HELIOS N-1

Passive Copper Ethernet Isolation for High-End Digital Audio

Technical White Paper

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Design premise

Reducing common-mode electrical interference between copper Ethernet-connected devices, while preserving reliable 10BASE-T and 100BASE-TX data transmission.

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1. Executive Summary

The Helios N-1 is a fully passive interface for 10BASE-T and 100BASE-TX copper Ethernet connections in high-end digital audio systems. It contains no active switch, PHY, reclocking circuit or local power supply. Its function is therefore not to alter digital data or regenerate Ethernet packets, but to influence the electrical conditions under which a twisted-pair Ethernet link connects two devices.

The design is based on the observation that a valid Ethernet data stream and an electrically quiet interface are not the same thing. This distinction is specifically relevant to copper Ethernet. Optical Ethernet uses a fundamentally different physical medium and does not create the same conducted electrical path between connected devices. In a twisted-pair copper link, differential Ethernet signalling is highly robust, but common-mode high-frequency energy can still couple between network equipment through cable conductors, parasitic capacitances, transformer structures, grounding paths and the local electromagnetic environment. In a sensitive audio system, this energy can reach downstream circuitry even when the transmitted data itself remains bit-perfect.

The Helios N-1 places two purpose-selected 1:1 Ethernet isolation-magnetic stages in cascade. This creates a fully passive, symmetric signal path with two stages of galvanic isolation. The architecture deliberately accepts additional differential insertion loss in order to introduce a second passive isolation stage and provide greater control over common-mode interaction. Because no active regeneration is present, adequate link margin at the source is essential.

A dedicated 1 meter coaxial earth lead is used to establish a controlled external reference. At the Helios end, the shield is connected to the aluminium enclosure while the centre conductor is connected to the internal common-mode reference between the two transformer stages. At the gold-plated banana plug, shield and centre conductor are bonded together. This keeps chassis and circuit reference on separate conductors inside the cable while bringing both to the same external grounding point.

The complete enclosure is CNC-machined from aluminium, bead-blasted and black anodised. Two identical machined halves are bolted together to form the housing. Wooden side labels carry the branding and regulatory marking and conceal the assembly screws, leaving no visible fasteners in normal use. The electrical topology and the mechanical construction are both symmetric; there is no designated input or output direction.

2. Design Objectives

Objective	Design response
No additional active noise source	Fully passive architecture; no oscillator, PHY, regulator or switching supply inside the Helios.
Reduce unwanted electrical coupling	Two cascaded isolation magnetics and a controlled external earth reference.
Preserve Ethernet integrity	Short, symmetric differential signal path supporting 10BASE-T and 100BASE-TX operation.
Avoid directional behaviour	Electrically and mechanically symmetric construction; either RJ45 connection may be used as input or output.
Maintain product-level mechanical quality	CNC-machined, bead-blasted and black-anodised aluminium enclosure with hidden fasteners.

3. Digital Data and the Physical Ethernet Interface

Ethernet is frequently described only in terms of its logical data layer. From that perspective, if packets are received correctly, two network paths can appear functionally equivalent. Ethernet, however, can use different physical media. The Helios N-1 is intended specifically for electrical twisted-pair copper Ethernet using RJ45 connections. Unlike an optical link, a copper Ethernet link establishes a physical electrical interface between the connected devices. At this physical layer, the data is represented by analogue voltage and current waveforms with finite rise and fall times. These waveforms contain energy over a broad frequency range and exist simultaneously in differential and common-mode forms.

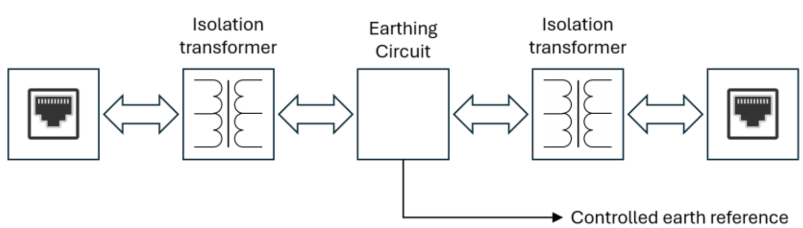
3.1 Differential and common-mode components

For a differential pair, the wanted signal can be expressed as **$V_{diff} = V+ - V-$**, while the common-mode component is approximately **$V_{cm} = (V+ + V-)/2$**. An ideal balanced link would produce negligible common-mode energy, but real interfaces contain transformer imbalance, parasitic capacitance, PCB asymmetry, connector geometry and external coupling. These mechanisms convert a small part of the differential signal into common-mode energy and also provide paths for externally generated RF noise.

For audio applications, the concern is not that common-mode noise changes the numerical value of correctly received audio samples. The concern is that high-frequency current can enter a streamer, network bridge or DAC through parasitic paths and then interact with local ground references, power supplies, clocks and analogue circuitry.

4. Passive Architecture

The Helios N-1 intentionally contains no active Ethernet electronics. There is no local clock and no active signal regeneration. The 10BASE-T or 100BASE-TX network waveform passes through two cascaded, purpose-selected 1:1 Ethernet isolation-magnetic stages.



Because the architecture is symmetric, the same passive transfer function is presented in either direction. There is therefore no technically preferred input or output side.

4.1 Galvanic isolation is not infinite RF isolation

A transformer provides galvanic isolation, but it does not provide infinite common-mode impedance. Real magnetics have parasitic capacitance between their windings, allowing high-frequency common-mode current to couple across the isolation barrier. The purpose of the Helios is not to claim perfect isolation, but to reduce and control the electrical interaction between the two Ethernet-connected devices without adding a new active noise source.

5. Insertion Loss and Ethernet Link Margin

Passivity has a direct consequence: the Helios cannot restore signal amplitude. Every passive element introduces some loss, and two transformer stages in cascade therefore reduce the differential Ethernet signal that reaches the receiving PHY.

The selected magnetics are specified by their manufacturer for a maximum insertion loss of 1.1 dB per stage over 100 kHz to 100 MHz. For two cascaded stages, a first-order insertion-loss estimate based on the individual component specifications is therefore approximately 2.2 dB, before connector, PCB and cable losses are included. A 2.2 dB voltage-ratio loss corresponds to approximately 0.776 of the original differential voltage amplitude.

Parameter	One magnetic stage	Two cascaded stages
Specified insertion loss	≤ 1.1 dB (100 kHz–100 MHz)	≤ 2.2 dB theoretical first-order sum
Approx. voltage ratio at 2.2 dB IL	≈ 0.881	≈ 0.776
Turns ratio	1:1 ±2%	Two 1:1 stages in cascade

5.1 Why source signal margin matters

The source device must deliver a sufficiently strong and well-formed Ethernet signal so that, after the passive insertion loss of the Helios and the connected cable, the receiving PHY retains adequate eye opening and signal-to-noise margin. If the link is already marginal, additional passive loss can increase the probability of physical-layer errors or discarded Ethernet frames. Depending on the protocol used by the audio transport, recovery may then involve higher-layer retransmission or additional network activity.

During development and comparative listening, operation with insufficient link margin has been associated with a presentation perceived as harder or sharper. This is treated as an empirical system-level observation, not as evidence that individual corrupted Ethernet bits are directly converted into altered audio samples. One possible system-level mechanism is that operation closer to the physical-layer margin changes error handling, packet activity and associated high-frequency/common-mode behaviour.

The design objective is therefore not maximum possible attenuation. It is a balance: reduce unwanted common-mode coupling while preserving sufficient differential signal margin for reliable Ethernet operation.

6. Common-Mode Behaviour of the Transformer Stages

Differential-to-common-mode conversion was an important criterion in the selection of the isolation magnetics used in the Helios N-1. This parameter is directly relevant to the design objective because it characterises how effectively the transformer structure limits conversion of the wanted differential Ethernet signal into common-mode energy.

Component-level performance, however, does not directly determine the common-mode behaviour of the complete Helios. The overall result also depends on source and load impedances, parasitic capacitances, cable geometry, grounding and the physical implementation of the full signal path.

7. Controlled Earth Reference

The Helios N-1 is supplied with a 1 m coaxial earth lead terminated in a gold-plated banana plug. The cable is intentionally used as two separate conductors within the product: the coaxial shield is connected to the aluminium enclosure, while the centre conductor is connected to the internal common-mode reference located between the two transformer stages.

At the banana plug, centre conductor and shield are bonded together. When the lead is connected to the intended external grounding point, the enclosure and internal common-mode reference therefore converge at the same remote point while remaining separate conductors over the length of the cable.

This arrangement is part of the product's common-mode strategy. It should not be interpreted as protective-earth wiring; its purpose is functional electrical referencing within the intended audio installation.

8. Mechanical Construction

The enclosure is CNC-machined from aluminium as two identical halves. The surfaces are bead-blasted and black anodised. The two parts are bolted together to form the complete housing, giving the product a rigid, compact and fully enclosed mechanical structure.

Wooden side labels are applied after assembly. These carry the Haandrikman branding and CE marking and simultaneously conceal the housing screws, so that no assembly fasteners are visible during normal use. The resulting construction is mechanically symmetric and visually clean, reflecting the same non-directional philosophy as the electrical signal path.

8.1 The enclosure as part of the electrical environment

At radio frequencies, a metal enclosure is not merely a cosmetic or mechanical element. Its conductivity, dimensions, grounding and proximity to internal conductors determine parasitic capacitances and possible surface-current paths. For this reason, the enclosure, internal reference and external earth lead are treated as parts of one electrical system rather than as independent mechanical details.

9. What the Helios N-1 Does — and Does Not Do

The Helios is designed to	The Helios does not claim to
Reduce unwanted electrical interaction between Ethernet-connected devices.	Change, reconstruct or “improve” correctly transmitted digital data.
Provide two passive transformer coupling stages without adding an active clock or power supply.	Reclock audio samples or substitute for the clock architecture inside a streamer or DAC.
Offer a controlled relationship between the internal reference, enclosure and external grounding point.	Guarantee identical results in every network or audio system.
Maintain a symmetric, non-directional Ethernet signal path.	Improve a link that does not have sufficient Ethernet signal margin.
	Provide infinite RF isolation.

10. Engineering Evaluation and Listening

The Helios N-1 was developed by combining conventional electrical engineering criteria with comparative listening. Electrical considerations include isolation, insertion loss, signal balance, common-mode behaviour, grounding and physical implementation. Listening is used as an additional system-level development tool, not as a replacement for electrical verification.

In comparative evaluation, particular attention is paid to spatial presentation, image position, focus, depth, low-level detail and perceived hardness or sharpness. These observations are system-dependent and should be regarded as empirical results rather than universal electrical specifications.

11. Technical Summary

Item	Implementation
Operating principle	Fully passive Ethernet coupling / isolation
Active electronics	None
Transformer stages	2 × purpose-selected 1:1 Ethernet isolation-magnetic stages in cascade
Transformer application	10BASE-T / 100BASE-TX; 1:1 transformer ratio
Transformer insertion loss	≤ 1.1 dB per stage, 100 kHz–100 MHz; theoretical first-order maximum 2.2 dB for two stages
Signal-path direction	Symmetric; no designated input or output
Earth connection	1 m coaxial lead with gold-plated banana plug
Earth cable internal termination	Shield → enclosure; centre conductor → internal common-mode reference between transformer stages
Earth cable plug termination	Shield and centre conductor bonded together at banana plug
Housing	CNC-machined aluminium, two identical halves
Surface finish	Bead-blasted and black anodised
Exterior detailing	Wooden side labels with branding and CE marking; labels conceal assembly screws

12. Conclusion

The Helios N-1 is based on a clear engineering principle: reliable digital data transmission over a copper Ethernet link does not eliminate electrical interaction between the connected devices. By remaining fully passive, using two cascaded Ethernet isolation-magnetic stages, maintaining a symmetric signal path and providing a controlled external earth reference, the Helios addresses this electrical domain without introducing an additional powered digital circuit into the network path.

The design necessarily involves a compromise. Passive isolation and common-mode control are useful only while sufficient differential Ethernet signal margin remains at the receiving device. For that reason, source quality and link margin form part of the intended operating conditions of the Helios N-1.

The objective is therefore not to alter digital information, but to reduce unwanted high-frequency and common-mode interaction around a correctly functioning Ethernet link. This distinction is central to both the design philosophy and the technical evaluation of the product.

13. References

[1] Manufacturer specifications for the Ethernet isolation magnetics used in the Helios N-1.

Relevant component-level specifications are incorporated into the engineering values stated in this document.

Document note. Statements regarding perceived sound quality describe development observations and are not presented as universally reproducible electrical specifications. Product specifications and compliance information should be checked against the production release before publication.