need its own connection to the router for internet access. Moving to HDMI 1.4 allows the gaming console to share its internet connection with the DTV via the HEAC interface.

The HDMI cable's integral Ethernet channel allows IP packets to be passed from the gaming console to the DTV where they are processed and displayed. This integrated internet connection also eliminates the need for the external WiFi USB dongle card that is often used to provide today's DTVs with web access. Eliminating this dongle allows consumer to save costs while simplifying the overall configuration of their home theater network.



Figure 6: HEC User Case #2 (DTV and Game Console)

User Case #3 (ARC)

Home Entertainment System with Terrestrial DTV, AV receiver and Hi-End Speaker System

The audio return channel (ARC) is typically intended for terrestrial DTV applications that receive their audio and video content through either the TV's antenna or a larger external array. In this case, the video stream is displayed on the DTV but users have their choice of listening to the decoded audio content on the TV's small internal speakers or diverting it to a home theater system (via an AV receiver). Since the sound quality of even a modest home theater system is significantly better than most HDTVs' internal speakers, many consumers opt for an external audio solution.

In systems using HDMI 1.3 (or earlier versions) that do not have the HEAC capability, a separate S/PDIF connector and cable are typically used to connect the DTV's audio data to an AV receiver (external high-end sound system). The ARC feature in HDMI 1.4 allows the audio data connection between a terrestrial DTV and AV receiver to be made through the HEAC channel. This eliminates the additional S/PDIF cable between the DTV and speaker system, resulting in a simplified home theater system configuration as well as reducing the overall cost to the consumer. DTV manufacturers will also appreciate the cost savings made possible from the elimination of the S/PDIF connector on the back panel of their products.

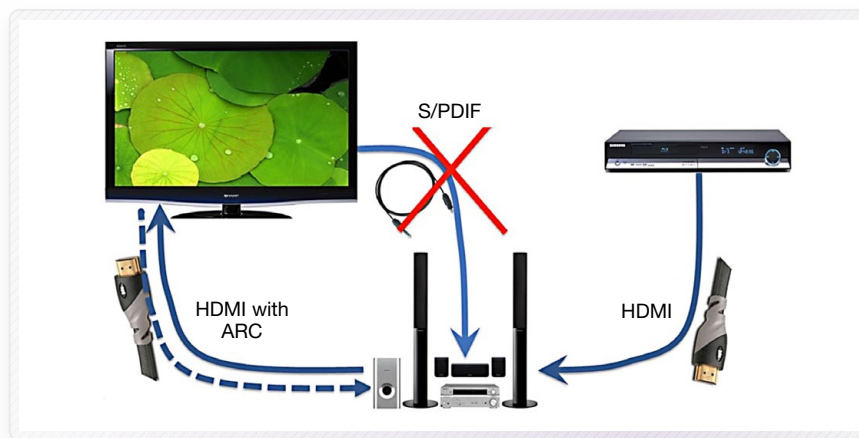


Figure 7: ARC User Case #3 (Terrestrial DTV)

A Closer Look at HEAC from the SoC/System Designer Perspective

Adding HEAC capability to an HDMI-equipped SoC design involves a backwards-compatible upgrade to the HDMI electrical interface and adding a functional block to the HDMI logic that resides within the SoC or system board.

The HEAC electrical interface is implemented within the HDMI connector/cable by using the existing hot plug detect pin and utility pin of the HDMI connector to drive a twisted shielded wire pair added in the HDMI 1.4 HEAC-compliant cables. The twisted pair uses the current Hot Plug Detect (HPD) line and Utility/Reserved line (pin 19 and pin 14 of the HDMI connector respectively) to support the bi-directional data channel. To minimize EMI and crosstalk, the shielding for the embedded wire pair is tied to the HDMI connector's existing DDC/CEC ground pins. This arrangement allows the HEAC block to function like a separate electrical connection/interface while it shares the same HDMI connector and cable as the existing TMDS channels that carry video, audio and control information.

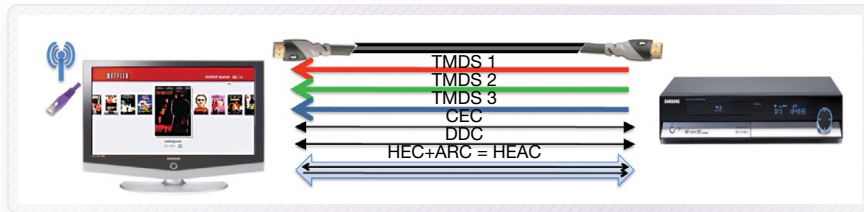


Figure 8: HDMI 1.4 cable can carry HEC+ARC in addition to TMDS, CEC and DDC

The HEAC functional block consists of a high-speed, bi-directional data communication link derived from the Ethernet 100BASE-TX standard and a unidirectional audio data interface based on the S/PDIF standard. Its 2-wire differential interface carries both 100BASE-TX Ethernet data and/or S/PDIF (ARC) data.

Simultaneous transmission of Ethernet and audio data is supported by the HEAC functional block. Ethernet data is transmitted differentially across the embedded twisted pair and the audio information is modulated in the common mode of the differential signal. If the HEAC interface is only required to support the Ethernet channel, it drives the line using differential signaling. If it is running in its ARC-only mode, it uses a single-ended signaling scheme, which is electrically compatible with either a differential or a single-ended interface. If both the Ethernet and ARC features are engaged, the HEAC block's ARC data must be transmitted using a differential interface. Synopsys' DesignWare® HDMI source (transmitter) and sink (receiver) IP cores support both ARC modes.

The HEAC macro cell is implemented as a fully asynchronous macro cell with an analog interface on the line side (going into the HDMI cable) and a digital interface on the system side (interfacing with the 100BASE-TX and IEC60598-1 blocks). Its system-side interface transmits its Ethernet traffic using MLT-3 coding while S/PDIF audio transmissions are separately encoded in a functional block that implements the IEC 60598-1 interface standard.

The HEAC macro cell's system-side digital interface is intended for integration with other elements within an SoC but, if an external connection is required, it can be used in conjunction with an external 100BASE-TX line transceiver and an IEC 60598-1 Line Driver or Receiver (depending on the application) off-the-shelf standard product to implement a complete Ethernet + S/PDIF to HDMI HEAC media converter.

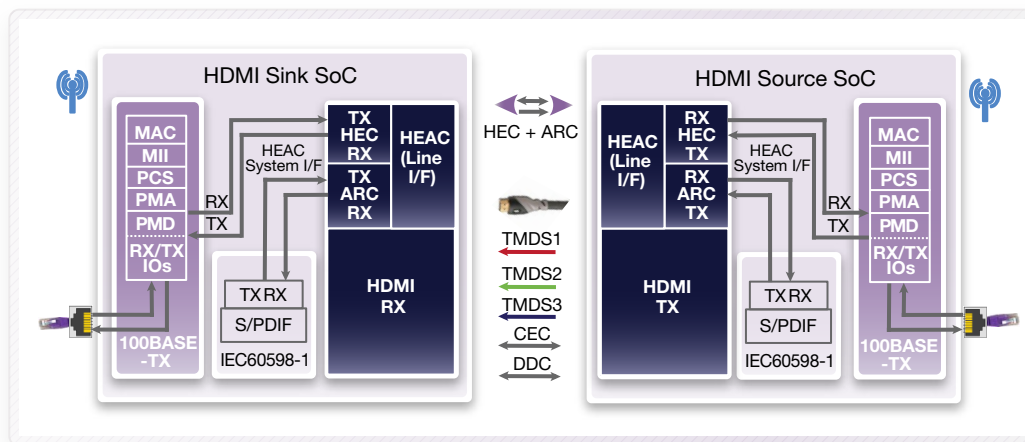


Figure 9: HDMI source/sink SoCs with HEAC/100BASE-TX/IEC60598-1 blocks

On the line-side interface, MLT-3-encoded Ethernet 100BASE-TX data is passed between a differential driver/receiver pair using relatively low-level signals (compared to a standard 100BASE-TX Ethernet signal). In full duplex mode, the receiver subtracts the data sent by its driver on the same side of cable. The receiver does not have the clock and data recovery or baseline correction capabilities found in a standard Ethernet transceiver.

The ARC line-side driver transmits a single IEC 60958-1 audio data stream as a common-mode signal component on the HEAC+/- differential pair. ARC audio stream data is transmitted independently with or without the presence of the MLT-3 signals used for transmitting Ethernet data. The ARC data transmission occurs independently of the single-mode component of the HEAC signal on HEAC+ line in one direction from sink to source. Likewise, the ARC receiver can be used for reception of the common mode or single-ended signal component carried by the HEACP and HEACN lines.

The HEAC macro block's transmission path includes DC wander compensation and line driving capability that allows it to be directly attached to the pulse transformer which usually sits just behind a standard 100BASE-T Ethernet connector. On its receive path, the block contains all the basic functions of an Ethernet line receiver. If direct attachment to a 100BASE-TX-compliant Ethernet interface is required, the SoC integrator would need to make it electrically compatible by adding the lowest sub-layer of the Ethernet PHY functionality (per the IEEE 802.3 standard). For a more complex application, which requires use of the Ethernet MAC layer, the SoC designer will need to add a near-complete implementation of the Ethernet PHY up to the MII, without the analog line driving/receiving capability.

The HEAC block implemented in the DesignWare HDMI IP solution is designed to be compliant for both inter-chip (where HDMI, Ethernet and S/PDIF protocols are on different chips on a system board) and intra-chip (where HDMI, Ethernet and S/PDIF protocols are on same SoC) link.

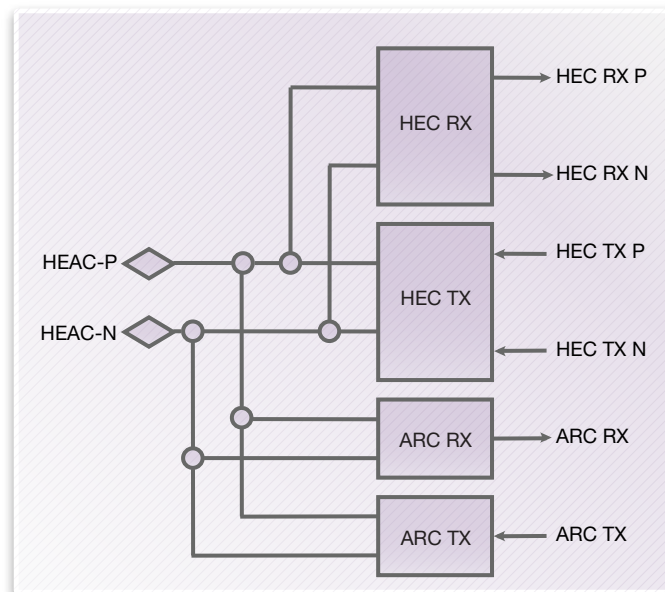


Figure 10: High Level Implementation of the HEAC Block

The Role of IP Providers in the HDMI Ecosystem

HDMI's overwhelming market acceptance has been largely due to the close cooperation between all the key players in the home entertainment ecosystem. This ecosystem's boundaries extend far beyond the semiconductor and equipment manufacturers to include content providers and system operators. Of course, it also includes most major consumer electronics makers as well as semiconductor providers.

IP providers like Synopsys play an important role in the commercialization of advanced technologies like HDMI. By providing the connectivity IP to system/SoC manufacturers and consumer electronic giants (and their ODMs), they eliminate redundant development efforts, cut development costs and shorten time-to-market. Additionally, the extensive testing and verification performed by a reputable IP provider can dramatically reduce the interoperability problems for IC and equipment manufacturers.

Manufacturers enjoy these benefits because IP providers closely track standards development efforts to insure their products deliver the best possible performance, full interoperability and support for all features. In addition, they keep close tabs on supporting technologies, such as high-speed SerDes and the latest IC foundry processes, to make sure their cores can deliver the highest performance with lowest power.

Designing world-class HDMI IP requires an interdisciplinary approach that combines the expertise and domain knowledge in many fields, including high-speed SerDes design, multimedia electronics and other connectivity technologies. Synopsys' ability to master this complex constellation of technologies has allowed it to offer HDMI logic in timing-hardened blocks that have been optimized for minimum silicon foot print and power consumption.

Likewise, Synopsys' DesignWare® mixed-signal PHY IP delivers industry-leading performance while consuming very low power, making it highly desirable for battery powered, mobile applications. Synopsys' mixed-signal PHY and digital IP employs a modular design that allows a designer to only include the functional blocks they need for their particular application. Like all Synopsys IP, the HDMI solutions are silicon-proven and verified to be 100% compliant with the latest specifications. Careful attention to the market requirements, technology and all aspects of implementation has helped make Synopsys a leading provider of both digital and analog IP for HDMI applications.

Conclusion

As the interface of choice for multimedia consumer electronics, the HDMI standard will continue to evolve, adding features, functionality and bandwidth to meet the needs of future applications. Likewise, IP providers will continue to invest the resources required to support these changing requirements with design elements that enable robust, interoperable and cost-effective products. For this reason, Synopsys believes that a growing number of SoC and system designers will choose to keep their development schedules and budgets on track and lower integration risk by buying their HDMI IP versus developing it internally. In this way, HDMI IP providers will continue to play a key role in expanding the role of HDMI connectivity in multimedia devices.

For more information on Synopsys' DesignWare HDMI TX and RX IP solutions, please visit:
www.synopsys.com/hdmi



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