ODU TECHNOLOGIES, PROCESSES AND CONCEPTS

A PERFECT ALLIANCE.

COMPETENCE IN
CONNECTOR TECHNOLOGY

ODU TECHNOLOGIES, PROCESSES AND CONCEPTS
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All dimensions are in mm. Some figures are for illustrative purposes only. Subject to change without notice. Errors and omissions excepted. We reserve the right to change our products and their technical specifications at any time in the interest of technical improvement. This publication supersedes all prior publications. This publication is also available as a PDF file that can be downloaded from www.odu-connectors.com.
For many years now, electrical connector technology has been an indispensable part of our daily lives. It enables smartphones, refrigerators and cars to work, makes it possible for airplanes to take off and life-support machines to fulfill their function. These application examples make it crystal clear that, more than anything else, connector technology must be reliable! If the transmission of data, signals or power is faulty or if it fails altogether, there may be dramatic consequences. A connector technology interface must often withstand harsh environmental conditions such as salty air, considerable temperature fluctuations or chemicals – not to mention potential pressure of up to 1,000 bar or high-vacuum conditions, shock and vibrations.

For over 75 years now, ODU has been developing electrical connector technology that fulfills these very requirements and functions reliably even under the most adverse conditions. Our technology is based on continuous in-house development aimed at meeting the growing challenges of our customers and their applications. For this reason, we currently have a high-performance electroplating plant at our German headquarters for surface finishing of Electrical Contacts and housings. Combined with a special geometry and carefully selected base materials, our contacts enable hundreds of thousands of mating cycles. According to some of our customers, ODU connectors have been known to continue working for over one million mating cycles, remaining stable in their physical and electrical contact features. This is a unique selling point of ODU technology, along with its high contact density in many different connectors. The requirement here is to maximize the functionality of the surface area. We’re able to meet this requirement not least thanks to our sophisticated simulation processes and refined measuring and testing technology – both of which are typically used throughout the development process. The shorter development lead times which result are greatly appreciated by customers around the world.

ODU is also a technology leader in the area of high-frequency and data transmission. Our products are setting the standards, particularly when it comes to data transmission under harsh environmental conditions, e.g., railway, military and security technology. Thanks to our expertise in the necessary technologies, we’re able to provide customer- or application-specific combinations of high-speed data technology, corrosion and vibration resistance, IP69 protection class and a minimum of 50,000 mating cycles. We continue to test the limits of what’s physically and electrically viable – to create customized products that precisely meet our customer’s application needs.

Here in this brochure, we’d like to present you with a small selection from our extensive technology portfolio. While it’s far from complete, both in terms of the product range and depth of detail, we hope it will provide you with an initial look into ODU’s work and expertise. We’d be more than happy to give you a more detailed overview of our experience, skills, knowhow and product range in a personal conversation around your specific requirements. We aim to be a partner you can depend on for reliable electrical connector technology that can stand up to various kinds of stress while delivering top performance.

Kind regards,

Dr. Joachim Belz
Dr. Kurt Woelfl
Dr. Georg Staperfeld

Managing Director
Technology Director

Dear readers,

For many years now, electrical connector technology has been an indispensable part of our daily lives. It enables smartphones, refrigerators and cars to work, makes it possible for airplanes to take off and life-support machines to fulfill their function. These application examples make it crystal clear that, more than anything else, connector technology must be reliable! If the transmission of data, signals or power is faulty or if it fails altogether, there may be dramatic consequences. A connector technology interface must often withstand harsh environmental conditions such as salty air, considerable temperature fluctuations or chemicals – not to mention potential pressure of up to 1,000 bar or high-vacuum conditions, shock and vibrations.

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Kind regards,
ODU stands for electrical connector technology of the highest standard. Our connectors and systems set the standards for mating cycles, contact density and reliability. Custom products we develop for specific customers and applications are used the world over. Our decades of experience, combined with modern simulation tools and testing and production processes, enable the shortest of development lead times for customer-specific product solutions.

ODU currently operates four development and production sites in Europe, North America and China. Together with our regional application centers, we achieve the necessary proximity to our customers so we can offer our expertise locally, tackling the respective challenges and requirements of that area.

What’s needed today and tomorrow are specifically laid-out contacts, connectors and transmission systems offering more power density in an ever smaller installation space with the highest number of mating cycles and transmission rates. At the same time, these contacts need to be lighter, more rugged, and user-friendly and of course reliable for the long term.
SKILLFUL AND CREATIVE

Our implementation skills are based on the combined expertise of a close ongoing collaboration among sales application engineers, development engineers, product designers and production experts throughout the complete product engineering process.

The very first step is to fully understand the customer’s application and derive the necessary technical and economic requirements and framework conditions from this understanding. The resulting specifications are arrived at in close coordination with the customer. Making use of pre-existing knowledge and a great deal of creativity, the product designer gets to work on the product. Together with Development and Production, the technical feasibility is tested. FEM simulations, rapid prototyping and sophisticated measuring and testing procedures are put to use in a careful interplay. The ODU Technology Test Center (T²C) plays an important role in this. Thanks to measurements and simulations carried out early on and throughout the process, ODU achieves very short development lead-times for new products. The latter has positive effects on the cost and efficiency of such new developments.

In this whole process, nothing can replace experience. This is true for the product designer as much as for the development engineer and test engineer. Experience can always be complemented with new insights we continuously acquire through fundamental work in product development. This combination of profound experience and application-oriented research is the basis for producing contacts with over 100,000 mating cycles with no loss of reliability or transmission features. Our knowhow in contact physics and expertise in surface finishing enable us to develop connectors that fulfill their specifications with stability and reliability for the long term – even in extreme framework conditions.

In order to optimally tailor high-performance materials to customer requirements, the tensile tests are carried out in a climate chamber. This process provides decisive information on the material’s behavior for the later, actual use.

Proven material parameters
In the case of FEM simulations, precise input parameters are of primary importance. The true strain, which can appear much higher locally, is rarely found in a manufacturer’s spec sheet. Yet it is of exceptional importance when it involves tensile strength, forming and fracture mechanics.

Prototypes made from production materials
By means of injection molding, for example, a cable can be surrounded with a grommet via injection in 3D-printed tooling inserts. This enables prototypes made of production-quality plastics to be provided and tested within a very short period of time.
Reliable contact technology is always the result of the right combination of contact properties: contact resistance, contact force, contact security, mating cycles and mating and demating forces. These aspects must be specifically adjusted according to each application and designed to meet the respective specifications. That’s precisely one of ODU’s strengths – based on experience and profound development and production expertise around contact technology.

ODU is a global leader in the development and production of high-performance contacts for electrical connector technology. Contacts that — depending on the application — can successfully complete up to one million mating cycles without any loss of reliability or transmission capacity continue to set the highest attainable standards. The same is true for current-carrying capacity in high temperatures or application-specific optimization of mating and demating forces. ODU possesses the necessary skills for perfectly adapting contact systems to precisely meet the customers’ needs.

CONTACTS, THE HEART OF THE CONNECTOR

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CONTACT PROPERTIES – PERFECTLY BALANCED

Reliable contacts are at the heart of every connector. The challenge for developers lies in creating an application-specific design taking into account the various contact properties. It’s about creating a stable balance between sometimes opposing physical values and transferring this balance to the reality of production technology.

Low contact resistance can be achieved through high contact force, however, this leads to high mating and demating forces and reduces the number of possible mating cycles. In any case, contact security and reliability are paramount. The right choice of parameters therefore strongly depends upon precise knowledge of the application, i.e., the customer specifications and joint expertise of the developer and product designer.

ODU designers however will never rely on their experience alone – they’ll also take into account T²C measurements supporting the product design throughout the process and, more importantly, reliable FEM simulation forecasts. Securing the electrical and mechanical properties for the complete service life of the future contact system is one of the most crucial objectives of the product development process.

At ODU it’s standard practice to determine derating curves for establishing temperature-related current-carrying capacities, perform mating cycle and wear tests while simultaneously recording contact resistance, and to carry out shock, vibration and EMC tests – and much more.

For some of our testing procedures, we’ve designed and built our own measuring equipment in order to capture data even beyond the standard DIN EN industry regulations.

The challenge of miniaturization (Illustration 1:1)

To be able to offer high-quality connector solutions, contacts (sockets and pins) of highly consistent precision and surface quality are required for current, data and signal transmission. These are manufactured in a contact area of diameters of 0.3 mm to 60 mm.

Thermal management

Electrical performance is already determined in the conceptual phase by means of thermal simulation. Extensive, in-house databases allow for the individual adjustment and consideration of the overall system.

Test of current-carrying capacity

With currents of up to 2,400 amperes, single contacts as well as completely assembled connector systems are tested for their current-carrying capacity on a specifically developed high-current test station.
ODU contacts transmit data, signals and energy (power and voltage). Reliable and error-free transmission must be guaranteed at all times in the respective framework conditions.

The requirements for such secure contact systems ensuring long-term reliability are constantly growing – as is the technical progress occurring in almost all areas of life.

With our customer-specific solutions, we meet the demand for connectors whose current-carrying capacity is high even in the smallest of installation spaces. The same is true for the requirements of e-car manufacturers regarding vibration-resistant, EMC-secure contacts for high currents at a temperature range of -40 °C to +180 °C. In such cases the developer looks beyond single contacts and also takes into account the combination of the right material for the insulator and the termination technology for the contact, in particular. For this, FEM simulation can provide decisive indications regarding, for example, a suitable design for the geometry of a crimp termination.

Electron microscope investigations demonstrate exactly how different surface finishings react to oxygen at 200 °C, how intermediate layers can oxidize and potentially flake off. Computer-tomographic measurements provide information about the physical processes occurring within the contact system when operated under load. All of these insights are taken into account throughout the product development process and enable ODU to frequently meet sophisticated customer specifications in a versatile fashion.
## CONTACT TECHNOLOGIES FOR THE BROADEST RANGE OF REQUIREMENTS

ODU's comprehensive contact portfolio offers each customer exactly the right contact system: both standard and customer-specific. Pins and sockets are designed in various diameters ranging from 0.3 mm to 60 mm, with various termination types (crimp, screw and solder) and with surface coatings tailored to the respective application.

### ODU SPRINGTAC®

**THE MARATHON RUNNER:**
Outstanding reliability, lifetime and durability with up to 1 million mating cycles

- Contact with springwire technology
- Very high contact security
- Low mating and demating forces
- Very high vibration resistance
- Low contact resistance
- High current-carrying capacity

### ODU LAMTAC®

**THE HIGH-PERFORMANCE CONTACT:**
Maximum current-carrying capability and temperature resistance of up to 180 °C

- Contact with lamella technology
- Current-carrying capacity of up to 2,400 amperes
- > 10,000 mating cycles
- High vibration resistance
- Low contact resistance
- Automated lamella assembly
- High contact security

### ODU TURNTAC®

**THE RUGGED ONE:**
Suitable even for harsh environments

- Turned, slotted sockets
- > 10,000 mating cycles
- Low and stable mating and demating forces
- Tiniest dimensions possible, down to 0.3 mm contact diameter
- Mating possible at an angle of up to 5°

### ODU STAMPTAC®

**THE HIGH-VOLUME CONTACT:**
Economical contact system for automatic processing

- Stamped contacts
- > 10,000 mating cycles
- Standard contacts for use in charging plugs (IP67)
- Cost-efficient alternative for high volumes

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An overview of our contact technologies

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ZERSPANUNGSTECHNIK

ODU manufacturing manufactures component parts for connectors in a wide variety of different versions including contact sockets with housing diameters from 0.3 mm to 300 mm. We produce 13,000 different articles using more than 100 machines, all of which are equipped with cutting-edge technology and specially developed high-performance tools.

ODU’s machining ensures the necessary precision as well as dimensional and geometrical stability of contact pins, contact sockets and housings or housing parts. With dependable flexibility and speed.

Pallet system for sensitive parts
Sensitive turned parts are extracted directly from the machine with a gripper and carefully placed on pallets. There, they are also cleaned and passed on to the next processing step.

Two different metal machining processes are particularly important in connector manufacturing: stamping or stamp-bending and machining. At ODU, we use both procedures and have been successfully applying them for decades. Machining is of particular importance to us since it plays such a key role in enabling ODU’s flexibility and speed around the development and production of application-specific connectors. We’re able to provide our customers with high-volume production, but also particularly smaller quantities, too, in a wide variety of different versions and within a short timeframe. This is one of our particular strengths.

03 IT ALL REVOLVES AROUND CONNECTOR TECHNOLOGY

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QUALITY AND EFFICIENCY IN EVERY DETAIL

ODU’s 65 million turned parts and 500 tons of processed raw material every year – from brass and aluminum to stainless steel – clearly demonstrate the high productivity of our production area. Efficient processes make it possible for ODU to provide both large-scale production and individual, customer-specific products.

Precise, versatile and flexible

The necessary raw materials are available directly in-house in bar or wire form, enabling the quick, flexible reaction to customer requests within short delivery times. Thanks to outstanding automated equipment, the production of the most varied geometries and process steps are made possible on one machine – which keeps throughput times as short as possible.

- From a few tenths up to several hundred millimeters in diameter – all geometries are included in the standard process.
- In machining processes (turning, drilling, thread-cutting, milling or cutting), ODU manufactures the connectors’ turned parts – from non-ferrous metal, stainless steel or plastic.
- Axial and radial driven tools implement various drilling and milling options.
- Even forming processes, such as bending, are integrated into this step of the process.
- Particularly sensitive parts are manufactured using handling and palletizing systems.

Finest workmanship for each product

In the component production for the ODU MINI SNAP®, elaborate housing parts are sometimes used. This includes, for example, broaching, planing, polygon turning and various milling operations. Heavy-duty connectors with a diameter of up to 250 mm are entirely processed in the automatic lathe. A component made of material 1.4404 for high-vacuum use is turned, drilled and milled.

Stamping technology

High-precision, mass-produced contacts are manufactured from various materials at 1,400 strokes/min and 360 kN in material thicknesses of 0.07 mm to 1.5 mm. The tooling technologies for this are naturally from ODU.

Turning at ODU

Over 100 automatic lathes equipped with up to 12 axes, numerous special tools, some equipped with high-frequency spindles, provide significant production flexibility with consistently high quality.
ODU is a leading provider of high-quality finishing systems, or “functional surfaces”. Through the integration of surface treatment technology at an early stage of all development and production processes, ODU connectors are guaranteed to have a finishing quality that is precisely tailored to each special requirement.

Surface treatment that delivers what it promises. Larger parts and special parts receive their finishing in our fully automatic rack system.

For more detailed information on ODU’s finishing technology, go to www.odu-oberflaechentechnik.com

FINISHING PROCEDURES FOR CONTACTS AND SYSTEMS

Turned and stamped contacts obtain their specific electrical and mechanical properties through application-specific surface treatment. Contact resistance, wear resistance and many other properties are achieved by means of a layering system applied to the base body. This of course also applies to metal housings, which often require resistance to environmental influences such as chemicals, seawater or aggressive air pollutants.
DEMANDING REQUIREMENTS – OUTSTANDING FUNCTIONAL SURFACES

Harsh environmental conditions, a high degree of mechanical stress, a particular vibrational load: Connectors’ coating systems must be able to withstand diverse factors. Yet they must also ensure the required application-specific properties: from inrush current behavior, to tribology and solderability to optics. Our surface engineering uses a wide variety of basic materials in 16 electrolytic processes and numerous chemical processes in 55 applications. This results in reproducible surfaces that can be made biocompatible, sterilizable, autoclavable, saltwater-resistant, high-gloss, light-absorbing matt, corrosion-resistant, solderable or simply pleasing to the eye.

Procedure is the key

Coating layers of 0.2 to 40 micrometers are applied in the flexible electroplating system, which has and maintains state-of-the-art technology. Multilayer systems for basic, hard-to-bond materials are standard at ODU. Continuous monitoring of the baths and coating thickness measurements based on X-ray fluorescence consistently ensure the highest surface quality resulting from IT-supported processes. Barrel, rack, vibrobot or conveyor systems are used for coating procedures. In selecting the right procedure, the functional requirements of the respective surface, the geometry, number of units and the further processing of the coated components, in particular, are all decisive factors.

Barrel/vibrobot procedure

- Barrel width across flats: 250 mm
- Max. weight: 20 kg
- Vibrobot: max. 280 mm, min. 160 mm
- Suitable for small parts starting at a diameter of 0.5 mm

Rack system

- Total length: 27 m
- Possibility of up to 7 goods carriers
- Max. 1,044 parts in 2 hours
- Suitable for parts with a diameter of 5 mm up to a total length of 1,000 mm

Conveyor belt system

- Conveyor belt material made of copper and copper alloys
- Maximum conveyor belt speed: 12 meters/minute
- Maximum conveyor belt height: 50 mm
- Maximum conveyor belt width: 1 mm
EFFECTIVE CORROSION PROTECTION

The occurrence and speed of corrosion depend on component part geometry, in addition to chemical and physical influences, and material composition, structure and combination.

In rare cases, corrosion can even be considered advantageous, such as when oxidation leads to surface passivation, thereby preventing further corrosion. Familiar examples are copper patination or the natural passivation of aluminium.

Generally, however, the complex phenomenon of corrosion must be avoided, or at least delayed, through suitable surface refinement. This can be achieved by applying galvanic surface treatments, thereby positively impacting contact resistance, tribology and contacts’ abrasion resistance at the same time.

Choosing the right layer or combination of layers requires a great deal of experience and detailed knowledge of chemical and physical processes. This choice also involves taking into account the component’s technical specifications and economic viability, since an inadequate choice of materials can also lead to corrosion.

ODU possesses the necessary experience and know-how to produce functional surfaces that are reproducible and stable over long time periods while also exceeding the customers’ requirements.

Quality control through salt-spray fog testing

ODU carries out its quality control of surfaces using standardized testing to assess the corrosion protection effect. The most commonly known test procedure is salt-spray fog testing. Various national and international norms, such as DIN EN ISO 9227, regulate the execution and evaluation of this test.
Transmission of data transmission protocols such as HDMI® 2.0, USB® 3.1 Gen1, Ethernet, CAT 5, CAT 6, FireWire®, eSATA®.

High-speed data transfer

An ODU AMC High-Density with a hybrid special contact configuration for transmitting power and data according to the USB® 3.1 Gen1 standard.

These ODU specific connectors can transmit common data transmission protocols such as USB® 3.1 Gen1, HDMI® 2.0, Ethernet, CAT 5, CAT 6, FireWire®, and eSATA®, but they are not USB®, HDMI®, Ethernet, CAT, and eSATA® standard connectors.

High-speed data transfer

Both the sheer volume of data to be transmitted and the electromechanical requirements of data transmission connectors are growing exponentially. When it comes to high-speed data transfer, these demands and the requirements of high-frequency transmission need to be combined in a connector — so optimal signal integrity can be ensured throughout the entire product life cycle.

05 HIGH-SPEED DATA TECHNOLOGY FOR THE MOST DEMANDING REQUIREMENTS

Knowhow, the use of suitable materials as well as the testing of S-parameters* at the earliest possible stage safeguard the permanently stable nature of signal integrity. In addition, and designed to fit each application, ODU high-speed connectors meet further requirements such as high contact density and a maximum number of mating cycles, tightness, low weight, vibration resistance and ruggedness.

* S-parameters: frequency dependent scattering parameters; transmission and reflection measurement on inputs and outputs of a high frequency system.
Early on in the conceptual phase of developing high-speed connectors, simulation tools are used to check the S parameters, the characteristic wave impedance and the voltage standing wave ratio. These tests provide important information for the CAD models of the product designers. The simulated interaction of the FEM calculations and CAD design enables important functional properties of new developments to be checked in advance and optimized according to the specific application. These reliable FEM forecast models are based on the comprehensive ODU-specific database whose results stem from systematic measurements and tests.

The perfect interplay of development and design

Among other things, the development and design departments both assess the following key factors and come to an agreement on the details of the product and implementation concept:

- The selection of a plastic for the insulator depends on more than simply its permissible, suitable temperature range. For example, it must also exhibit a stable dielectric constant over a certain frequency.

- The arrangement of contacts must not only withstand voltages (compliance with clearance and creepage distances). It must also reduce crosstalk between the signal pairs.

- Depending on the application, the housing must be watertight and simultaneously provide good electromagnetic shielding.

- The contacts must do more than simply be reliable and continuously transmit current. They must also ensure that the connector has the correct characteristic wave impedance.

Accurate FEM models

The objective of the simulation procedure is a validated statement on the basis of a reliable FEM forecast model, such as regarding mechanical stability, high-frequency transmission and dynamic behavior. The reliability of the connector system and long-term behavior are also simulated. Understanding the correct material parameters in the respective frequency range of the application is particularly important for reaching an accurate FEM model in high-frequency technology. This data is available thanks to many years of systematic basic research and high-frequency simulation experience. Which is why today, ODU can refer to a stable, accurate FEM model and offer its customers significantly shortened development times up until the prototype stage as well as process reliability for serial production.

Material comparison and adjustment to standard specifications

Even in the early conceptual stage, simulation can help make certain statements about future high-frequency behavior and aid in selecting the best possible variations.

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- These ODU specific connectors can transmit common data transmission protocols such as USB® 2.0, USB® 3.1 Gen1 and CAT 5, but they are not USB®- and CAT-standard connectors.

- High-speed solutions

  Contact arrangements especially for data transmission and appropriately shielded implementations are available for many of our products (4 positions for CAT 5 and USB® 2.0, 10 positions for USB® 3.1 Gen1).
When it comes to high-speed data transmission, the connector itself must be taken into consideration, along with the connecting cable on the mating side and the PCB termination on the device side. For the optimum connection of the receptacle to the PCBs, ODU has developed a solution for transmitting high-frequency signals via flexible or rigid-flex PCBs, as the case may be.

By means of this new development, an innovative connector and connection concept which is easier to assemble has become available on the market – for the demanding application area of magnetic resonance imaging (MRI). Moreover, the principle can be used with, and modified for, other applications.

Despite the high requirements of an impedance adjustment to 50Ω with a voltage standing wave ratio of VSWR ≤ 1.1, ODU has managed to ensure this for the entirety of ODU's supplied path [cable connection – rigid-flex – connector – rigid-flex – cable connection].

The PCB layout of the connector's PCB termination plays a decisive role in this case. The simulation procedure available at ODU enables the board layout to be taken into consideration as well, and thereby to synchronize the signal integrity of the overall systems.

**Example: the connection of a standard SMA connector.**

The PCB has a double-sided design. The signal is routed on the board with controlled impedance as a microstrip line. For this purpose, one side is used only as a ground layer and the second side contains the cable routing.

The design of the print layout on the board plays a decisive role in the transmission behavior. The diagram depicts the voltage standing wave ratio of four different termination layouts. The limit value thereby changes from 120 MHz to over 1 GHz at a strict limit value of VSWR = 1.1.

**VSWR – OPTIMIZATION VIA A CHANGE TO THE PARAMETERS “a”**

- **a = 0 µm**
- **a = 250 µm**
- **a = 500 µm**
- **a = 750 µm**

Crucial for the signal integrity: the PCB layout

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**ODU CONNECTORS IN HIGH-SPEED DATA TECHNOLOGY**

Customers trust ODU's high-speed products and system solution varieties tailored to their specific application area:

1. In **medical technology**, our ODU-MAC White-Line modular connector system is used in imaging diagnostics for transmitting high-resolution X-ray, CT and MRI images. High-quality contacts guarantee the transmission properties of the signals. Non-magnetic varieties are also included in our standard portfolio.

2. In **railway technology**, train couplings are fitted with ODU high-speed interfaces that transmit Gigabit Ethernet. These interfaces are reliably stable for 50,000 mating cycles and remain fully functional at all times, even in harsh environments and when exposed to strong vibration. Such applications typically make use of ODU's springwire contacts or the ODU SPRINGTAC. They offer a consistently low contact resistance, thereby ensuring minimal insertion loss at the same time.

3. In **military technology**, ODU AMC data technology interfaces are typically used. In addition to being high-speed performers, they offer IP69 tightness and vibration resistance. The interfaces are easy to clean, compact and lightweight, while also offering a high number of mating cycles. They also ensure quick and secure mating and demating.

4. ODU has developed an application-specific small connector for the **oil industry** that is used in a pipeline inspection system. It is pressure-tight to 200 bar and combines data rates according to FireWire® S800® with power contacts in a shock- and vibration-resistant variety.

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3 These ODU specific connectors can transmit common data transmission protocols such as FireWire® and Ethernet, but they are not FireWire® and Ethernet-standard connectors.
For small connectors, it is indispensable to calculate and adhere to necessary clearance and creeping distances in order to reach consistently strong electrical current. It is equally important to avoid inhomogeneities in the product design such as sharp edges or corners, since under constant contact distance, these can intensify the electrical field many times over. Some material combinations can even promote this effect on the strength of the electrical field. ODU goes even further by taking into account yet another important parameter: the so-called partial discharge.

The challenge of developing and designing high-voltage resistant connectors lies in the mutual influence and necessary dielectric strength as well as an increasing demand for miniaturization. In smaller construction sizes, the distance between individual contacts decreases, thereby strengthening the electrical field. This also raises the risk of electrical breakdown and destruction of the insulator as well as the overall system.

PROFOUND EXPERTISE IN HIGH-VOLTAGE APPLICATIONS

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Meeting the challenges

Even when taking into account clearance and creepage distances and their proper layout, inhomogeneities of the electrical field (such as through blowholes in the insulator) or contaminations in the assembly process could lead to the local exceedance of a system’s dielectric strength.

If the operating voltage is applied for a longer period of time, the smallest of local discharges occur at the molecular level on these locally excessive field strengths. Over the course of the connector’s service life, a “tree” can form as a result [misalignment from continuing local carbonizations]. If the first partial discharge occurs on a field excess, the field excess will then be increased due to carbonization. This, in turn, can lead to an avalanche effect that, over the short or long term, can bring about a destructive electrical breakdown.

Experience shows that the connected cable is frequently a critical factor. For this reason, ODU selects an appropriate cable that enables improved field guidance in the case of applications where partial discharge is critical. In high-voltage applications, a grout is also frequently used in the cable connection area. This eliminates any remaining air in this area and a higher dielectric strength is achieved. The precise, high-quality processing of the grout, and the selection of the suitable grout, of course, is of particular importance. At ODU, this is completely covered.

The same is true for insulators. These materials demonstrate a kind of self-healing process, despite the occurrence of partial discharges. Due to their chemical structure, these materials either have no avalanche effect or only a very weak one. In some cases, field excesses can even be reduced.

Partial discharge measurements at ODU

ODU possesses an in-house test stand for partial discharge measurements. It enables the long-term stability of high-voltage connectors to be tested, and various application-specific layouts to be tested and optimized. It also allows for the quick and effective comparison of various insulator materials in the context of partial discharge measurements.

A combination of this test stand and the necessary experience enabled ODU to bring a wide range of possibilities to the development of a connector for the international research project on the ITER fusion reactor. The connector in question is partial discharge-free up to the double-digit kilovolts range and is also suitable for ultra-high-vacuum situations.
ODU systematically solves varied challenges such as these – and brings to the task the necessary knowhow together with production expertise from one single source. ODU’s fundamental knowledge – developed over the decades and now systemized – has been used to create a database from which our ODU EMC solution matrix has been developed. Our 3D CAD simulations also make use of this substantiated and exact data. EMC-shielded ODU connectors are especially valuable and successful where failure-free electronics are called for, such as in the automotive field, military and security applications, medical diagnostic devices and the entire field of data technology.

Electromagnetic compatibility (EMC) is considered a matter of course in many of today’s application areas. In standard solutions it can be achieved in fixed, e.g., bolted, connectors or application areas with a low number of mating cycles. Yet the real challenge is to design an EMC-shielded connector for products with many sophisticated mechanical specifications that also offers a high number of mating cycles.

THE MATRIX FOR AN OPTIMAL EMC SOLUTION
For years now, ODU has attached a great deal of importance to basic research in the area of electromagnetic compatibility (EMC). In this context, we have developed an extensive solution matrix containing a wide range of connector property combinations and specifications – from watertightness to vibration resistance. All these features have been thoroughly examined regarding their impact on shielding effectiveness and transfer impedance.

In our age of networks and data communication, EMC is not just about electrical devices or active electronic circuits. The connective elements – cables and connectors – play an important role, too. Connected cables can function as an antenna and significantly impair interference both from and to the system. For this reason, cable shielding and connection to the electronic casing via a connector are paramount for the overall performance of the system.

ODU has the necessary expertise to meet various EMC classes and to compare and select component parts for each application area with respect to costs, flexibility and functionality in harsh environmental conditions.

Optimal shielding effectiveness and transfer impedance across the entire life cycle

Shielding effectiveness and transfer impedance are clearly defined for electrical connectors. Inappropriate connector impedance in an application leads to a drop in voltage and undesirable compensation currents in the system. This can bring about unintended disruptions between systems that are interconnected with cables. When designing a connector – as with a cable shielding – the contact resistance and inductive part of the connector must be kept as low as possible.

When an electromagnetic wave spreads within the connector-cable-system, the shielding effectiveness becomes an important quality feature of the overall system. A connector or a connector assembly with low shielding effectiveness can absorb radiation from its surroundings and thereby disrupt the electronics connected with it, and also emit into the environment high-frequency signal components occurring within the electronics. This can even interfere with systems located some distance away. ODU, therefore takes special care to design and produce unbroken shielding systems with maximum conductivity.

Based on its many years of experience and associated knowledge, ODU also develops special solutions for particularly rough, high-vibration environments. Continuously low contact resistance levels between connectors and receptacles can be achieved through the use of special conductive components. ODU connectors thereby meet shielding effectiveness regulations and transfer impedance even after maximum product life stress.

ODU measures shielding effectiveness and transfer impedance according to relevant standards with a combined triaxial cell (or triaxial pipe) and network analyzer. Regarding the resulting coupling transmission function for EMC resistance, a distinction is typically made between the measure of transfer impedance in the lower frequency range and the shielding effectiveness for higher frequencies.

In-house measurements and 3D CAD simulation

In addition to the EMC solution matrix, the designed concepts are assessed via in-house simulation and measurement, and are optimized for the specific application. The ODU simulation imports the 3D CAD model of the design and replicates the measuring environment. Problem areas – such as the plug gap in the connector, as seen here – can be identified and the quality of various solution concepts can be compared in an assessment.

Depiction of the magnitude of electrical field strength for testing the housing for EMC leakages or problem areas. In this case, the housing is perfectly sealed. No radiation is being released.
A connector or connector system’s tightness requirement can be required for very different reasons. A high-pressure water cleaner, for instance, requires an IP69K-tightness compliant connector to ensure the long-term functioning of the facility (e.g., in railway technology). A connecting cable for data transmitted from a sonar or camera to a submarine must remain watertight even at a diving depth of 1,000 meters. The high-voltage feed-through of a high-vacuum system requires connectors that are reliably tight in a high vacuum of $1.3 \times 10^{-6}$ mbar. The task becomes particularly interesting when different seals in connectors must also withstand such additional challenges as vibration, chemicals, mechanical shock or thermal shock, i.e., warming up in the air and spontaneous cooling down when immersed in ice water. Material stress under such framework conditions is enormous and must not impair tightness, as this could potentially cause failure of the connector technology.

ODU has the necessary expertise for developing and manufacturing connectors that meet particularly demanding requirements for tightness and ultimate compressive strength. This development of suitable connectors is based on our profound knowledge of materials, application-specific choice of sealing methods, command of different sealing techniques, comprehensive FEM calculations and required experience.
SECURE CONNECTIONS FOR HIGH-PRESSURE AND HIGH-VACUUM APPLICATIONS

Vitaly important security for technical diving equipment

Many divers like to use oxygen circulation devices called rebreathers. The exhaled air is led back into the system via a second tube, processed and oxygenated. A number of sensors in the computer-controlled system ensure that the exhaled air is properly processed according to the respective situation. The dive computer in a rebreather such as this is fitted with an ODU connector system that, in a stretched position, is watertight up to 21 bar nominal pressure. Similar specifications apply to high-performance diving lamps used at great depths or in other low-light areas, e.g., wreck or cave diving. In both applications, tightness was achieved by combining a sealing technique and special seal ring. Additional provisions were taken for increased seawater and corrosion resistance.

Fail-safe application in water management

The secure and efficient management of hydroelectric power stations and public water supply and disposal systems requires the measurement of flow volumes in the piping systems. Replaceable sensors are built into the piping system. An ODU connector links them to the electric signal line. Depending on its use, the connector can be placed either in the drinking water, in an up to 1,000 meter-high downpipe of a pumped-storage power plant or in the piping of a sewage treatment plant. It must therefore meet a wide range of specifications, including high resistance to a varied range of chemicals, watertightness up to 100 bar and compliance with German KTW approval for drinking water. A failure in either the sensors or the connector would necessitate unscheduled maintenance work which would bring the system to a standstill. For this reason, ODU connectors for applications such as these are equipped with a redundant sealing system for pressure levels of up to 100 bar in the cable and several 100 bar at the interface with the receptacle.

Stringent requirements in oil industry applications

Several systems for controlling and monitoring piping systems are used in the oil industry. The hardware is typically located in the pumping medium and therefore must be able to withstand the conditions of that medium. Pressure shock resistance of up to 50 bar or compression of up to 550 bar are typical requirements, along with complete tightness when cleaned with a steam jet cleaner and tenside solutions. A particular challenge arises from the combination of the water in the steam jet and the tensides, which are used to reduce the water’s surface tension. Thanks to glass potting, ODU is able to meet all the relevant electrical, mechanical and compression specifications of such systems.

High-speed feedthrough in a high-vacuum situation

For the ITER fusion research project, ODU and the Karlsruher Institute of Technology (KIT) have jointly developed a high-voltage, high-vacuum feedthrough suitable for transmitting signals directly from the superconductive coils from the vacuum tank to the monitoring unit. Inside the cryostats exists an isolating vacuum of approximately $1.3 \times 10^{-6}$ mbar that enables the superconductive coils to cool their operating temperature to approximately -260 °C. A maximum permissible helium leak rate of $5 \times 10^{-9}$ mbar l/s was specified for the feedthrough. Unlike the materials typically used here, such as ceramics, glass or specially treated metals, ODU used a high-performance plastic, in this case an electrical line sheathed in polyimide. The connection of two separate high-voltage cable sheathings was only able to be achieved using plastic insulators and special resins.

Extreme requirements of high-voltage feedthrough: The leak rate must be extremely low and the materials must be suitable for use in reactor construction as well as for high-vacuum applications. In addition, electricity must be reliably transmittable from one side of the vacuum container to the other on an inner conductor at a voltage level of 56 kilovolts.
In general, redundancies should be avoided – but not when it comes to questions of safety, or as with connectors, tightness in extreme boundary conditions. The right combination and coordination of different tightness concepts or procedures enable us to create long-term stable sealing systems that ensure the reliable functioning of connectors. The combination of a classical O-ring with glass potting demonstrates such a sealing system.

**Application-specific sealing rings**

Apart from the various sealing methods, the precise layout of the sealing rings in the sealing system is a central factor for permanently safeguarding the specified pressure-tightness. This depends on many crucial aspects: the choice of a suitable cross-sectional shape for the sealing rings, their diameter and the cord size as well as the geometry, tolerance and nominal dimension of the seal seat. Our development department’s wide range of resources enable it, for example, to calculate the expected elastic deformation of the sealing and seal seat as well as the compression level. This provides important information about the correct geometry of the seal area and reduces development time by securing the design of the sealing system at an early stage.

**Glass potting technology for the highest pressure levels**

Since materials with high mechanical stress resistance are used in glass potting technology, extremely high pressures must be successfully managed. Depending on the construction size, ODU achieves up to 1,000 bar burst pressure as well as extremely low helium leak rates of $1 \times 10^{-9}$ mbar l/s for a variety of applications.

Successful glazing presupposes knowledge, in addition to experience, and the selection of appropriate physical parameters – such as thermal expansion coefficients, E-modulus and transversal contraction. Even the diameter ratios and wall thicknesses are to be included in detail. As only a limited selection of materials are suitable for glass potting, the right design can compensate for these restrictions.
Sealing processes can be applied to different geometries, construction sizes, construction forms and connector numbers in a highly flexible manner. These processes are therefore especially suited to sealing products required in small batches but in many different versions. ODU’s sealing methods have successfully included epoxy resins, polyurethanes and silicones for many years – for the ODU MINI-SNAP and ODU AMC product series, but also for many application-specific connectors, too.

Due to the special quality requirements around sealing, the process is typically performed in specially prepared production rooms in which the temperature, humidity and cleanliness are monitored. The ongoing control of process parameters in the production process is as much a part of the quality control system as the extensive measuring and testing in the development phase and on the serial product. We manage this using a broad range of laboratory equipment for the testing of protection classes, for example. To test gas-tight receptacles, we use a helium leak rate method based on a mass spectrometer.

High-pressure test station
Through the use of forming gas (95% N₂ / 5% H₂), the gas tightness of a connector of up to 200 bar can be determined. The detection of possible leaks is carried out with a specially developed sniffer probe that can detect hydrogen test gas.

Helium leak rate measurement
ODU performs tightness tests for our gas-tight receptacles using the helium leak rate procedure according to DIN EN 1779 A1.

Quality stability through automation: here, the ODU AMC connector.

Ideal production conditions: In climate-controlled cleanrooms, the sealing is carried out automatically, or manually in the case of small batches – as seen here.
Automated crimping technique:
Large series are assembled along highly automated assembly lines.

ODU has the relevant expertise for developing and manufacturing reliable solutions that are stable for the long term even for critical, performance-limiting termination areas. To achieve this, ODU mainly uses three termination types: screw, solder and crimp. Solder and crimp terminations are most widely used on the cable side, and crimping is used particularly in highly critical applications. Therefore, the more detailed focus here will be on crimp termination.

The termination of the connector is often underrated regarding its impact on the performance and functioning of the overall connector system. The transition from the connector to the cable is a critical area when it comes to the flow of current and heat. An incorrect layout may limit the system’s overall performance. This is true for high-voltage and high-speed applications as well as for high-current and high-temperature applications. When extreme requirements are added to this, such as temperature fluctuations or vibration and shock, it means the termination area is under permanent stress.

The termination for a perfect connection

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The ideal crimp connection constitutes a non-detachable, gas-tight, permanently corrosion-free and contact-reliable connection between the connection cable and the contact. It is highly stable against vibration and applied force, as well as resistant against environmental conditions such as high temperature, thermal shock and humidity.

The crimp connection is created by means of the exact crimping of the conductor and contact material. This process involves the contact-welding of the metals at the pressing point, thereby leading to a gas-tight connection. Neither liquid nor gaseous media are able to penetrate the crimp under normal atmospheric conditions, which prevents oxidation between the crimped single wires, among other things. The mechanical and electrical requirements for such connections are defined in the IEC 60352-2 standard.

In addition to parameters such as the material properties, the structure of the cable or single conductors, and the current and thermal load, the right crimp geometry in particular must be determined and established for fault-free crimping. This is decisive for the quality and long-term stability of the crimp connection.

The layout of the application-specific geometry of a crimping involves experience and the use of the ODU crimp database, which has grown over the years. The development process is naturally supported by ongoing FEM calculations and measurements that accompany the development, such as the current-carrying capacity. Each new strand-contact combination is precisely aligned at ODU, and the quality of the crimp connection is confirmed by means of comprehensive laboratory tests. This is also when the parameters to be checked during manufacturing are defined.

Flexible connection technology:
1. In the upper part, a high-quality solder termination. Below this, a socket contact with the adjustable hex crimp developed by ODU crimped on a fine-wire strand.
2. The FEM simulation shows the stress within the material. The adjustable crimp profile results in a highly balanced stress distribution in the crimp barrel.
3. The micrograph of the transverse section shows a flawless pressing of the cable strands; the crimp barrel has no cracks.

The right layout:
An extensive database makes it possible to create a reliable forecast map of crimp processes by means of FEM simulation. In addition to making visible the quality of the pressing operation of the wires (Ill. left), it also makes it possible to reliably recognize critical stress conditions in the case of over-crimping of the material. To the right, an optimally crimped layout.
PUTTING TERMINATION TECHNOLOGY TO THE TEST

In order to ensure the long-term stability of crimp connections, comprehensive test scenarios are sometimes required. Only through the detailed knowledge and understanding of the connector’s future application area can the tests be precisely and specifically coordinated.

Comprehensive tests and consistent checking

The entire crimp qualification is specified at ODU in the PB 1120 in-house standard.

- The visual inspection of the crimping by means of microscopy. In this part of the test, particular attention is paid to material cracks or scratches on the surface.
- The crimping height is measured by means of a micrometer screw – for process control in later serial production. The measurement of the crimp height shows perfect compression around the contact’s conductor.
- Determination of contact resistance via the 4-wire measuring method. The electrical resistance is decisive for the capability of the connection to conduct electricity. An excessively high electrical resistance is an indication of an insufficiently broken-up oxidation layer of the single wires.
- Assessment of the polished sections using the metallographic microscope as well as documentation regarding the compression level and thus the quality of the crimp connection. The formation of the originally round single wires into irregular rectangles provides information about gas-tightness. The crimp barrel must also show a slight deformation on its inner surfaces and exhibit no gaps.
- Tensile tests regarding the draw-out strength of the connection cable and a comparison of the standard specifications. This test also determines existing damage to strands or incorrectly set crimp tools.
- Environmental and aging tests are performed on the crimp connection in an application-specific manner.
- Following series release, the contact resistances, crimp heights and draw-out strengths of the strands are inspected and documented during production prior to each production batch.

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As described in the previous chapters, the termination and cable can have a decisive impact on the overall system. Therefore, a perfect connector system offers a perfect interplay of the contact, termination technology and cable assembly. To ensure this, we offer our customers complete solutions in which potential factors impacting the system’s properties have been carefully assessed. FEM simulations also ensure the specified functionality of the product early on in the process.

For applications that are all about high currents, EMC, high temperatures and tightness, providing a high-quality connector – and leaving the termination technology and assembly to the customer – is simply not enough.

CABLE ASSEMBLY

Cable assembly delivered by the connector manufacturer – one-stop connector technology.

FROM A SINGLE SOURCE – THE SYSTEMS APPROACH

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Our flexible production enables us to carry out cable assembly under economically viable conditions both for small batch sizes as well as for large-scale serial production. This ranges from AWG 36 strands with a single connector diameter of 0.127 mm to the processing of AWG 2/0 strands with a single connector diameter of 10.5 mm, and from IPC soldering for military applications to high-temperature-resistant crimping in the automotive sector. We can also produce head shrink parts and tight silicone overmolding for medical technology applications.

We know what it takes to turn a high-quality connector into an equally high-quality and reliable connector system.

Flexible and expertly – with a regional presence

Our cutting-edge production facilities in Europe, China and North America enable ODU to make local deliveries to our worldwide customers or in combination with logistics services – so we can guarantee the shortest of delivery times. Our sites, processes and assembly facilities are always state of the art and deliver first-class service and quality. At ODU, standard procedure means 100 percent testing of each and every assembly.
Functionality, reliability, quality and security are key features in connectors and systems. A profound understanding of the underlying physical interrelations is necessary to ensure them. It’s also important to confirm the mechanical and electrical properties of the products in every development and design phase through numerous qualification tests along the way as well as strict quality control during production.

Our Technology Test Center – T²C for short – is the central linchpin for application-specific baseline investigations as well as for the development and use of many different testing procedures. In this double function, the T²C delivers the all-important knowledge base for the technical development of connectors and systems.
SPECIAL MEASURING TECHNOLOGY AND TESTING PROCEDURES

It’s not rare for ODU to test the limits of what’s physically viable both in the development and the manufacturing of new products. We consider state of the art the minimum dimension of what can be achieved. But this requires measuring and testing equipment that isn’t always available on the market. That’s why we develop and build it in-house. Experience, calibrated measuring devices, skilled personnel and fixed testing procedures are the basis for reproducible measuring results and the right layout of mechanical and electrical connector parameters. At the same time, measurement and testing results constantly extend the database from which these very extensive and reliable simulation procedures are pulled.

Central testing procedures – exemplified

Mating cycle testing – the yardstick of a long service life

ODU is known for contacts that offer a particularly high number of mating cycles with consistent functionality. Depending on each application, up to one million mating cycles can be reached. The balance between high mechanical load capability and long-term stable electrical transmission properties is decisive. ODU’s testing equipment developed in-house, especially for mating cycle testing is used for measuring the most important contact features even during development. In addition, contacts can be energized during the cycles. The testing device thus delivers a reproducible picture of wear and contact resistance under real-life ambient conditions.

High-voltage measurements for security

In the design of a connector, the correct dimensioning of clearance and creepage distances and adjusted choice of materials is laid out to resist high voltage. Partial discharge measurements and high-voltage testing confirm the design during the product development process. Thanks to our fully automatic 5 kV high-voltage test bench, error-free processing is also ensured during production. This integrated approach guarantees the highest quality standard and longest service life for the customer.

The mating cycle test simultaneously records the contact resistance and mating and demating forces of each process (an ODU in-house development).

Fully automatic serial high-voltage testing – an ODU quality standard

Individual evaluation (7,040 cycles)
PREMIUM QUALITY THROUGH COMPREHENSIVE TESTING SYSTEMATICS

At this point, not all of ODU’s in-house measuring and testing methods, which are also an expression of the company’s consistent quality strategy, can and should be listed. The examples of procedures named here are those upon which ODU places particular value and where the particular application knowledge contributes to the continuous development of product functionality.

Special electrical testing

- Measuring stations for current-carrying capacity for particularly high currents used for testing temperature-dependent energy transmission (derating)
- Testing station for partial discharge: for ensuring the long-term stability of a high-voltage connector
- For data-bus applications: network analyzer for measuring insertion loss, return loss, crosstalk as well as TDR (time domain reflectometry) for recording impedance profiles
- Measurement of EMC stability (EMC = electromagnetic compatibility) using the standard triaxial measurement method

Comprehensive mechanical testing

- Continuous recording of the lowest forces and contact resistances
- Monitoring of wear and friction coefficients as well as evaluation of climatic load
- Targeted and tested selection of surface materials in regard to vibratory stress: using a specifically developed testing device that can reproduce friction paths of 10 to 100 μm

Application-specific material selection and testing

- In-house material science laboratory for the selection of materials and surface finishes: mechanical testing methods, chemical analyses and micro-section preparation
- ODU’s own material database with comprehensive data portfolio, also available for future applications
- Chemical area of laboratory: testing of media resistance and autoclavability based on E2 13485 medical product regulation
- An extensive equipment pool is available to simulate environmental conditions, including cold, heat and humidity chambers. Salt-spray fog chamber, extensive testing equipment for environmental conditions such as in off-shore or military sectors.
- High-pressure chamber for testing maximum tightness
- Helium leak rate measurement equipment: for high-vacuum applications

Wide range of tests in ODU’s own test laboratory:
1. By means of a testing machine, the key mechanical data of basic materials – even temperature-dependent ones – can be determined via force transducer and extensometer based on tensile test pieces.
2. S-parameter measurements of an assembled data-technology connector in quality assurance.
3. The S-parameter measurement on the network analyzer ensures transmission characteristics for data and reports.
ODU’s experience and understanding of electrical connector technology makes it an ideal partner – particularly around customer- and application-specific products. Many of our special developments have now become part of our standard product portfolio. Custom modifications are often based on catalog products. This interplay between standard and customer-specific connectors and systems has been an especially formative part of our more than 75-year-long history. This is a specialty area of ours where we continuously adjust and redefine the limits of the technically viable and the economically sensible.

We’re a creative company that continues to attach great importance to inventiveness, innovation and technical progress for the long term. At ODU, we’re fully prepared to take on tomorrow’s challenges – and amaze our customers with our connectors in the future, too.