Designing for audio quality

How we ensure clear and comprehensible sound in our audio products

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AXIS®
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Summary

Axis speakers are designed according to a rigorous process of accurate component selection, systematic testing and precise tuning. Throughout the design phase, there is tight interplay between hardware and software development. When the speakers are integrated in an audio system, users can enjoy a robust, cybersecure solution that includes remote health monitoring of the devices.

When we design a speaker we carefully evaluate many factors, including:

- Driver characteristics. The driver is the electromechanical component that converts electric audio signals to sound waves. Important specifications relate to frequency response, distortion, and power handling capabilities.

- Hardware design for the right sound coverage.

- Digital signal processing to achieve the right sound characteristics. This is optimized in the speaker's software, by help of dynamic range control and loudness compensation.

- Mechanical design for a robust product. This requires selecting plastics, electronic circuits, and driver components accordingly.

- Keeping power consumption down by choosing low-power amplifiers perfectly matched to the driver.

- Thoughtful design to make product installation easy.

Acoustic measurements in our R&D labs are instrumental in fine-tuning the critical components. To complement our objective measurements we also conduct perceptual listening tests according to strict scientific standards in order to assess the subjective aspects of sound quality. During development, Axis products spend over a year in in-house test environments, including hardware quality tests.

Table of Contents

1 Introduction

Axis network audio gives you sharp, distinct sound in a system that's really easy to set up and maintain. With high-quality hardware and built-in, pre-configured digital signal processing, we take responsibility for the sound being optimized to your use case.

This white paper explores Axis approach to ensuring outstanding audio quality in our speakers. It examines our rigorous design process and component selection, thorough testing, and precise software tuning. This paper also highlights the interplay between audio quality, hardware quality, and system quality.

2 The benefits of network audio

With Axis network audio you connect speakers to your IP network and get a distributed audio system without any main unit. The system is flexible and easily scalable when you want to expand. Moreover, each speaker functions as a standalone smart audio unit. You can put our multipurpose speakers to work in different ways as needs change.

2.1 Active speakers

Axis speakers are active, meaning that they have a built-in amplifier as well as software for digital signal processing (DSP). Part of our design process is adjusting the sound to the use cases we have in mind and make the audio sound right regardless of the audio content. The DSP pre-configuration is done in our state-of-the-art R&D facilities and includes adjustment of the tonal balance (how different frequencies are reproduced) and the dynamic range. These settings are also adjusted dynamically dependent on the speaker output level. This way, we make sure that you receive a product that offers excellent intelligibility so your listeners can clearly hear your announcements.
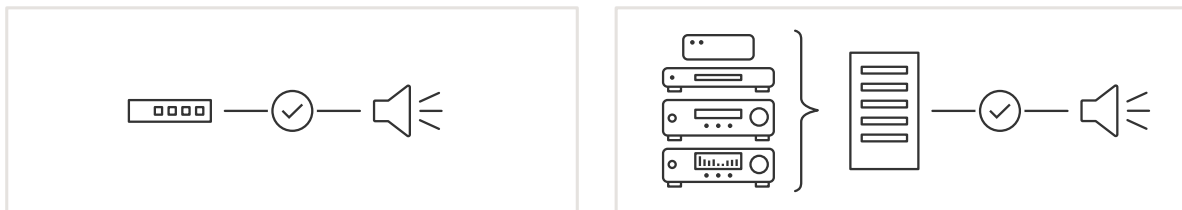
Network audio and a traditional audio system
>   *Left: Network speakers are complete audio systems.*
>   *Right: Traditional speakers require additional hardware.*

In a large system with Axis speakers you don't need a control room with mixing console, amplifier, equalizer, and compressor. All this functionality is instead integrated in the speakers. Compared with a traditional audio system you need fewer pieces of audio equipment, which means you minimize space requirements and maintenance needs. The sound is also more reliable because the signal doesn't have to go through multiple devices before reaching the speaker. And you don't need programmers or sound engineers to configure, adjust, and test the system. You get clear sound anyway because all the components are already tuned to each other.

Furthermore, most of our multi-driver speakers use active crossover filters, which enable us to achieve a precise reproduction of the audio signal, with improved accuracy and detail. The audio signal is split before amplification. This means we can optimize the built-in amplifiers to perfectly match our driver units. Also,

unlike passive filters, which can introduce inefficiencies and compromise the signal quality, our active filters ensure a clean and accurate signal transfer, resulting in improved dynamics, reduced distortion, and a more detailed and engaging listening experience.

2.2 Digital audio

The audio signal is digital all the way from the recorded source material to the intersection between the built-in amplifier and the speaker driver terminals. Digital audio means immunity to electrical noise and interferences, so you don't get distortion from any radiated immission. Additionally, as a digital signal, it's resistant to energy losses due to parasitic effects, such as capacitance and inductance, which can occur over long cable runs. As a result, the signal stays strong and intact, unaffected by cable length, giving you the freedom to position your speakers wherever you need them.

2.3 Power over Ethernet

Using Power over Ethernet (PoE), Axis speakers connect to the standard network for both power and connectivity. You don't need any power cables or dedicated audio cabling.

2.4 Remote health monitoring

Our speakers serve diverse purposes across various applications. For critical uses like emergency warnings and crime deterrence, speaker reliability is essential. In this context, optimal audio quality is not just about delivering well-balanced sound but also for ensuring the proper functioning of the speakers and entire system. With remote health monitoring and built-in test functionality in Axis speakers you always know that all your devices are fully functioning, connected to the network, and sound the way they should. You can use the speakers in large, critical systems and be confident that they're working without having to go onsite to check.

2.5 Cybersecurity

To secure the data and systems on your network, it is key to protect networked devices and software services from cyberthreats. At Axis, we're committed to ensuring the cybersecurity of our offerings. Our audio devices use the same operating system as our cameras, and build on 40 years of experience of designing network devices with the high standards that are critical to a surveillance system. Axis products and services, technologies, and tools reflect and support best practices. Read more at *axis.com/cybersecurity*

3 Audio quality relies on system and product quality

Quality is in focus throughout the development process of an Axis audio product. We're meticulous about every aspect of quality, starting when we set the desired specifications for a new product and not ending until the finished product has been thoroughly tested and evaluated. Any sub-suppliers that we use must also adhere to strict quality requirements.

Our commitment to quality goes beyond developing individual products. By integrating them into a smart system that monitors each device, we ensure that they stay connected and functional. The system's robustness is crucial for the audio quality. If a speaker were to get disconnected from the network, it

would no longer be able to operate regardless of its high-quality audio. A robust system would notify the operator if a device was disconnected or damaged.

Various aspects of product quality directly impact audio quality. For example, making sure that the speakers can operate in a wide range of temperatures and environments is part of the product design but ultimately secures audio performance. Good product design protects speaker drivers and electronics to remain functional without degrading.

4   Developing products for superior sound

Specification and development of Axis network audio products is an in-house process from the planning phase to the finished product. Our engineers develop the hardware and software to be a perfect match. This is possible because Axis invests extensively in Research and Development.

The design process begins with understanding what our customers need considering the type of content to be played, the acoustic environment, and the context in which the product will be used. This comprehensive approach enables us to create a tailored solution that meets specified requirements.

With a clear understanding of the customer's needs, we proceed to develop a concept design using advanced modeling and simulation techniques. Our team carefully selects an acoustic design and pairs it with a speaker driver optimized for the product's unique characteristics. Both the internal and external shape of the product play crucial roles in defining the final sound quality.

Once the concept is finalized, we transition from the drawing board to prototyping. From the initial handmade units to the qualification of a high-volume production line, every prototype undergoes rigorous evaluation through objective measurements to ensure both design and assembly integrity.

With a validated and reproducible design in place, we leverage digital signal processing to unlock the full potential of our creation.

Axis speakers in our R&D labs.

4.1 Understanding the variables that affect quality

A multitude of factors play their part in defining a speaker's final sound quality. Designing a speaker and tailoring the sound to its use cases is a complex process where we carefully evaluate many factors:

- **Driver characteristics.** The driver is the delicate electromechanical component that converts the electric audio signal to sound waves. Important specifications for a driver relate to frequency response, distortion, and power handling capabilities.

- **Sound coverage.** The way sound propagates in its surroundings is largely determined by the choices we make for the hardware design. The intended use case determines the choice between a wide-dispersion design, suited for broad coverage in public address systems, and a narrow-dispersion solution, ideal for focused sound beams.

- **Maximum sound pressure level.** This is measured in dBSPL, using the human hearing threshold of 20 µPa as reference. When we choose the target maximum sound pressure level, we consider the end listener's position and ambient noise conditions.

- **Sound characteristics.** Based on the capabilities of the selected hardware and acoustic design, we tailor the software features (through digital signal processing, DSP) to maximize the speaker's performance.

- **Power consumption.** The PoE classification of the product imposes strict limits on the allowed power consumption. With low-power class D amplifiers perfectly matched to the drive unit, our speakers keep power consumption down.

- **Mechanical design.** Axis speakers are developed with very tough requirements on robustness. The speaker's IP classification and IK classification reflect how waterproof, dustproof, and impact-resistant it is. When selecting materials we also consider the environmental aspect. Our products should withstand extreme conditions while minimizing waste and ecological footprint.

- **Operating temperature.** Most Axis speakers are designed to withstand extreme temperatures. We select the plastics and electronic circuits accordingly, as well as the integral components of the drivers, such as voice coils, suspension systems, and magnets.

- **Visual design.** We have several award-winning designs that we're extra proud of. The aesthetics of the hardware has an impact on your audio system experience because you don't want your speakers to interfere visually with the environment. But the visual design isn't only about aesthetics. Thoughtful design also affects product quality by making installation easy, safe, and time-efficient – for example, click-in mounting options or an LED that lights up when the device is successfully connected.

4.2 Preconfigured sound

Throughout the design phase, there is tight interplay between hardware and software development. As the hardware design reaches maturity, we focus on fine-tuning the product's performance through software optimization, adding the finishing touches to achieve optimal results. We use digital signal processing to improve speech intelligibility but also optimize music. The sound quality is ensured in any environment because several methods of audio optimization are integrated in the speakers:

- **Dynamic range control.** The audio signal often has peaks and lows in volume, and this feature can balance so that the sound is transmitted at the perfect volume for the listeners.

- **Loudness compensation.** At low volume levels, some frequencies are less perceptible to the human ear. Loudness compensation boosts these frequencies so that the listener doesn't miss them. This happens automatically in Axis speakers and is especially good for use cases involving music.

- **Frequency optimization.** The edge processing in Axis speakers means they're frequency optimized, which gives the same characteristics to every speaker. As a result, they can combine without the need for manual tuning or configuration, and the system can be easily expanded just by connecting more Axis speakers.

In addition to the optimizing settings, we also provide an extra layer of processing through our audio profiles. They enable you to select the best individual settings depending on whether you're, at the time, using your system for security messages, safety alerts, or background music.

4.3 Exhaustive testing

To confirm the audio quality as well as the mechanical quality, we test prototypes continuously throughout the development process.

4.3.1 Sound quality tests

In our state-of-the-art R&D labs, acoustic measurements are instrumental in fine-tuning critical components such as panels, meshes, and waveguides, to achieve optimal performance. By combining industry-leading tools with our own bespoke methodologies, we're able to optimize performance and drive innovation.

Acoustic measurements in Axis R&D labs

To complement our objective measurements, we conduct perceptual listening tests to assess the subjective aspects of sound quality. Inspired by the pioneering work of scientists like Floyd Toole and Sean Olive, our listening tests adhere to strict scientific standards, employing blind testing methodologies to eliminate bias and ensure reproducibility. A diverse group of trained listeners evaluates multiple design iterations, providing valuable feedback that informs our design decisions. We also test whole systems of several units of the same speaker type to make sure that they sound good together.

4.3.2 Hardware quality tests

During development, Axis products spend over a year in in-house test environments, where they're tested for their ability to withstand mechanical wear and tear, water and humidity, vandalism, extreme

temperatures, vibration, and more. Products are certified to external standards, but Axis testing also goes beyond the required quality approvals.

To ensure that our products don't degrade after installation, we also perform highly accelerated life tests (HALT). This means testing the reliability of a product by exposing it to extreme conditions, that simulate the stress conditions a product might encounter in its lifespan, but of a higher degree than what's expected from actual use. HALT helps identify design problems and potential weaknesses so that we can further improve the product for better quality, reliability, and lifespan. Read more about hardware quality and testing at *whitepapers.axis.com/tested-without-compromise*

About Axis Communications

Axis enables a smarter and safer world by creating solutions for improving security and business performance. As a network technology company and industry leader, Axis offers solutions in video surveillance, access control, intercom, and audio systems. They are enhanced by intelligent analytics applications and supported by high-quality training.

Axis has around 4,000 dedicated employees in over 50 countries and collaborates with technology and system integration partners worldwide to deliver customer solutions. Axis was founded in 1984, and the headquarters are in Lund, Sweden

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