HDMI® Enhanced Audio Return Channel (eARC) Future Proofs Home Theater Connectivity with Uncompromised Audio Quality

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By Marshall Goldberg

Lattice Semiconductor
111 5th Ave., Suite 700
Portland, Oregon 97204 USA
Telephone: (503) 268-8000
www.latticesemi.com

Introduction

HDMI Version 2.1 is the specification's most substantial upgrade. Video delivery speed increases 300%, and a compression feature can increase this another 300%, for up to nine times higher video bandwidth than the 18 Gbps of HDMI 2.0. HDMI 2.1 adds a host of additional features, including Dynamic HDR, Variable Refresh Rate (VRR), and Quick Media Switching. To use any of these features, it is necessary to upgrade to a new source box and a new television. These feature upgrades will roll out gradually in the market over many years; they will not all be bundled into any single device.

Because HDMI 2.1 features will roll-out gradually in products released over the next several years, audio devices such as AV Receivers (AVRs) will become incompatible. For example, if a gamer purchases a new TV and game console with VRR, the AVR which goes in-between the game console and TV will also need to be upgraded, which is very expensive – even though the audio features of the AVR don't change. If the AVR isn't placed in the HDMI path between the game console and the TV, it won't be able to play advanced audio formats such as Dolby® Atmos and DTS®:X.

To preserve AVR compatibility, HDMI 2.1 includes the new Enhanced Audio Return Channel (eARC) feature. eARC technology introduces forward compatibility between the AVR and television, along with uncompromising quality and better ease of use.

Compared to existing home theater audio connectivity methods, HDMI 2.1 eARC provides a number of improvements:

1. eARC is the only forward-compatible solution, which ensures that the AVR will continue to work with newer televisions
2. Delivers uncompromised, full audio quality with nearly 30 times the bandwidth of optical
3. Engineered for far better inter-brand interoperability
4. Is easier to use
5. Simpler connectivity

Challenges of Forward Compatibility

Over the last 8 years, television technology has shifted from 1080p to 4K video. Along with this shift, the release of new HDCP copy protection technology was required for the use of 4K video content. Unfortunately, this rollout occurred gradually, and over several years, as 4K features were added to 4K AVRs:

1. 4K30 Video with HDCP 1.4 Copy Protection
2. 4K30 Video with HDCP 2.2
3. 4K60 Video with HDCP 2.2
4. 4K60 Video with HDCP 2.2 and High Dynamic Range support

These progressive rollouts meant that most 4K AVRs could not fully support 4K video products, such as 4K Blu-ray. Although all four types of these AVRs were marketed as "4K AVR," only the most recently-released AVRs offer full compatibility with today's 4K Blu-ray discs and other 4K film content.

Maintaining forward compatibility is a constant challenge. This is an especially significant problem for customers purchasing AVR systems, as an AVR often has the longest lifespan of any major home theater device.

HDMI 2.1 eARC is designed to safeguard AVR and sound bar purchasers against obsolescence which would otherwise occur as the progressive roll-out of HDMI 2.1 continues. eARC also substantially improves the overall quality, interoperability, usability, and connectivity of home theater systems.

Delivering Forward Compatibility

eARC delivers forward compatibility by removing the audio device from the video path. With a conventional AVR system, both the audio and video flow from source devices through the AVR and onto the TV.

Figure 1: AVR Connection without eARC

With eARC, devices are attached directly to the TV, which then sends the audio-only eARC signal to the AVR. This type of connection bypasses video format issues, dramatically extending the lifetime of an eARC-enabled AVR. eARC also ensures the best quality home theater audio experience at all times.

To connect an eARC-enabled AVR or sound bar to a television, attach an HDMI with Ethernet cable from the audio device to the TV's HDMI-eARC input. Then, attach the remaining HDMI devices to the television. The connection is illustrated below:

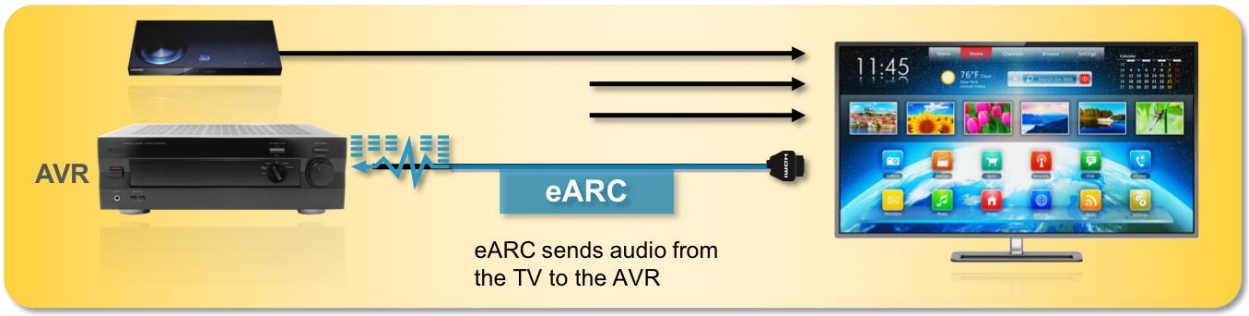

Figure 2: AVR Connection with eARC

It is easier to connect a home theater system this way. Instead of using the AVR remote to switch inputs on the AVR and the TV remote to switch inputs on the TV, the user of an eARC-based system simply uses the TV remote to handle all input switching. This includes not only HDMI inputs, but also apps built into the TV as well as any other inputs, such as analog video and the TV tuner. If the TV and AVR support the CEC feature, using the TV remote will automatically send Power On/Off, Volume Up/Down, and Mute commands to the audio device. With eARC, however, the use of CEC is optional.

It's still possible to use an AVR in the traditional way, with source devices attached to the AVR. However, if advanced devices which exceed the AVR's video capabilities are later purchased, they can be attached directly to the television, and eARC will send the audio to the AVR.

Very often, a consumer's TV and AVR are made by different manufacturers. eARC is designed to ensure exceptional compatibility and interoperability between these mixed-brand TV and AVR connections. The improved compatibility comes about firstly because video doesn't flow through the AVR, and because the discovery mechanism of eARC is brand-new and dedicated specifically to audio devices and format discovery, as described below.

HDMI eARC is a must-have feature to look for when shopping for an HDMI AVR or sound bar because eARC is the only way to ensure future compatibility with HDMI 2.1 devices. In addition to future compatibility, eARC brings substantial improvements in simplicity, audio performance, and compatibility over any other audio interface, and is designed to last decades into the future.

Technical Details

How does eARC work?

eARC transmits a high bitrate audio signal from the television to the audio device using an HDMI with Ethernet cable. This cable was designed in HDMI 1.4. An HDMI with Ethernet cable has the same connector and pins as an ordinary HDMI cable. However, inside an HDMI with Ethernet cable, pins 14, 15 and 19 are constructed as a twisted, shielded pair – originally intended to serve as an Ethernet channel alongside HDMI. In HDMI cables without the Ethernet feature, these are simply straight-through pins, which cannot support transmission of the eARC signal.

The eARC signal transmitted by the television is similar to the format of a SPDIF audio signal, but it is transmitted at up to 98 megabits per second. Because of the protocol overhead, the maximum raw audio speed is about 37 megabits per second, which is the rate of eight channels of 192 kHz, 24-bit uncompressed PCM audio. (8 x 192,000 x 24 ≈ 36,864,000 bits per second)

A one megabit per second, bi-directional data signal is modulated on top of the eARC audio signal. This bi-directional signal is used to allow the eARC TV to discover the eARC audio device. This data signal has several other functions: It allows the TV to read a list of audio formats supported by the audio device, allows the TV to send lip sync correction data, and it lets the audio device send regular “heartbeat” signals to the television, letting the television know that its built-in speaker should be muted. These data-related signals are mandatory in eARC devices. None of these signals are available in optical (TOSLINK) or SPDIF audio, and are optional in the older HDMI-ARC audio.

eARC compared to other audio connections

There are other methods to transmit audio from the television to an audio device, such as optical (TOSLINK) and HDMI-ARC. However, these methods have limitations, which eARC overcomes. The comparison table below demonstrates some of these differences.

Function	**TOSLINK**	**HDMI-ARC**	**HDMI-eARC**
Cable Used	Optical SPDIF	HDMI	HDMI with Ethernet
Stereo Support	**Yes**	**Yes**	**Yes**
Compressed 5.1	Very Limited	Yes	**Yes**
Uncompressed 5.1	No	No	**Yes**
Uncompressed 7.1	No	No	**Yes**
High Bitrate (Dolby® TrueHD, DTS-HD)	No	No	**Yes**
Dolby Atmos® Support	No	No	**Yes**
DTS: X® Support	No	No	**Yes**
Maximum Audio Bandwidth (Payload size)	~384 Kbit/sec	~1 Mbit/sec	**37 Mbit/sec**
Link Discovery	No	CEC	**eARC data channel**
Capability Discovery (Audio EDID, etc.)	None	CEC	**eARC data channel**
Lip Sync	No	(Optional)	**(Mandatory)**

Function	TOSLINK	HDMI-ARC	HDMI-eARC
TV Mutes & Controls Volume	No	**Yes (CEC)**	**Yes (CEC)**
Powering TV Powers Audio Device	No	**Yes (CEC)**	**Yes (CEC)**
ARC Fallback	No	N/A	**Yes**

A key benefit of eARC is support for all of the home theater formats in HDMI. Previous generation HDMI 1.4 ARC transmits over a single pin which only supports 1 Mbit/sec audio, making it insufficient for today's high-end audio standards. Particularly in Blu-ray formats, audio almost always uses higher bandwidth than TOSLINK and ARC can support, and with some titles using the full bandwidth of eARC.

The built-in eARC Data Channel is intended to greatly improve reliability and compatibility compared to ARC and also the traditional "flow-through" AVR connectivity method. Although the older HDMI-ARC standard has a discovery mechanism which provides the same kinds of messaging as eARC, most of this messaging is optional, and the discovery/messaging scheme is based on HDMI-CEC. The CEC pin in HDMI is designed to let devices send remote control commands among one another. Unfortunately, CEC has been implemented in various proprietary methods by different manufacturers, and the results of using it can be unpredictable. There's no way to be assured that CEC will work when attaching numerous devices of different brands together. Sometimes, the CEC feature is turned off, and sometimes turning it on can cause undesirable behaviors. For these reasons, eARC was designed without reliance on CEC. At the same time, eARC devices can be designed to automatically fallback to ARC mode if the other device does not support eARC. eARC compatibility is only necessary in the TV and the AVR (or sound bar); the other HDMI devices have no awareness of eARC.

One frequent question: If eARC's design overcomes some problems of CEC, then why does eARC rely on CEC for automating user remote control commands? This is because the eARC data channel supports only "invisible" operations, such as discovering and setting up the eARC link, determining formats, and lip sync. However, the eARC data channel was deliberately designed to not send user commands such as volume up/down and mute. This decision was made because there are already many different ways to send user commands, including CEC, which is built into all versions of HDMI, or a programmed universal remote, or with a smartphone app. eARC deliberately left remote control functions out of the eARC data channel in order to prevent potential usability problems. In addition, the CEC pin has special attributes which make it perfectly suited for sending a "Power On" message across HDMI, so in systems where CEC is effective, this method can still be used. The important thing is that eARC audio can operate flawlessly without CEC, and the user can choose whether to use CEC for device control.

eARC bypasses not only the CEC connection, but the rest of the HDMI connection. In the transition between HDMI 2.0 and HDMI 2.1, most of the signaling on other HDMI pins have changed. By removing these concerns from eARC, maximum compatibility

can be assured, especially when purchasing a newer television. However, to use an eARC-compatible device in (HDMI 1.4) ARC mode, such as when using an HDMI-eARC AVR with an HDMI-ARC TV, CEC must be enabled, because CEC is part of the ARC discovery process.

eARC can lower the cost of audio devices, because there is no need for the AVR or sound bar to support four to eight input/output ports of ultra-high speed, 48G HDMI 2.1.

eARC Bandwidth

eARC is based upon a maximum audio payload size of 36.8 Mb/s. This value corresponds precisely to 8 channels of 24-bit, 192 kHz uncompressed audio. It is the maximum audio bandwidth used in Blu-ray. It also corresponds to the audio bandwidth of a four-channel I^2S interface, which is the electrical, chip-to-chip interface most often used to transmit audio within high-end audio devices. Lastly, eARC was designed to work with existing HDMI with Ethernet cables, which are designed to support 100 Mb/s Ethernet. With eARC's protocol overhead, the maximum actual bandwidth is 98 Mb/s, which is a perfect fit for the HDMI with Ethernet cables already in use today.

Supported Audio Formats

Below is a list of audio formats which eARC can support:

Uncompressed Formats:

- 2 to 8 channels, all HDMI standard sampling rates, frequencies, and bitrates up to 192 kHz and 24 bits
- Up to 32 channels, using reduced sampling rates, such as 16-channel 96 kHz and 32-channel 48 kHz

Dolby Formats:

- Dolby Digital (AC-3)
- AC-4
- Dolby Digital Plus (E-AC-3, 192 kHz x 2 ch x 16 bits bandwidth)
- Dolby TrueHD
- Dolby Atmos

DTS Formats:

- DTS
- DTS-HD Master Audio
- DTS: X

Fraunhofer Formats:

- MP3
- AAC-LC
- HE-AAC
- HE-AACv2
- AAC-LC and HE-AAC combined with MPEG surround

- MPEG-H 3D Audio

HDMI does not define or limit which formats can and cannot be used, so more formats could be added to this list. However, there are two audio cases which may present difficulties with eARC: DVD-Audio and Super Audio CD. These are audio-only discs that are largely obsolete, bearing bear in mind that DVD-Audio is not the same as the audio track from a DVD movie. For the most part, you can overcome this limitation by plugging these high-end audio players directly into your amplifier.

Lattice Solutions for eARC

SiI9437 and SiI9438

The Lattice SiI9437 eARC Receiver and the SiI9437 eARC Transmitter are 32-pin QFN ICs, which transmit and receive eARC over HDMI. These two ICs were designed so that manufacturers of televisions, computer monitors, AVRs and sound bars could easily implement eARC onto their existing designs, even designs in which HDMI is integrated into a system-on-chip.

The two ICs don't transmit or receive HDMI signals; they connect only to the eARC pins, 14 and 19. This allows the ICs to be integrated into solutions with existing HDMI transmitters and receivers, using any version of HDMI, as illustrated below:

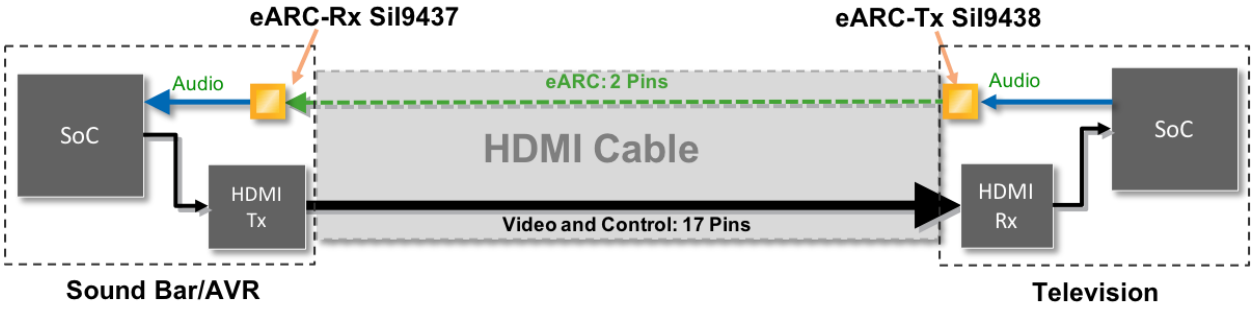

Figure 3: Lattice SiI9437 and SiI9438 Solutions for eARC

The ICs bridge between the SPDIF/I^{2}S audio interfaces and the differential eARC signal, up to the full rate of 98 Mb/s. An I^{2}C interface on the ICs is used for control, and also for a bridge of the eARC Data Channel, which is supported by the SiI9437/SiI9438 hardware.

The SiI9437 and SiI9438 eARC Receiver and Transmitter are available in volume now, as well as their corresponding development kits, CP9437 and CP9438.

Conclusion

With a design that will ensure forward compatibility with future devices, substantial improvements in simplicity, audio performance, and better compatibility over any other audio interface, eARC provides a significant upgrade to the home theater sound experience and should be a key feature when shopping for an HDMI AVR or sound bar.

It is very likely that eARC will find its way into most, and perhaps all, HDMI-based audio devices over the coming year or two.