SICK AG WHITEPAPER

CABLE AND CONNECTOR FOR HIPERFACE DSL® MOTOR DRIVE APPLICATIONS

INFORMATION AND RECOMMENDATIONS FOR MOTOR APPLICATIONS AND INSTALLATIONS NOTE-1_06

AUTHOR

Jürgen Funkhänel
Application Engineer, SICK STEGMANN GmbH

SUMMARY

This document summaries the requirements onto the cable, cable utilization conditions, connection point design and shielding of a HIPERFACE DSL® system.

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The HIPERFACE DSL® technology as a digital protocol offers a single cable connection between motor and drive controller. By reason of the protocol robustness it is possible to route the motor feedback wires within the motor energy cable as a shielded twisted pair wires. For the communication cable lengths up to 100 m can be realized. It simplifies the motor connection and saves costs.

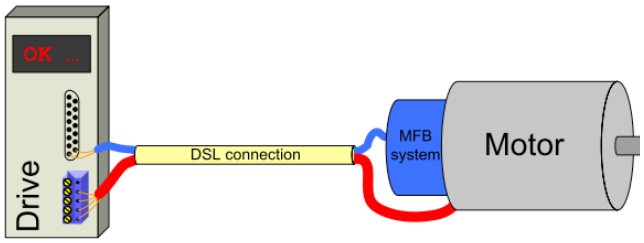

Fig. 1 – principle HIPERFACE DSL® connection

The great advantage of a single cable connection creates some requirements for the communication at the same time when routing the communication wires within the same cable where also the power supply wires for the motor are located. In this case impacts from the power cables can create a signal disturbing crosstalk.

Within this application note SICK Stegmann GmbH provides general guidelines for the utilization of HIPERFACE DSL®-interface for servo-motor controlling. Recommendations were made for the configuration of applications to minimize the signal disturbing crosstalk. Furthermore information and questions are listed for cable and connector selection as well as installation assessment. These information are based on today‘s best practice and should help to achieve a stable and reliable HIPERFACE DSL® connection.

The user is responsible for the overall and final application design including the motor power supply and the requirements for particular installations also in terms of dynamics, temperature or hazardous materials. The information provided in here are subject to change based on ongoing tests and continuous improvements.

Communication & interfaces

HIPERFACE DSL® is a common digital interface based on fast RS485 transceivers with a transmission rate of 9,375 MBaud. The chosen devices should be suitable for 25 MBaud and a switching time of 106,6 ns shall be reached. Cycle times for position reading down to 12,1 µs become possibly. Including signal pre-emphasizing band width of up to 60 MHz are possible.

The data transmission is realized with differential signal technique from an inverted and non-inverted voltage with a minimum differential level of ΔV_{DSL} [3]±0,2 V for reliable signal processing. Please refer also to the specification of the used interface devices. As long as the communication wires are twisted and located closely together in the same environment data transmission is relatively insensitive to crosstalk impacts especially against ground. [3]

A mismatch of the line impedance with the load on both end of the line can lead to signal reflections within the line. The correct matching is typically done by the motor controller supplier. The DSL line impedance is matched inside the drive unit (DSL-master) as well as the encoder (DSL-slave) and balanced with 112 W (symmetric 2 × 56 W) and unbalanced with 56 W and 2,2 µF to ground. [6] The required line impedance is listed within [1].

Fig. 2 – example of an undisturbed DSL-signal (one line), detected on the drive controller end of the line

Crosstalk

Crosstalk means a noise signal coupling during exposure to electro-magnetic interferences, finally caused by a changing electrical (to higher frequencies) and magnetic (to lower frequencies) field. Inductive crosstalk means, the cable operates like an AC- or pulse transformer from an energy wire to the DSL wires or to another energy or the PE-wire. The model approach of a power wire is an assumption of serial stacked broadband transformers. Capacitive crosstalk is related to the distance of the wires as well as the dielectric properties of the material in-between (see fig. 3). Within [2], [3] and [7] there are some theoretical information required for cable model as well as crosstalk mechanism.

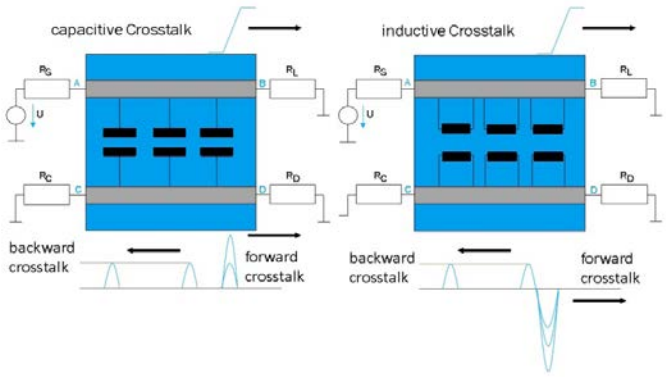

Fig. 3 – capacitive and inductive crosstalk and signal propagation (forward and backward) [3]

The connection of a motor winding at one end of the cable is some kind of a high-ohmic load by reason of its much larger characteristic impedance. In this case the conditions are comparable to a nearly “RF-open” line. This means a “Total Reflection” to the pulse signal and needs to be considered for crosstalk disturbances. The propagation of the noise signal happens in both directions – forward & backward (see also fig. 3). The forward crosstalk of capacitive and inductive coupling has an opposite sign and is compensating up to a certain extent. [2]/[4]
This compensating effect can also be obtained at twisted pair wires. Based on the twist the wire has different positions within the fields, which causes different signs of the coupled noise signal. This also leads to a certain compensation of the different noise contents.
Here we consider the cross talk from the power and/or brake lines into the data lines. This causes disturbances of the communication between the drive controller and the encoder.
The coupling factor can be decreased by an increased wire distance and a decreasing dielectric thickness in-between. With this the line capacity to the shielding [ground] is increased what reduces the coupling into the neighborhood wire. [3] So finally proper wire insulation and shielding are the most important measures against crosstalk and communication signal disturbance. To avoid cross talk or reduce its level a high and stable shielding coverage and its proper connection to ground is required. Therefor these properties of the desired cable need to be checked.

Cable

Nowadays various cable manufacturers offer so-called “Hybrid-cables” where communications lines are integrated within the motor power supply cables. Fig. 4 shows an example of such a cable type (principle sketch and real cable cross section photo). Basic information for suitable motor cable requirements mainly in reference to the signal lines are provided within the White Papers “Cable and Connector for HIPERFACE DSL® Motor Drive Applications – Information for cable manufacturers “ [1]. Cable design including measures to reduce crosstalk interferences and to meet standards is in the responsibility of the cable manufacturer. When designing an application with HIPERFACE DSL® interface the cable specification from the vendor shall be checked against these numbers and recommendations.
It needs to be considered that a combination of different requirements can reduce the limits of different properties.

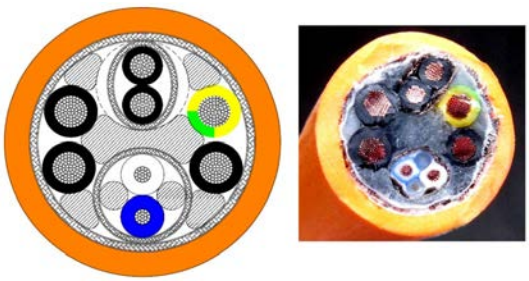

Fig. 4 – Example of a Hybrid cable design; principle cable structure and the picture of the real cable cross section; below [blue/white] data lines; (source: Tecnikabel/Italy)

Cable utilization conditions

For an installation it is quite important to choose the right cable by carefully analyzing the actual application. The following list shows some different application conditions which need to be considered when choosing a suitable cable.

(1) Desired connection length
(2) Dynamic requirements
(3) Motor power
(4) Environmental conditions
(5) Legal/standard requirements

The cable manufacturer needs to be asked for the according data and test results to prove the required cable performance.

(1) – Cable length

The cable length is defined as the distance between the motor and the drive controller location. For the current HIPERFACE DSL® configuration a total length of 100 m can be reached. For this length a wire size of AWG22 or equivalent and a propagation delay of 4,8 ns/m and velocity rate of >0,66c respectively is required [1].

For distances below 25 m the data wire size can be reduced, e.g. AWG24 or equivalent can be suitable. During start-up of the communication the system checks the signal delay time and provides the result within the register DELAY. If this value reaches or even exceed the limit of 1 µs for the signal round trip delay the cable length and/or wire size need to be checked and changed. [6]

Furthermore the performance of the drive controller interface should be verified to the electrical cable properties like capacitances or resistances, especially in reference to the desired connection lengths and the encoder power supply (especially during start-up). Please refer also to the according encoder product information brochure for the inrush power supply requirements.

It is recommended to avoid any couplers in-between the cable. If there is a need for a coupling point the shielding of the DSL-lines must be routed separately from the other shielding within & through the connector (at least with a separate pin). When using large connectors (i.e. Harting-type or M40-size) the data line shieling shall surround the connector section for the data lines.

(2) – Dynamic requirements

Cables can be routed within flex cable chains, twisted within robot arms or are fix installed. For flex cable chain or robot applications the cable design must meet the needs for the dynamics (like speed, acceleration, torsion). Min. required bending radius, max. number of bending cycles during a period of time and the max. possible torsion angle of the cable needs be considered when designing an application.

During the rated lifetime and within the rated limits for the application (à see cable data sheet) the cable design must guarantee stable and repeatable electrical conditions in terms of shielding, wire position to each other, insulation performance and cable cross section.

Changing positions of wires or different condition of the shielding (i.e. by openings) as well as broken wires or a damaged insulation will cause random failure situations and instable operation conditions.

(3) – Motor power

Wire sizes listed in [1] are related to the communication lines only. The user is responsible to choose the right wire size for his particular motor power application including motor brake as well.

For heavy duty applications in terms of motor power and cycle changes potential cross talk impacts shall be taken under consideration, also for a suitable shielding and grounding. Additional tests could be required to verify selected cables.

(4) – Environmental conditions

Special environmental conditions needs to be considered when choosing a suitable cable. Cable manufacturer need to be ask for the according data and test results to select the optimal cable type.

Typical conditions, which will impact the cable performance over the time of utilization, are

- the temperature range (typically limits between -40 ... +90 °C)
- hazardous materials, e.g. chemicals, ozone
- radiation (UV; IR)
- electro-magnetic field from heavy or special machinery (like welding equipment or induction heating)
- indoor or outdoor cable installation including potential mechanical stress (step-on/drive over) or under water/oil routing

A wide range of different standards exist for cable material requirements for different utilizations under hazardous conditions like flame retardant types, non-halogen cables, oil- and/or hydrocarbon resistant or water proof cables.
Please note - it needs to be considered that a combination of different requirements can reduce the limits of particular properties (e.g. temperature or dynamics). Furthermore different materials and/or changing environmental conditions can change cable capacitances and resistances, respectively.

(5) – Legal/standard requirements
The cables need to meet the requirements of various standards like the Low Voltage Directive 2006/95/EG as basic documents for the CE-confirmation procedure. For abroad applications UL or CSA or other local guidelines can apply. The RoHS directive restricts the utilization of hazardous substances for cable manufacturing. Cable manufacturer shall provide the according data on request.
Before choosing a cable for a particular application the applicable standards shall be checked upfront.

Connection points design best practice

Connectors and connection points are the most critical positions within the cable, because the shielding is open. Therefore connections shall be done very carefully.
Couplers should be avoided within the line, ideally only one piece of cable should be used between motor/encoder and drive controller. Each additional connector inherits the risk for pigtails being too long or bad shielding connections.
The proper and undamaged outer shielding of the cable as well as its good contact at the connector is very important to avoid or reduce disturbing impacts from the power wires to the DSL-wires as well as from environmental impacts.
The best practice for shielding of the data line is to make sure there is no contact to any other shielding in couplers within the line from the motor to the drive controller. There must be a separate feed-through of the data line shielding at the coupling connectors.
Based on tests and current experiences for the connector design the following general design recommendations can be made as guideline for a selection:

- Support the wire arrangement throughout the connection point.
- physical largest possible distance between DSL-line and power-line cable pins
- Symmetric arrangement of the different wires as well as pins within the connector
- Pigtail style shielding connections need to be avoided within the connector
- Separate and electrical isolated contacts for the signal line shield and the other motor cable shielding (for couplers within the line)
- Reliable and easy connection possibility also for the shielding to achieve a low-ohmic contacting
- It shall be noted that the servo system integrator or manufacturer is ultimately responsible for their own system design.

Unshielded data wires should be avoided or in case needed shall be as short as possible (<30 mm) and twisted as long as possible. Especially when using large size connectors like M40-size couplers or motor connectors the shielding of the data lines shall be maintained through the connector and should surround the data lines. Within the (typically large) motors with a distance of >200 mm between motor connector and encoder a shielded connection line should be used between the motor connector and the encoder with a suitable shielding connection to the encoder housing. The current widely used M23 type connectors or couplers are less sensitive at a large number of different applications.

Shielding & ground

The shielding of the hybrid cable type contains the outer (main) shielding and the individual shielding for the data-wires and the motor-brake wires. (à cable data sheet). As shown previously and emphasized during different tests with modified shielding, the shielding quality and a proper ground connection has a significant impact on the performance of the DSL-connection and can be considered as its key factor.
Shielding will prevent the distribution of disturbing electromagnetic interferences to the DSL-line as well as also its emission to the environment (à EMC-requirements). As a conductor within an electromagnetic field it acts as a sink and drains the disturbing energy.

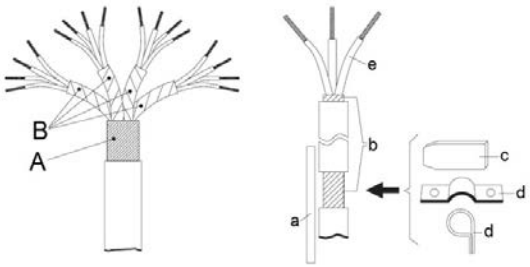

Fig. 5 – cable shielding and shielding connection types [5]
left: A – main shielding + B individual shielding; right: contact of the shielding (b) to the ground bus-bar (a); with spring clamps (c) or staple brackets (d)

The selection of a suitable cable is based on the actual application including a good shielding with a stable and high coverage. A proper connection method guarantees a good electrical contact of the shielding (see fig. 5 + 6). The connection to ground must be large in cross-section, low in resistance and on the shortest possible distance. It is required on both ends of the line. Not used wires shall be connected to ground on one end.

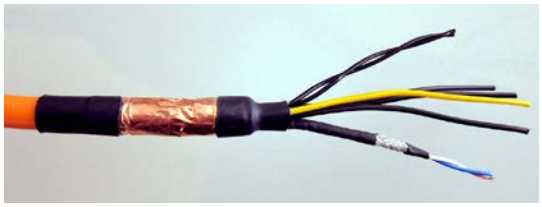

Fig. 6 – cable connection at the motor controller side (example), large contact area for the main shielding (1); with the shielding for the motor brake line), and a separate shielding contact for the data line shielding (2); (source: Tecnikabel/Italy)

Depending on the distances between the motor location and the drive controller installation, which can be separated by 50 m or more or even on different floor levels, different values for R_{GNDx} and V_{GNDx} can occur (fig. 7). During installation and start-up of the system it should be assured that R_{GNDx} is minimized. It will define the quality of the shielding. Equalization cables can be used to carry expected currents between different ground potentials. [5]

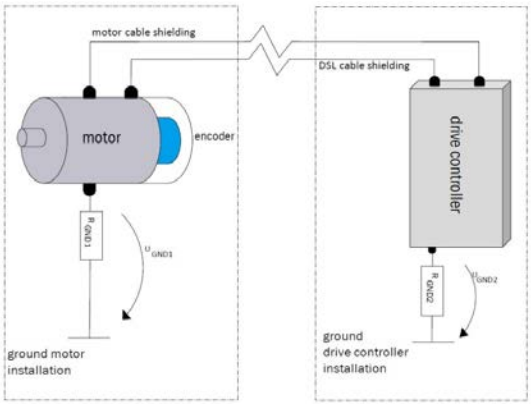

Fig. 7 – shielding and ground connection for motor, cable and drive controller

Depending on the actual conditions on a particular installation site it might be necessary to test different ground connecting points to achieve an optimal system performance.
Fig. 8 shows an example for the connection of the different wires and shielding at the motor and controller side.

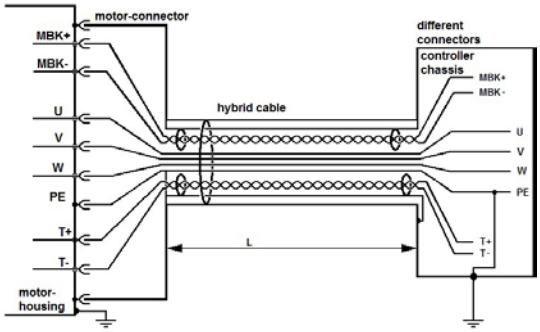

Fig. 8 – Wires and shielding at the motor and controller side (no connectors in-between the line). Depending on the actual grounding conditions PE is connected to ground, too.

Actual wirings and connection points might be different to them shown within fig.: 8. For the connection of the HIPERFACE-DSL® interface to the servo controller currently two different systems are in use:

- Shielded data lines are routed off the motor cable to a metallized connector housing, shielding is connected to the controller via connector housing, the data lines are routed inside the connector housing (i.e. sub-D-connector type or proprietary style)
- Shielding of the brake and the data lines connected together, common connector for the data and brake wires to the controller, (i.e. Weidmüller connector type)

Further information for shielding & grounding including theory, calculations and practical examples are also provided in [7].

Disclaimer

Not all specific conditions of each application or installation site can be tested and investigated upfront, e.g. different cable lengths and routings or different grounding situations at the motor and drive controller locations around the world. In a case of concerns or problems please contact SICK Stegmann GmbH with a detailed description of the situation for further support. If possible tests are recommended at the desired installation site.

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