Hybrid plug-in connectors for the single-cable interface between drives and motor with encoder

E.g. based on HIPERFACE DSL® or SCS open link

Whitepaper

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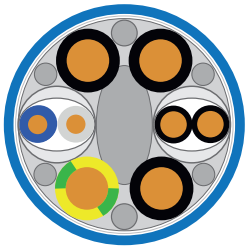
1. Introduction

Just five years ago, a motor with encoder and the associated drive (used here as a general term to describe drive control, drive, servo controller, servo drive, frequency converter etc.) were usually connected using two cables. This allowed for the reliable separation of data and power. However, this method increased space and material requirements, as well as some additional costs during production and installation. Single-cable installations provide a more economical alternative. This development was also accelerated by the HIPERFACE DSL® and SCS open link protocols, which are based on the RS485 transmissions standard. These open, non-proprietary protocols are used to transmit motor feedback (encoder signals). The cable manufacturers developed suitable hybrid shield-in-shield motor cables with one external shield and multiple internal shields.



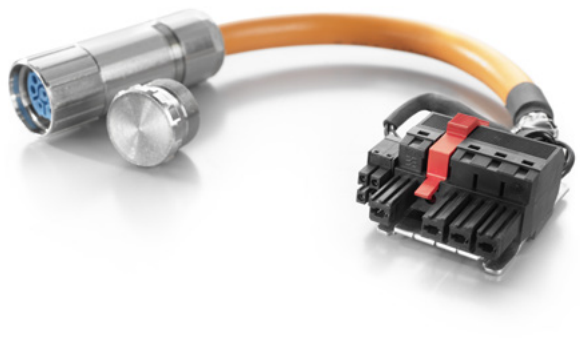
Example of a typical cable construction for single-cable interfaces

Consequently, it follows that a cable is fitted with one plug-in connector for connection on the motor and one on the drive. M23 circular connectors have proven effective on the motor side, but not on the drive side. Up until now, the cable on this side has often been split and routed to two plug-in connectors. A logical solution here is of course hybrid plug-in connectors, the development and installation of which requires care and expertise. As with any shielded connection, the interfaces, such as the shield support, connection terminals and the transitions between the plug-in connector and the housing, constitute critical areas. Furthermore, the distance between power and data lines in the hybrid connector are naturally a lot smaller than with separated cable routing. As the physical design is not standardised, drive manufacturers need to develop their own standards here. Selecting the right plug-in connector and integrating it into a drive's device structure ensures a reliable and robust connection. This white paper is designed to help with this part of the process.

Single-cable solutions between motors and drive regulators,
created using M23 circular connectors and a hybrid plug-in connector
as an efficient and space-saving device interface.

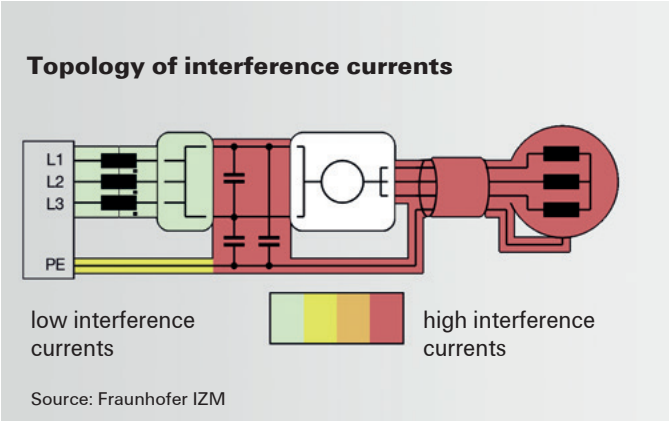
2. Simple device integration of plug-in connectors for single-cable interfaces

As explained above, interfaces such as plug-in connectors and connection terminals constitute critical points in the shielded connection between a drive and a motor with encoder. It's therefore advisable to set up uninterrupted connecting lines wherever possible, and to limit the number of interfaces to simply the connection to the drive and the motor with encoder. A single cable and one plug-in connector on the motor/encoder and one on the drive is therefore the perfect setup. Circular or rectangular connectors with a full circumferential metal enclosure are often used on the motor here, which is the optimal solution with regard to the EMC shielding.



Connecting cable between motor and drive,
on the left the motor connection, on the right the plug-in connector for the drive

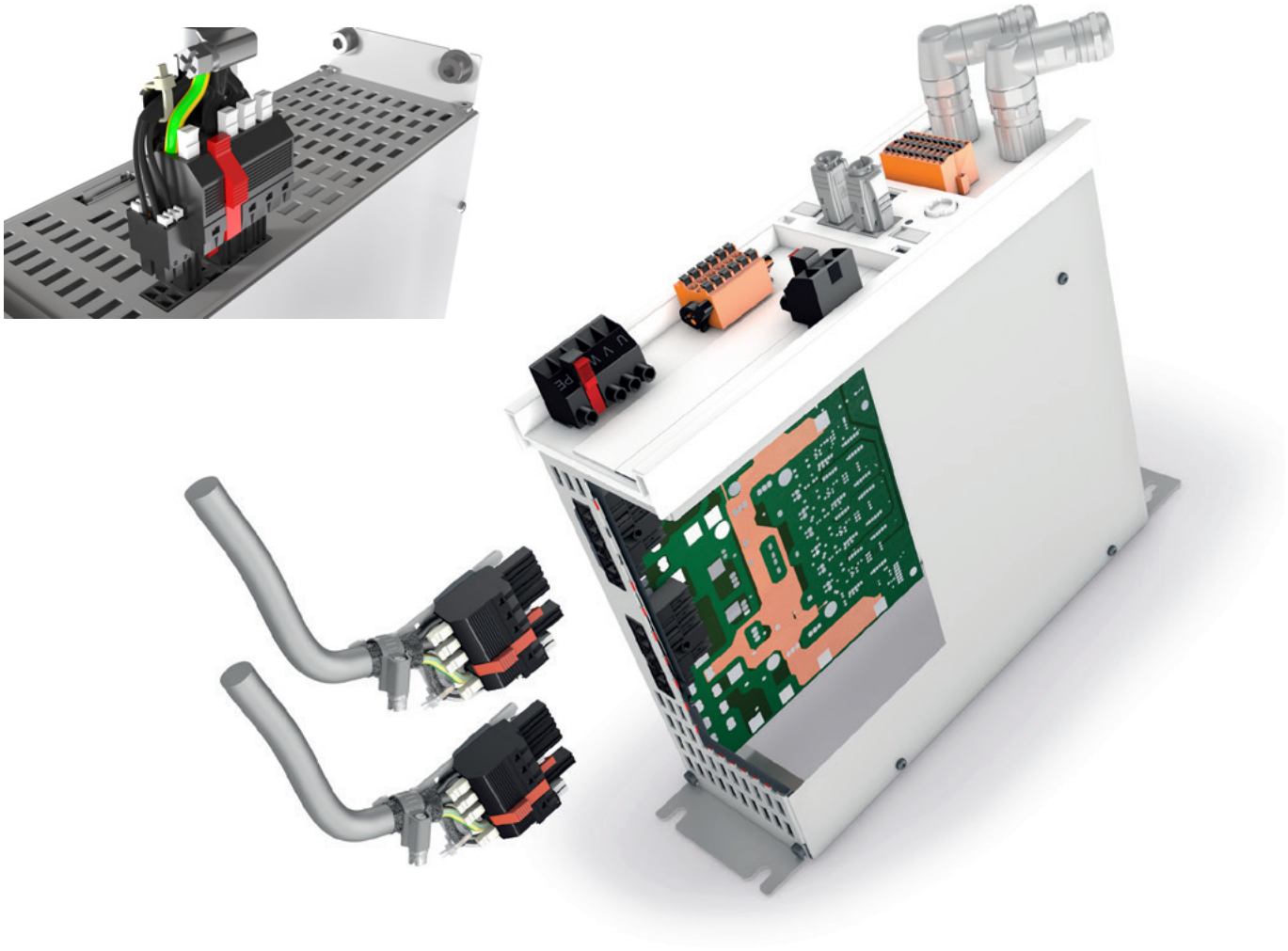
When designing and using plug-in connectors or connection terminals for drives fitted in the control cabinet (IP 20 environment) on the other hand, there are a number of additional important points that need to be taken into account. For cost reasons, plug-in connectors with metal enclosures are not used here; instead, terminals without enclosures are used, which more closely resemble terminal blocks rather than traditional plug-in connectors. Therefore, the shielding must be designed particularly carefully. Continuous and undamaged cable shielding and reliable contact with the plug-in connector is crucial in preventing negative influences from the motor power contacts and environmental influences (see illustration of the possible interference currents) on the encoder line. This is very important because EMC errors are easy to analyse but very difficult to locate. A short circuit, loose contact or cable break can be determined and verified by means of a measurement and/or a mechanical actuation. This is not the case with shielding errors. With shielding, it is difficult to determine the contact resistance at a contact point. In the case of hybrid connections in particular, not only are the individual shields applied on both sides of the cable, they also have a shared potential. This makes it difficult to measure the contact resistance of a connection even when the plug-in connectors are disconnected. However, even with a low-impedance contact resistance, it is not possible to carry out a conclusive evaluation of the shielding effect. The shield may not be fitted close enough to the connection point. One crucial factor is the manufacturer's design of the shield connection. The least effective shielding is achieved by "pigtails". This involves twisting the shield and attaching the resulting bundle at a particular point using a clip or soldering tag. The manufacturer of the plug-in connector must design the shield support so that the shield is in extensive contact with the cable and over its entire circumference if possible, and that it extends to directly in front of the connection terminals. With shield-in-shield cables, there must be a separate support for each shield



Topology of interference currents, source: Fraunhofer IZM

Recommendations for the selection and integration of plug-in connectors for drives fitted in the control cabinet can be summarised as follows:

- A symmetrical arrangement of the various cables and plug-in-connector contacts must be ensured. Electromagnetic fields are best compensated in adjacent cables, i.e. there is less EMC interference.
- "Pigtails", i.e. the twisting and point-based contacting of the shield, should be avoided.
- The shielding of data and motor cables should be kept separate as much as possible.
- The shielding should be connected reliably and with as low impedance as possible. Pluggable EMC shield supports that are attached directly to the plug-in connector and that have extensive contact with the device have proven particularly beneficial here.
- The sections that are unshielded when connecting the cables should be as short as possible; ideally under 30 mm. With the encoder data cable, they should take the form of a twisted cable as much as possible.
- There should be as large a distance as possible between the motor power contacts and the encoder data interface. Ideally, this should be achieved by means of the arrangement of the PE contact and additional attachment points such as the middle flanges (flanges between the motor connection and the data interface) on the plug-in connector

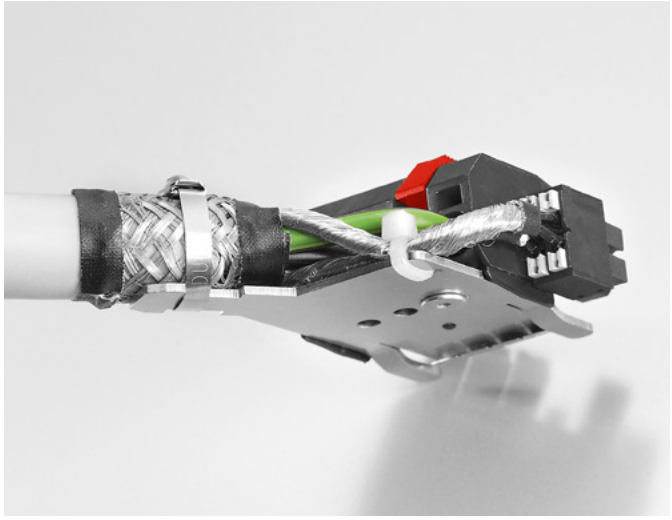


Example of a hybrid plug-in connector on a drive where the arrangement of the PE contact and the red locking flange has been designed to ensure the largest possible distance between the motor connection and the encoder connection.

3. Practical example of IP 20 plug-in connectors and application recommendations

As described at the start of this white paper, the single-cable interface and also the plug-in-connector solution are increasingly gaining acceptance. The associated benefits, such as the low installation costs and compact design, are convincing from both an economical and technical perspective. If the plug-in connector is correctly designed, this means that the perfect combination of handling and reliability is practically guaranteed. The basic technical principles have been described in the previous section. This section will deal with the practical implementation in the form of a hybrid plug-in connector.

Ensuring the largest possible distance between the motor connection and the encoder connection is a good way of ensuring important protection against EMC problems. This can be achieved by positioning all "neutral" elements such as the PE contact and the locking flange in the middle. Laterally arranged, symmetrical data/signal contacts are suitable for both the encoder connection and the integration of the DC brake into the single-cable/plug-in-connector interface.



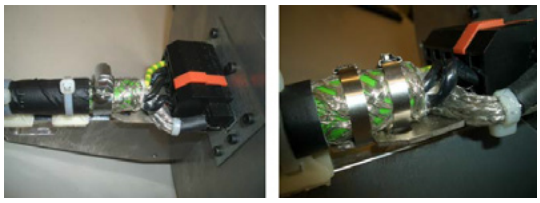
Example connection of the shielding to a single-cable and plug-in-connector solution on a drive in a way that has proven successful in practice.

Another important criterion for the reliable functioning of the single-cable interface with hybrid plug-in connector is having a low-impedance connection between the cable shielding and the device. A shield connecting plate connected to the plug-in connector with pluggable spring contact to the device has proven particularly beneficial here. A spring-loaded design ensures a long-lasting and vibration-proof shield connection to the device, and allows for the separate connection of the shielding braid for the power and encoder cables. Ensuring the correct shield connection is absolutely essential in hybrid technology. The following section describes the related issues in more detail.

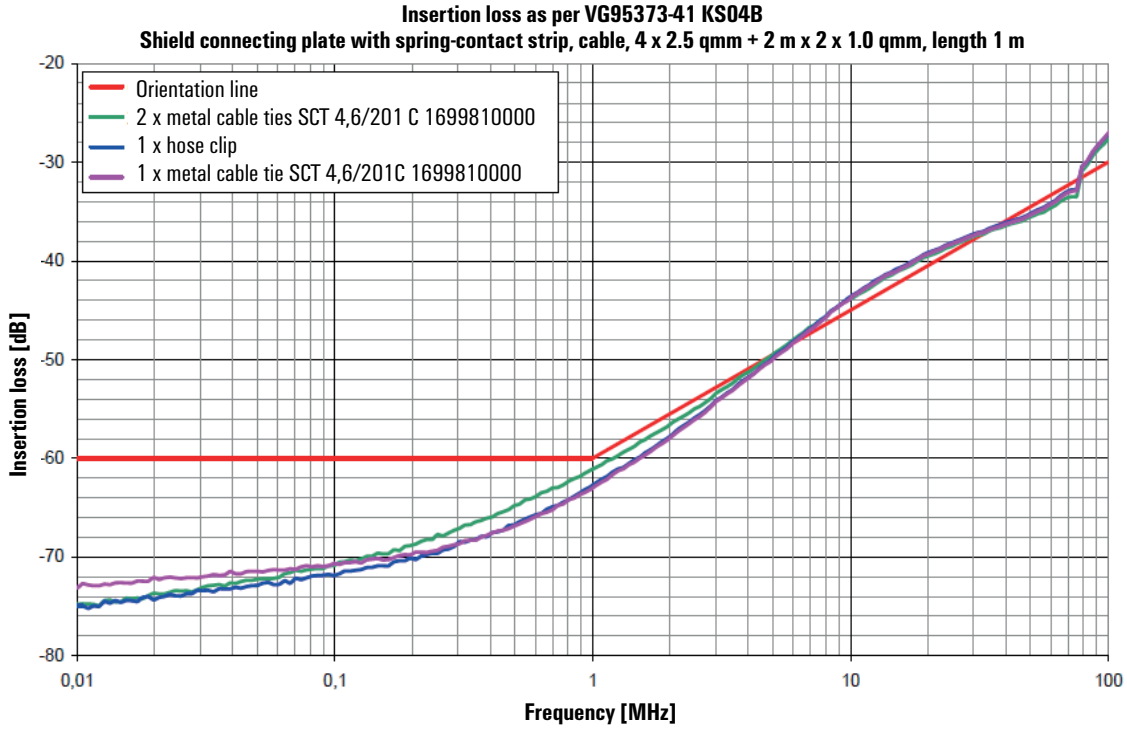
Cable connection and coupling resistance in accordance with VG 95373-41 for the connection of the shield connecting plate

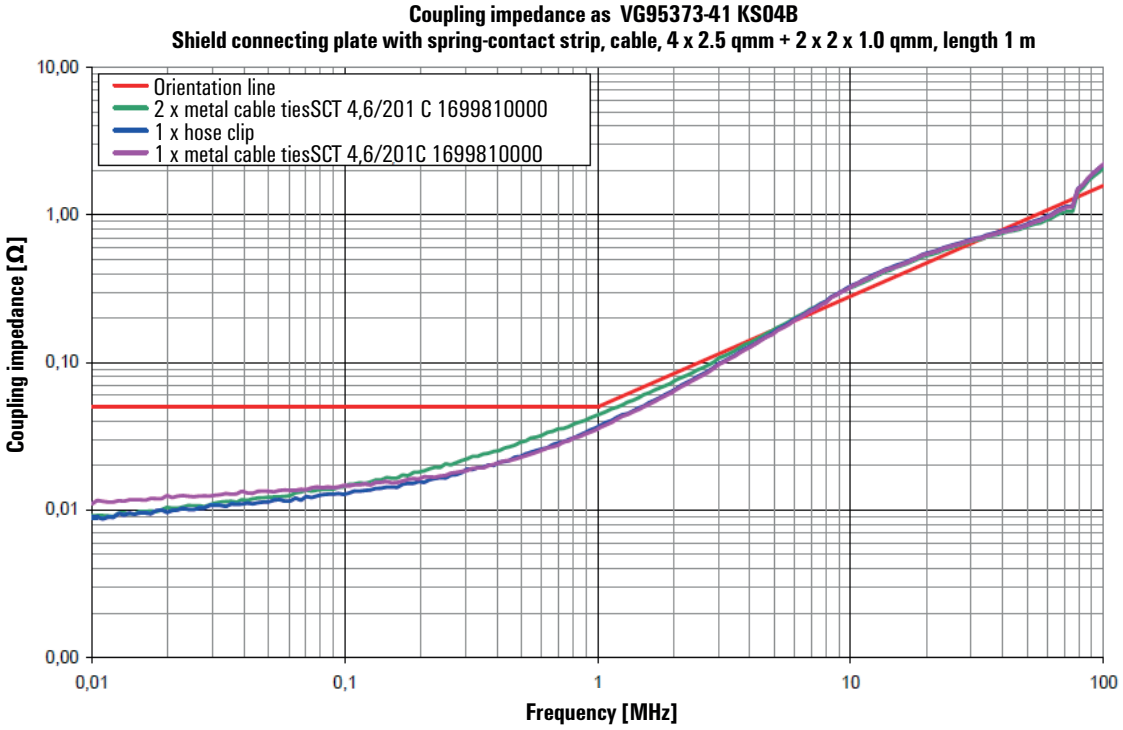
The cable shield is usually connected to the shield connecting plate using standard hose clips or stainless steel cable ties. Both of these achieve good results, as shown by the following tests.

There are several types of measurements that can be used to determine the effectiveness of a cable shield. The method used here is the KS 04 B measurement from VG 95 373-41 "Electromagnetic compatibility of devices – methods for measuring shielded cable and shielded protective cable hoses". This method makes it possible to evaluate both the quality of the shield and the influence of the contacting points on the shielding braid and the sockets and plugs. A standardised test cable length of 1 metre is used here. This, and the fact that this measurement is carried out in a 50-ohm system which does not take the actual cable impedance into account, leads to characteristic resonance effects. The measurement method therefore only provides meaningful measurement results up to a max. frequency of 30 to 100 MHz, but is particularly suitable for comparing and evaluating the effectiveness of difference shields and shield-contacting methods.



Different ways of connecting the cable shielding to the plug-in connector



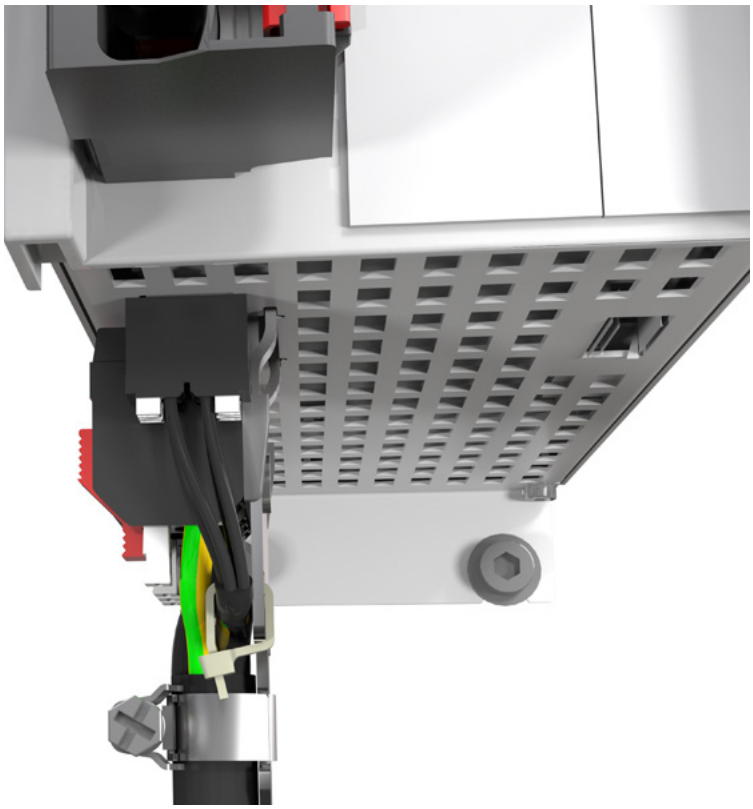


There are generally no crucial differences between the different investigated shield connection options. Essentially, the coupling impedance is determined by the geometry of the shield connecting plate's design. The orientation line inserted in the diagram represents practical values and illustrates the effectiveness of the different shield connection options and of the connection between the shield connecting plate and the device.

Integration examples of a plug-in connector with pluggable shielding plate in an IP 20 drive

A pluggable shielding plate can be integrated into a drive in a number of different ways. Practical experience has shown that having a metal enclosure or conductive metal cooling body with as extensive surface contacting as possible to be the best option here. However, direct contacting of the printed circuit board and deflection of the shield via conductor paths is another possible option when a corresponding design is used.

Contacting of the printed circuit board with the shield support



Contacting of a metal enclosure or diecast aluminium cooling body

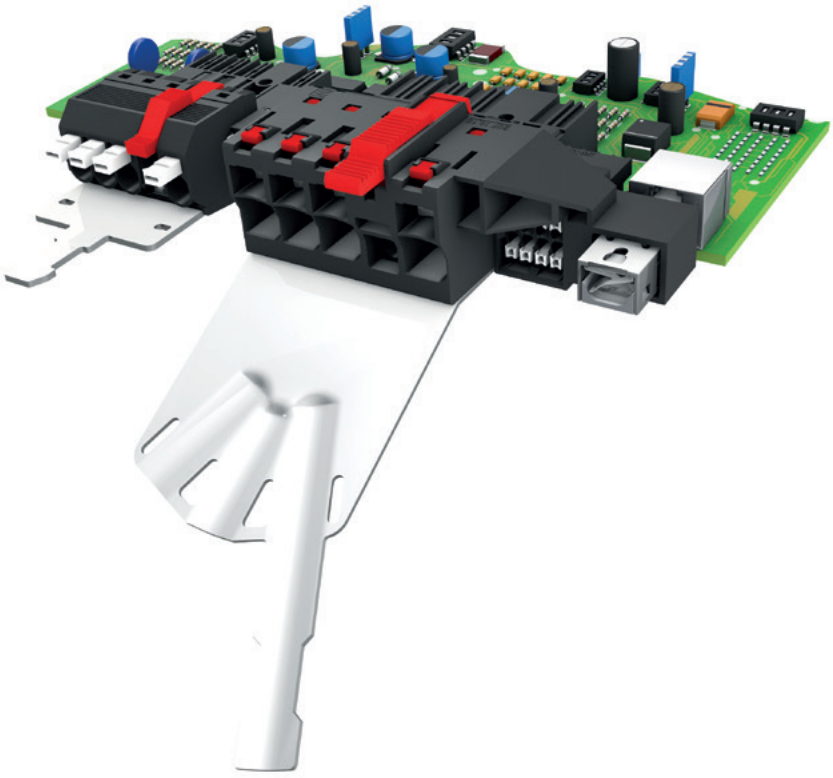
4. Hybrid plug-in connectors from Weidmüller

OMNIMATE® hybrid connector for single-cable interfaces on drives, e.g. with HIPERFACE DSL® or SCS open link

Weidmüller has developed a hybrid connector that meets all of the aforementioned criteria and requirements. The hybrid motor connector simultaneously combines power, signals and pluggable EMC shield support, thereby saving space on the printed circuit board, on the outside of the enclosure and in the control cabinet. The shield connecting plate provides attachment options for the outer and inner shields. These are arranged such that the shielding braid can be routed up to just before the wire connections. The pluggable hybrid shield support features a special EMC spring-contact strip, which ensures that the shield connection to the enclosure, the diecast aluminium cooling body or the corresponding pads on the printed circuit board is long-lasting and vibration-proof with extensive surface contact. This provides drive developers with maximum design freedom. Reliable contact is ensured at all times, regardless of whether the plug-in connectors are used with a metal or plastic enclosure. Thanks to its spring-loaded properties, the contact support on the device does not need any other specific attributes. The shield connecting plate compensates any vibrations or temperature fluctuations automatically. It is therefore able to eliminate the "EMC" error source, which is particularly difficult to locate.

And the plug-in connector also ensures problem-free connection in other ways too. Weidmüller has replaced the conventional external flange with a middle flange, meaning that the distance between the individual cables remains as large as possible despite the compact design. The self-engaging single-hand locking mechanism reduces the amount of installation and maintenance time, as there is just the one connection step. It is easy to handle without any risk of incorrect operation and locks automatically, even in difficult installation conditions. The geometry of the shield connecting plate features a slender 30-degree cable routing, which reduces the amount of space required between the rows by up to 100 mm.

The plug-in connector complies with protection class IP 20 and is therefore touch-safe. It is nevertheless essential to ensure that no voltage is present when carrying out work in the control cabinet. The drives are designed to have high capacities. Even if the cabinet has been de-energised, the operator will need to wait for several minutes for these capacities to discharge. In practice, this step is often forgotten about or omitted, particularly when a device needs to be replaced quickly in the event of a defect. When correctly wired, the plug-in connectors from Weidmüller provide reliable touch protection here too. Thanks to the open design, the user will be able to immediately tell whether all cables are correctly connected and undamaged.



With the OMNIMATE® hybrid connector, Weidmüller is offering a plug-in power connector that gives drive developers maximum freedom when designing the device, which makes hybrid cables extremely simple to assemble, and that is fail-safe and easy to operate.

Information and best practices for the implementation of your projects

As an expert in device connectivity, we are happy to share our expertise. Have a look at our other white papers to find out more about topics such as the following:

- PUSH IN connection technology
- Device design according to UL 600
- Connection system and printed circuit board design in motor controls
- Integration of device connectivity into the SMT process

www.weidmueller.com/whitepaper

More information on the OMNIMATE® product range, the associated design-in services and an application-oriented product-selection tool can all be found at:
www.weidmueller.com/omnimate

Rene Arntzen

Author of the white paper

After obtaining a degree in Industrial Engineering, René Arntzen (born 1985) began his career as a Product Manager at the Weidmüller Group. Since 2011, he has been responsible for the power connectors product family for device manufacturers. Before studying for his degree, he completed an apprenticeship as an electrical engineer and worked in electrical maintenance during his university studies. During this time, he was able to gain a great deal of practical experience in and expand his knowledge of electrical connectivity.

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