WHITE PAPER

HIGH-SPEED COMMUNICATION PROTOCOLS FOR ETHERNET, USB & HDMI

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fischer® CONNECTORS

REIMAGINING CONNECTIVITY TOGETHER

HIGH-SPEED COMMUNICATION PROTOCOLS FOR ETHERNET, USB & HDMI

A communications protocol is a system of digital message formats and rules for exchanging messages in or between computing systems and in telecommunications. A protocol may have a formal description. Protocols may include signaling, authentication, and error detection and correction capabilities. The first part of this document provides an overview of the most relevant parameters that determine whether a connector and/or a cable assembly can withstand a defined data protocol. The second part shows the performances of the Fischer MiniMax™ Series and the Fischer UltiMate™ Series cabled connectors according to Ethernet, USB and HDMI protocols.

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New product development manager, Fischer Connectors

Jean-Marie Buchilly focuses on innovation and creating products that make a difference in the lives of users. He works closely with Fischer Connectors' customers to deliver new connector technology to the marketplace.

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INTRODUCTION

A **communications protocol** is a system of digital message formats and rules for exchanging messages in or between computing systems and in telecommunications. A protocol may have a formal description. Protocols may include signaling, authentication, and error detection and correction capabilities.

A protocol defines the syntax, semantics, and synchronization of communication; the specified behavior is typically independent of how the protocol will be implemented. A protocol can be implemented as hardware, software or both. Communications protocols have to be agreed upon by the parties involved. To reach agreement, a protocol may be developed into a technical standard.

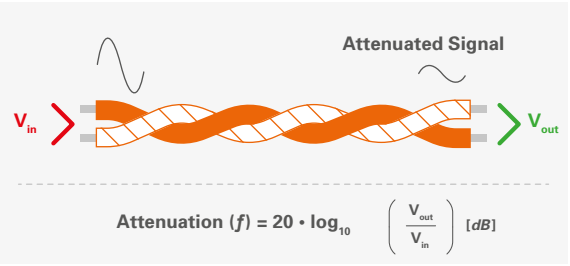
COMMUNICATION PROTOCOL: IEC 11801

International standard ISO/IEC 11801 specifies general-purpose telecommunication cabling systems (structured cabling) that are suitable for a wide range of applications (analog and ISDN telephony, various data communication standards, building control systems, factory automation). The standard defines several link/channel classes and cabling categories of twisted-pair copper interconnects, which differ in the maximum frequency for which a certain channel performance is required.

Balanced cabling performances are defined by a set of multiple parameters. The most relevant are listed below.

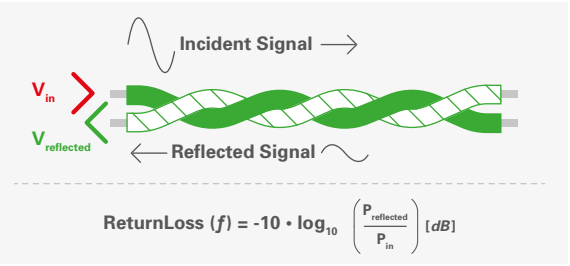
Insertion Loss (IL)

Insertion Loss, or attenuation, is the reduction in amplitude of a transmitted signal in a wire pair as a function of the frequency.



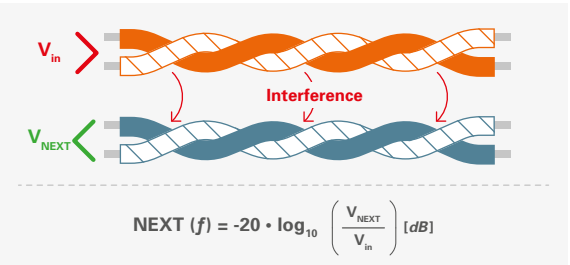
Return Loss (RL)

Return Loss is the measurement of the intensity of the reflected signal in a wire pair (measured on the same side of the cable from where the signal is emitted). The signal reflection is due to impedance mismatches (usually caused by manufacturing defaults).



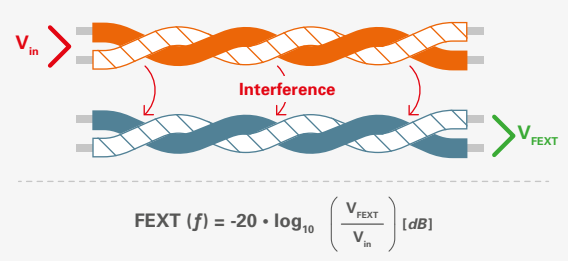
Near End Crosstalk (NEXT)

Near End Crosstalk (NEXT) is the ratio of the amplitude of the transmitted interference and the amplitude of the signal creating this interference applied on another wire pair, measured on the same side of the cable from where the signal is emitted.



Far End Crosstalk (FEXT)

Far End Crosstalk (FEXT) is the ratio of the amplitude of the interference transmitted and the amplitude of the signal creating this interference applied on another wire pair. The transmitted interference is measured on the other side of the cable from where the signal is emitted.



COMPONENTS CATEGORY VERSUS BALANCED CABLING PERFORMANCES

In ISO/IEC Standards, structured cabling components (e.g. cables, connecting hardware, and patch cords) are characterized by a performance "category", and are mated to form a permanent link or channel that is described by a performance "class". (In TIA Standards, components and cabling are both characterized by a performance "category".)

ISO/IEC 11801 defines the following correspondences between component category and balanced cabling performance class:

- Category 5 components provide Class D balanced cabling performance;
- Category 6 components provide Class E balanced cabling performance;
- Category 6A components provide Class EA balanced cabling performance;
- Category 7 components provide Class F balanced cabling performance;
- Category 7A components provide Class FA balanced cabling performance.

ISO/IEC 11801 defines what performances have to be achieved within the frequency range for all classes.

ISO/IEC 11801 also defines the balanced cabling class that is recommended for the type of application.

For example, you need Category 5 (Cat. 5) components to produce a Class D balanced cabling that can be used for Ethernet 1000base-T applications (Gigabit Ethernet, IEEE 802.3ab).

USB 2.0 protocol is less severe and only requires a minimum Insertion Loss value in the 0-400MHz frequency range. Other common parameters, such as Return Loss, Near End Crosstalk and Far End Crosstalk, are not specified in the USB 2.0 Specifications.

TWISTED PAIR & CABLE CATEGORY

Twisted pair cabling is a type of wiring in which two conductors of a single circuit are twisted together for the purpose of canceling out electromagnetic interference (EMI) from external sources; for instance, electromagnetic radiation from unshielded twisted pair (UTP) cables, and crosstalk between neighboring pairs.

The twist rate (also called pitch of the twist, usually defined in twists per meter) makes up part of the specification for a given type of cable. Where nearby pairs have equal twist rates, the same conductors of the different pairs may repeatedly lie next to each other, partially undoing the benefits of differential mode. For this reason, it is commonly specified that – at least for cables containing small numbers of pairs – the twist rates must differ.

ISO/IEC 11801:2002 (Annex E) aims to internationally standardize the various designations for shielded cables by using combinations of three letters – U for unshielded, S for braided shielding, and F for foiled shielding – to explicitly indicate the type of screen for overall cable protection and for individual pairs or quads.

When shielding is applied to the collection of pairs, this is usually referred to as screening. However, different vendors and authors use different terminology, employing "screening" and "shielding" interchangeably; for example, STP (shielded twisted pair) or ScTP (screened twisted pair) has been used to denote U/FTP, S/UTP, F/UTP, SF/UTP and S/FTP constructions.

Common shielded cable types used by Cat. 6a, Cat. 7 and Cat. 8 cables include unshielded and shielded twisted pair, screened twisted pair and screened shielded twisted pair. The main categories are described below.

Unshielded twisted pair (UTP)

UTP cable is the most common cable used in computer networking. Modern Ethernet, the most common data-networking standard, can use UTP cables. Twisted pair cabling is often used in data networks for short- and medium-length connections because of its relatively lower cost compared to optical fiber and coaxial cable.

Shielded twisted pair (U/FTP)

U/FTP, also known as pair in metal foil, is individual shielding with foil for each twisted pair or quad. This type of shielding protects cable from external EMI entering or exiting the cable, and also protects neighboring pairs from crosstalk.

Screened twisted pair (F/UTP, S/UTP and SF/UTP)

F/UTP, S/UTP and SF/UTP, or foiled twisted pair for F/UTP, are overall foil, braided shield or braiding with foil across all of the pairs within the 100 Ohm twisted pair cable. This type of shielding prevents EMI from entering or exiting the cable.

Screened shielded twisted pair (F/FTP and S/FTP)

F/FTP and S/FTP – also known as fully shielded twisted pair, shielded screened twisted pair, screened foiled twisted pair, or shielded foiled twisted pair – are individual shielding using foil between the twisted pair sets, and also an outer metal and/or foil shielding within the 100 Ohm twisted pair cable. This type of shielding prevents EMI from entering or exiting the cable and also protects neighboring pairs from crosstalk.

Examples of common industry abbreviations

Industry acronyms	ISO/IEC 11801 name	Cable screening	Pair shielding
UTP	U/UTP	none	none
STP, ScTP, PiMF	U/FTP	none	foil
FTP, STP, ScTP	F/UTP	foil	none
STP, ScTP	S/UTP	braiding	none
S-FTP, SFTP, STP	SF/UTP	braiding, foil	none
FFTP	F/FTP	foil	foil
SSTP, SFTP, STP PiMF	S/FTP	braiding	foil

The code before the slash designates the shielding for the cable itself, while the code after the slash determines the shielding for the individual pairs:

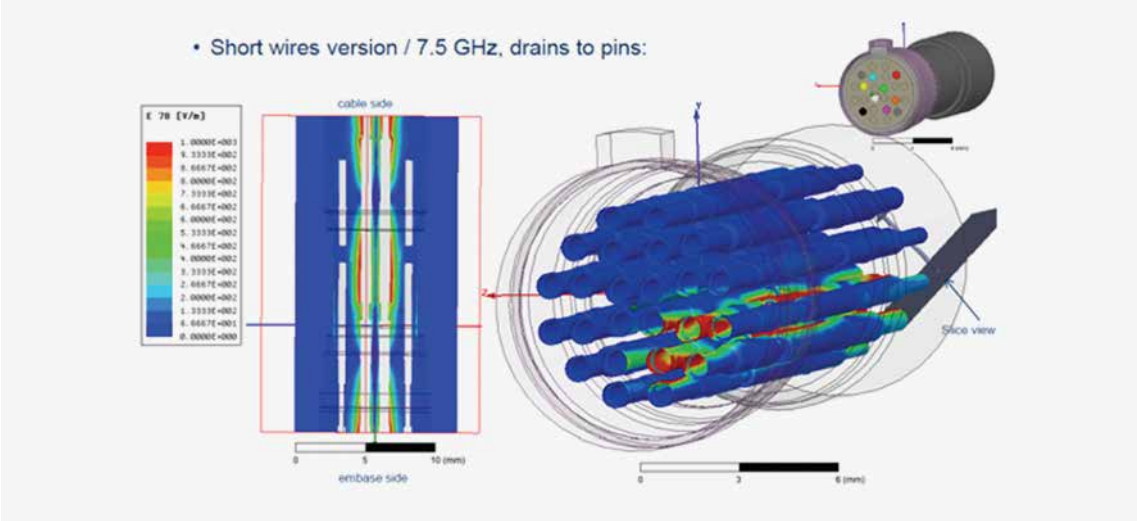
TP = twisted pair
TQ = twisted pair, individual shielding in quads
U = unshielded
F = foil shielding
S = braided shielding (outer layer only)

DESIGN RULES & SIMULATION

Designing a connectivity solution for a specific data protocol requires optimizing the design of both the connector and the cable. The first condition for a functional solution is to have a connector that is capable of handling a specific protocol.

Each protocol requires specific design rules for the connector. All of these specific rules are combined for multi-protocol connectors. Software simulation is the perfect tool for this design process, since it allows the designer to check the compatibility of the designed connector/cable assembly with the targeted protocol. The effects of design modifications can immediately be evaluated in time and in the frequency domain, which enables an optimized design with a high confidence level that the connector will perfectly match the desired protocols.

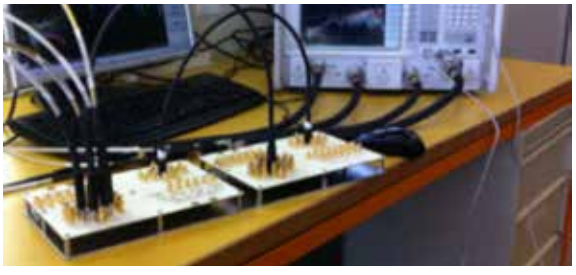
Driven Terminal analysis: E Field, excitation on SSTX pins 7 and 8



CHARACTERIZATION & QUALIFICATION

Once the design has been optimized for a defined protocol, a physical product prototype needs to be tested to validate the full characterization using a Network Analyzer.

S-parameters of the cable assembly are measured and compared with the target values defined in the protocol specification (e.g. USB 3.0, HDMI, Ethernet). If one of the parameters fails, an iteration loop will be made on the design until the cable assembly fulfills all protocol requirements. At this time, the product can be declared "protocol compatible".



PRODUCT LINES FOR HIGH SPEED APPLICATIONS

Fischer UltiMate™ Series for High Speed Applications

The Fischer UltiMate™ Series offers rugged, compact, lightweight, sealed connectors and cable assembly solutions ideally suited to withstand a variety of severe environmental, industrial and chemical conditions.

PROTOCOL		NUMBER OF CONTACTS REQUIRED	ULTIMATE™
USB 2.0		4	yes
USB 3.0		9	application dependent
Ethernet Cat 5e (1Gb/s)		8	yes
HDMI		19	yes

- IP68/69 sealing mated and unmated
- 10,000 mating cycles
- Blind mating and extremely robust keying
- Operating in temperatures: -55°C to +135°C
- 1,000 hours corrosion resistance.
- 5 sizes: 07, 08, 11, 13 and 18, with 4 to 42 pins
- 360° EMC shielding

Fischer MiniMax™ Series for High Speed Applications

The Fischer MiniMax™ Series helps you add power and miniaturization to your devices. It is particularly suited to ruggedized devices designed for handheld or body-worn applications for patients or soldiers, instrumentation and test equipment, where user-friendliness and ease of handling are a must.

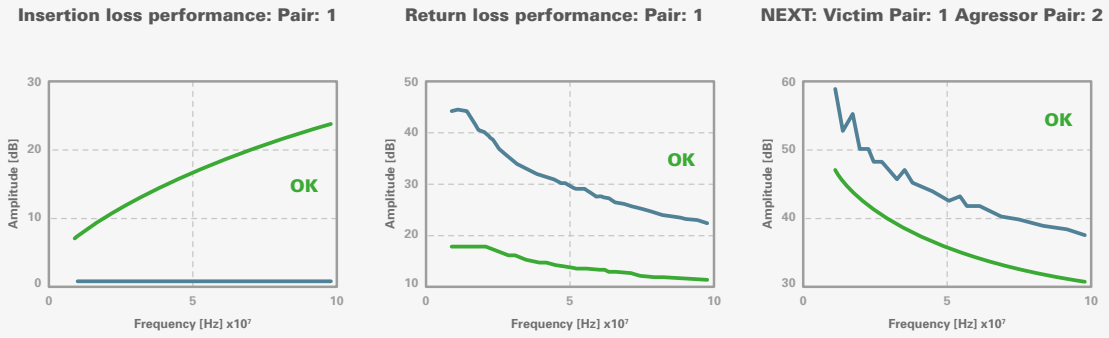
PROTOCOL	NUMBER OF CONTACTS REQUIRED	MINIMAX™
USB 2.0	4	yes
USB 3.0	9	yes
Ethernet Cat 5e (1Gb/s)	8	yes
Ethernet Cat 6a (10Gb/s)	8	yes
HDMI	19	yes

- IP68 sealing mated and unmated
- 5,000 mating cycles
- High pin density, saves up to 45% space and reduces weight by up to 75%
- Unique combination of up to 20 signal contacts and 4 power contacts in a single connector
- 3 reliable and user-friendly locking systems: push-pull, screw and quick release
- 4 to 24 pins
- 360° EMC shielding

ETHERNET

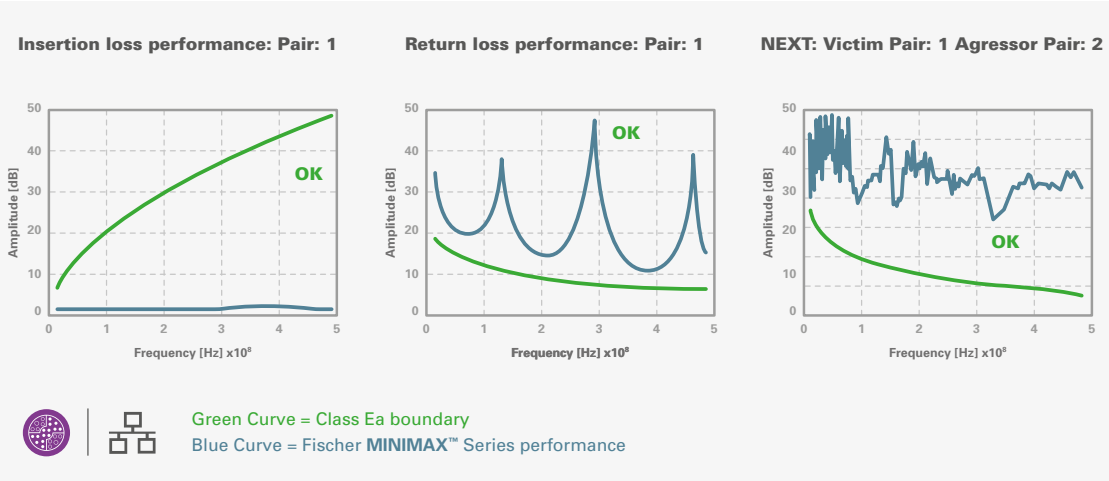
Fischer UltiMate™ Series High Speed Performance for Ethernet

The Fischer UltiMate™ Series (size 07 / 9 electrical contacts) with a screened twisted pair cable has been fully characterized with a Network Analyzer. It belongs to Class D, which means that it can be used for applications such as Gigabit Ethernet, Firewire or Power over Ethernet (see typical measures below).



Fischer MiniMax™ Series for high speed applications for Ethernet

The Fischer MiniMax™ Series (12, 19 and 24 contacts) with a screened twisted pair cable belongs to Class Ea. This means it can be used for applications such as 10 Gigabit Ethernet, Firewire or Power over Ethernet (see typical measures below).

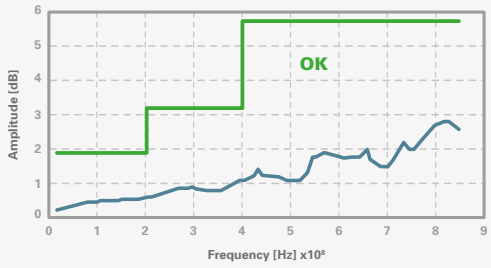


Please refer to the MiniMax™ Technical Specifications (section PCB hole layout) for recommended Ethernet pin layout for 12-, 19- and 24-contact configurations.

USB 2.0 & USB 3.0

Fischer UltiMate™ Series for USB 2.0

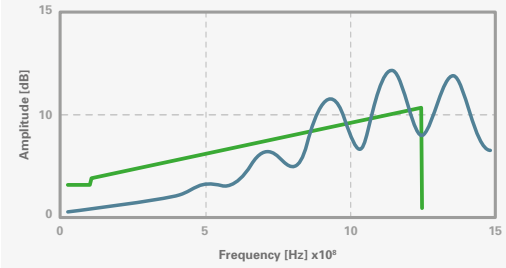
The Fischer UltiMate™ Series (size 07 / 4 electrical contacts) can also perfectly handle USB 2.0 applications as illustrated in the graph below.



Green Curve = USB2 boundary
Blue Curve = Fischer **ULTIMATE™** Series performance

Fischer UltiMate™ Series for USB 3.0

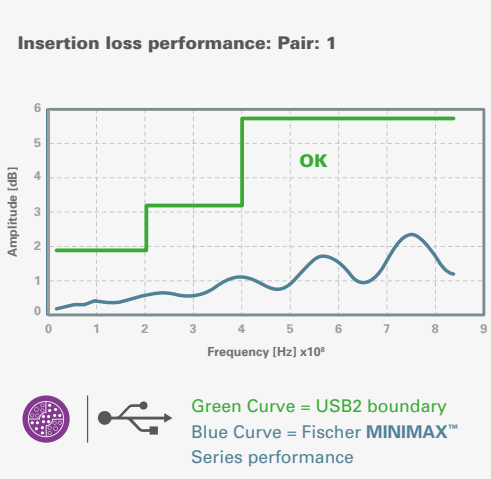
The Fischer UltiMate™ Series (size 07 / 9 electrical contacts) does not formally fulfill the requirements of the USB 3.0 standard. Depending on the performance required by the application, the UltiMate Series connector might still give satisfactory results.



Green Curve = USB3 boundary
Blue Curve = Fischer **ULTIMATE™** Series performance

Fischer MiniMax™ Series for USB 2.0

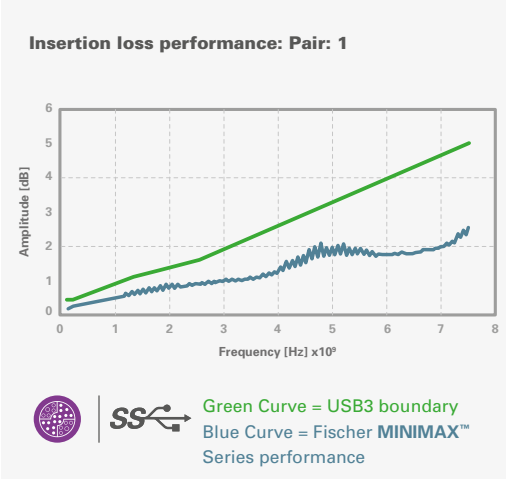
The Fischer MiniMax™ Series is also perfectly suited for USB 2.0 applications, as shown in the graph below.



Green Curve = USB2 boundary
Blue Curve = Fischer **MINIMAX™** Series performance

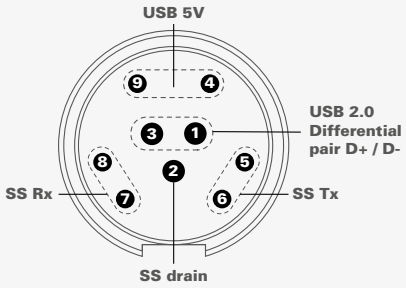
Fischer MiniMax™ Series for USB 3.0

The dedicated 9–contact configuration of the Fischer MiniMax™ Series meets the full requirements of the USB 3.0 standard as illustrated in the graph below.



Green Curve = USB3 boundary
Blue Curve = Fischer **MINIMAX™** Series performance

Fischer MiniMax™ Series pin layout for USB 3.0



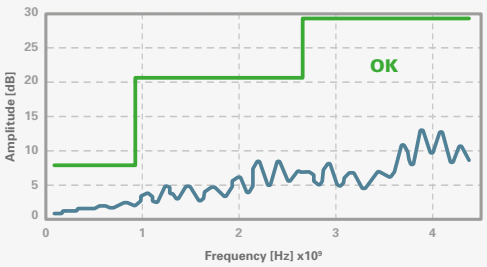
1) USB2.0 D-
2) SS drain
3) USB2.0 D+
4) Vbus 5V
5) SS Tx+
6) SS Tx-
7) SS Rx +
8) SS Rx -
9) Vbus GND

HDMI

Fischer UltiMate™ Series for HDMI

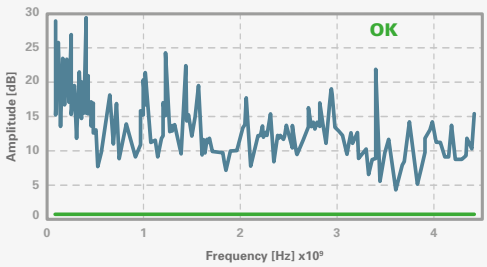
The Fischer UltiMate™ Series (size 11 / 19 electrical contacts) fulfills all of the requirements of the HDMI protocol and can be used for highly demanding audio/video applications (see typical performances in the graph below).

IL TMDS pairs: Pair:1



Green Curve = HDMI boundary
Blue Curve = Fischer **ULTIMATE™** Series performance

FEXT TMDS pairs: Victim Pair: 1 Agressor Pair: 5



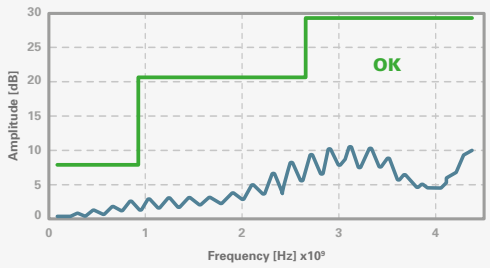
Green Curve = HDMI boundary
Blue Curve = Fischer **ULTIMATE™** Series performance

Fischer MiniMax™ Series for HDMI

HDMI (High-Definition Multimedia Interface)[4] is a proprietary audio/video interface for transferring uncompressed video data and compressed or uncompressed digital audio data from an HDMI-compliant source device, such as a display controller, to a compatible computer monitor, video projector, digital television, or digital audio device. HDMI is a digital replacement for existing analog video standards.

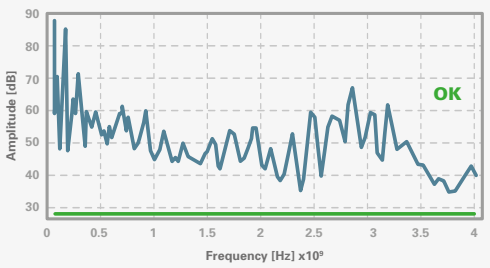
The Fischer MiniMax™ Series fulfills all of the requirements of the HDMI protocol and can be used for audio/video applications in the broadcast market, for example (see typical performances in the graphs below).

IL TMDS pairs: Pair:1



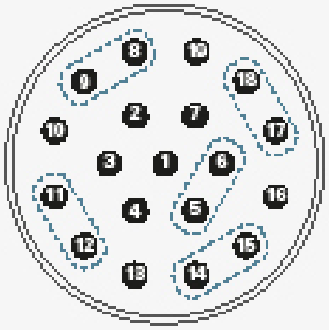
Green Curve = HDMI boundary
Blue Curve = Fischer **MINIMAX™** Series performance

FEXT TMDS pairs: Victim Pair: 3 Agressor Pair: 2



Green Curve = HDMI boundary
Blue Curve = Fischer **MINIMAX™** Series performance

Generic HDMI pin layout for 19-contact configuration



1) +SV
2) SCL
3) SDA
4) CEC
5) HEC-
6) HEC+
7) Hotplug
8) data 0-
9) data 0+
10) shield
11) clk-
12) clk+
13) shield
14) data 2-
15) data 2+
16) shield
17) data 1-
18) data 1+
19) shield

10. CONCLUSION

The Fischer MiniMax™ Series connectors with screened twisted pair cabling have been demonstrated to belong to Class Ea.

The Fischer UltiMate™ Series connectors with screened twisted pair cabling have been demonstrated to belong to Class D.

Our tests have shown that the Fischer MiniMax™ Series with screened twisted pair cabling is perfectly suited to the most demanding applications, such as Ethernet 10GBASE-T, as long as key rules (well-chosen pairs, maximum cable length) are followed.

HDMI applications can be covered by the Fischer UltiMate™ Series and Fischer Minimax™ Series, which perform higher than HDMI standards.

Connector performance is only one part of the equation when speaking about data transmission performances. Cable quality, the cabling process and cable length are other key factors that directly influence the performances of the cable assembly.

A design process that integrates a simulation step (ANSYS HFSS, for example) and a qualification step (with a Network Analyzer) will maximize the performances of the cable assembly and guarantee that the system meets the standards and customer requirements for a specific application.

Last but not least, the interface between the Fischer MiniMax™ Series and Fischer UltiMate™ Series cabling and the connected device is also fundamental, in order to guarantee the performance of the complete system.

References

1. ISO/IEC 11801 ed 2.2
2. Universal Serial Bus Specification, Rev 2.0, April 27, 2000
3. http://en.wikipedia.org/wiki/Twisted_pair
4. http://en.wikipedia.org/wiki/HDMI

ABOUT FISCHER CONNECTORS

Fischer Connectors has been designing, manufacturing and distributing high-performance connectors and cable assembly solutions for more than 60 years. Known for their reliability, precision and resistance to demanding and harsh environments.

Fischer Connectors' products are commonly used in fields requiring faultless quality, such as medical equipment, industrial instrumentation, measuring and testing devices, broadcast, telecommunication and military forces worldwide.

Primary design and manufacturing facilities are located in Saint-Prex, Switzerland, with subsidiaries and distributors located worldwide.

Fischer® CONNECTORS

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