



Hybridisation

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In developing new ways to hybridise connectivity, BIRNS is pushing the boundaries of performance in one small package

Today's subsea connector industry is benefiting from an array of advanced technology, including state-of-the-art connectors – elegant solutions that can include combinations of electrical, optical and coaxial contacts along with mechanical terminations. Industry trends of making things smaller, stronger and faster have resulted in such hybrid designs becoming increasingly popular, as they provide far more flexibility to designers of subsea vehicles and systems.

There are a myriad of reasons for wanting a connector to do the work of many while only taking up the real estate of one – reducing weight, size and even cost while increasing capabilities, and having one connector deliver the performance of what would have otherwise taken several in the not too distant past. However, by definition, hybrid connector designs require manufacturers to combine electric contacts, optical fibres and/or coax contacts in the connector's backshell space, a process not without its complexities. The advantage, though, is one clean, compact solution requiring a single hull penetration.

BIRNS, Inc. has a long and successful history, starting in 1954, of changing the face of technology in the subsea industry, and has been engineering these complex hybrid connector systems in the BIRNS Millennium series for years. The company



The 30-2F2 combines electrical and optical contacts in a small, one-inch hull penetration

is an industry leader in creating such custom connectivity solutions for its customers worldwide in demanding markets from subsea research, military, hydrographic and vehicle control to HD cameras, tracking and sensors. The BIRNS Millennium series is versatile and robust with high density six-kilometre rated dry-mate connectors that can be used with solid or oil-filled cables in straight or 90-degree configurations. The connectors are available in high and low voltage, coax, fibre optic and hybrids of electro-coax, electro-optical, electro-opto-coaxial and electro-opto-mechanical (EOM) formats. Developing such hybrid connector solutions requires numerous careful engineering decisions, given the intricacy of combining and terminating different types of contacts, not to mention the demands of the subsea environment itself and what is often prolonged usage of vehicles and other devices. Plus, it is key to make informed decisions before combining fibre, electrical contacts and coax contacts and their integration into a design from its inception to achieve the

maximum advantage of the technology.

BIRNS' hybrids usually include electrical contacts, all of which have 50 micrometres of hard gold plating for superior data transmission and provide performance properties that are ideal for subsea systems requiring power and fast data transfer. BIRNS electrical contacts for a high-density hybrid connector were recently successfully



With BIRNS' breakthrough coaxial contacts, pin configurations like the 3P-2C6, which include two coax contacts and six electrical pins, offer the industry its first coax connectors with both open face pressure rating and superior signal performance





in connectivity

tested to MIL-S-901D: Grade A, Class I, Type C and MIL-STD-167-1A, TYPE 1. BIRNS Millennium series inserts have insulated solder pots to minimise electromagnetic interference, noise and cross-talk and are available with both high (≤ 3.6 kilovolts) and low (≤ 600 volts) contact combinations.

Integrating fibre requires finesse, but is ideal for demanding applications that require massive data rates, while requiring a connector with a minute footprint. The series' optical configurations provide combinations of single-mode or multi-mode fibres and can be paired in hybrid configurations with both high and low voltage contacts and mechanical load bearing greater than 50,000 pounds (22,700 kilograms). Typical insertion losses per ANSI/TIA/EIA-455 for cable assemblies with single-mode are 0.1dB, and for multi-mode 0.25dB. Designers of end solutions generally must determine whether to use single-mode or multi-mode fibre, based on a number of factors. The distance or bandwidth will influence the decision to use single-mode or multi-mode – long distance generally indicates the use of single-mode fibre, whereas those developing shorter distance or low bandwidth applications will find multi-mode preferable. It is also important to note that if the system's fibre needs to be routed through tight bends, multi-mode may be necessary, as it is less bend sensitive than single-mode.

SMALL BUT MIGHTY

An exceptionally popular hybrid connector that combines electrical and fibre contacts is the BIRNS Millennium 3O-2F2, with two



BIRNS created a massive custom EOM cable assembly for a work-class ROV with a cable with a 35,000-pound breaking strength in straight pull and 10,000-pound in side load

optical fibres and two 16AWG electrical contacts. It is chosen for a wide range of subsea system applications due to its size, weight and performance attributes. This configuration is frequently used by BIRNS customers when developing AUVs where space and weight considerations are at a premium. This hybrid connector is extremely versatile, given its powerful design and performance capabilities in a tiny footprint – it can transmit gigabits of data per second and more than 24 amps of power with just a one-inch (2.5-centimetre) diameter hull penetration.

Cameras are another popular application for the 3O-2F2. In fact, a recent BIRNS customer needed the six-kilometre rated connector for the housing of a new hyperspectral camera that required options for tilting on an ROV. BIRNS provided a solution in an oil-filled cable assembly (3O-2F2-CP-OF-CA) with two single-mode fibres. Still another solution was provided when two titanium flanged receptacle 3O-2F2 custom cable assemblies were requested for a naval contractor for an application that would

need to be submerged in salt water for nearly 20 years.

BREAKING BARRIERS IN COAXIAL CAPABILITIES

Coax connectors are ideal for GPS-frequency systems, large data and HD video signal applications. However, coax connector development has historically had some limitations not found in electrical or optical connectors, in that open face pressure resistance was not an option. BIRNS recently developed completely new proprietary radio frequency (RF) technology that has yielded coax contacts with unheard of performance attributes, including open face hydrostatic pressure to depths of 1433 metres, so far in just initial testing protocols. To achieve this breakthrough, BIRNS designers optimised transitions to prevent extrusion and minimise impedance discontinuities, and also incorporated seals made of low dielectric constant materials to prevent leakage under pressure.

BIRNS hybrid connectors with these new RF contacts have had trailblazing testing





BIRNS developed a unique side exit design to facilitate cable routing for this EOM cable assembly, which included Millennium 3O and 3T optical and electro-optical hybrid connectors

results, including a maximum insertion loss of 0.7dB at signal frequencies to three gigahertz, with an associated maximum standing wave ratio (SWR) of 1.7:1. Plus, this new design offers both significant ease of assembly and connects directly to a standard MIL-STD-348 subminiature version A (SMA) connector.

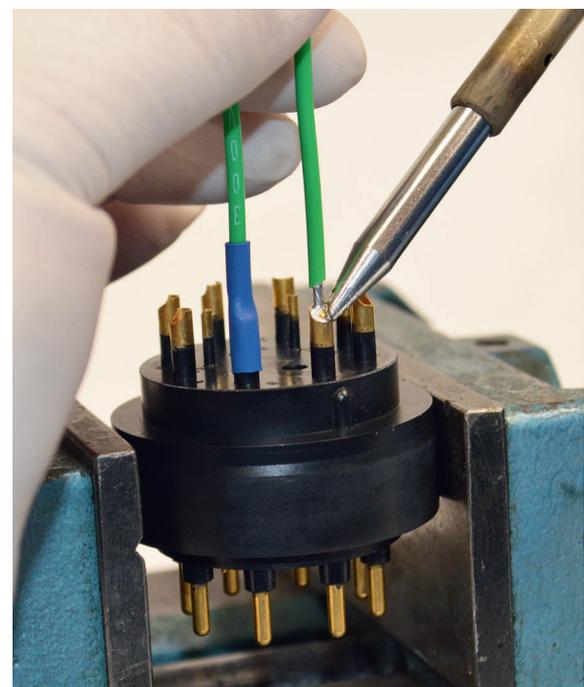
BIRNS offers a number of shell sizes which are available with impedance of 50- or 75-ohm and most can be hybridised with electrical contacts and/or optical ferrules. A popular hybrid coax pin configuration is the BIRNS Millennium 3P-2C6, with two 50-ohm coax contacts, four 16AWG electrical contacts and two 22AWG electric contacts – all in one compact connector with a diameter of just 1.94 inches (4.92 centimetres)¹. This configuration has already had tremendous success in the military market, particularly within the towed array field for submarines and surface ships.

A TRIPLE THREAT

Electro-opto-mechanical cable assemblies must deliver the best of all three worlds, and in so doing, provide immense performance capabilities. These complex systems are developed with precision to preserve the integrity of the fragile optical fibres, as they often are also required to have high voltage contacts placed in close proximity to the optics, and then include mechanical protection. BIRNS is renowned for its EOM solutions, which deliver huge levels of power, signal and data and withstand extreme environments, while providing enormous load strengths.

One challenging but exciting example was a project in which BIRNS was asked to develop a highly specialised electro-opto-mechanical cable assembly to be used on a 7000-pound (3175-kilogram) work-class ROV. The vehicle required a connector that had three fibres, three high voltage contacts and a termination that could, if need be, lift the entire vehicle out of the water by the connector from the surface, and also provide quick disconnect ability. The overmould also served as a bend-limiting device; hence a single shot was needed in order to have continuous mechanical properties throughout the overmould. BIRNS designed the massive connector needed, with extreme mechanical strength, along with capability to handle high voltage and delicate optical fibres. The cable assembly included a BIRNS Millennium flanged receptacle (FR) mating pair with three 10AWG conductors with 3600 voltage operating current (VAC) and three single-mode fibres. The bend limiting device was the overmould itself, and the BIRNS team built an in-house custom pull test up to 20,000 pounds (9072 kilograms) for the mechanical testing of the massive assembly. The cable

A technician electrically terminates a 3T-2F12. The solder pots are insulated with glass reinforced epoxy (GRE) partway up the shaft, and shrink fit tubing then covers the GRE, ensuring a completely insulated termination and eliminating EMI



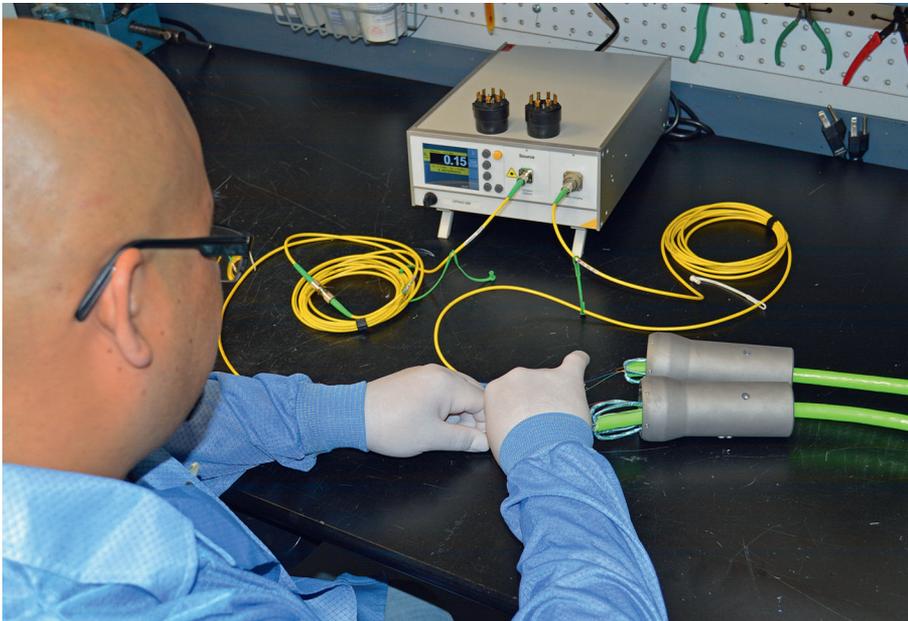
had a 35,000-pound (15,876-kilogram) breaking strength in straight pull mechanical capability and 10,000-pound (4536-kilogram) side load requirement.

While the huge ROV tether was an interesting engineering challenge, not all hybrid connectivity projects today are even a fraction of that size, yet still offer impressive performance characteristics. One such recent project was a customer specialising in smaller AUVs and subsea vehicles. The team needed an EOM cable assembly that included a hybrid cable with a Kevlar strength member and a rear-exit mechanical termination for an unarmoured tow cable with a breaking strength of 8000 pounds (3629 kilograms). BIRNS developed a unique side-exit mechanical termination design to facilitate cable routing, which included BIRNS Millennium 3O and 3T optical and electro-optical hybrid connectors.

The system required a lightweight, yet high performance solution, so BIRNS' custom option integrated a hybrid BIRNS Millennium 3T-2F12 connector. It featured 12 electrical contacts, eight of which were high voltage, and two optical fibres, but the connector was a mere 2.63 inches (6.68 centimetres) in diameter². The two optical fibres' surfaces on the connector insert were just 0.1 inches (0.3 centimetres) from the three-kilovolt 14AWG contacts³. It required

¹Dimension listed is that of the CP's coupling ring. ²Dimension listed is that of the CP's coupling ring. ³Electrical gap, versus centre distance.





Left: An electro-optical connector is tested with the Opto-Test insertion and return loss meter to test and measure loss on tiny optical fibres on multiple connection points at once on a hybrid electro-optical cable assembly with a 400-foot (122-metre) cable. Below: A complex hybrid connector with four coax contacts, two fibres and 67 electrical contacts is tested by BIRNS quality personnel on an ENA network analyser

exact precision in the development of the inserts in order for them to perform perfectly and consistently for the application that would include extended submergence operations at great depth.

Another custom EOM project required BIRNS to design a rear-exit mechanical termination fork for a stainless steel armoured hybrid tow cable assembly. The BIRNS engineering team devised a solution that included the development of a modified mould approach to form strain relief for the sub-cable. This cable assembly also included a BIRNS 3T-2F12-CP connector with single-mode fibres, terminated and overmoulded to the wet end.

PUTTING IT TO THE TEST

One of the many ways BIRNS has remained an industry leader on a global scale for more than six decades is through achieving the highest quality and training certifications, and performing the most advanced testing protocols. The company's quality management system is ISO 9001:2008 certified by DNV GL, and its world-class cable shop is SUBMEPP-certified to NAVSEA S9320-AM-PRO-020. The company serves as an independent testing resource for other organisations, as well as providing economies of scale for hydrostatic and helium pressure testing of its own products. BIRNS' custom-engineered hydrostatic pressure testing system has digital data recording capabilities and can be controlled remotely or via automatic programming.

BIRNS' powerful electrical test system was also custom-designed and permits the simultaneous testing of up to 16 electrical circuits, automatically, with up to 99 different programmable test sequences, at voltages of up to ten kilovolts, while subjected to hydrostatic and hydrodynamic pressure. In the development and testing of hybrid optic connectors, production team members use tools like an Opto-Test insertion and return loss meter to test and measure loss on tiny optical fibres on multiple connection points at once. For testing hybrid connectors with RF contacts, BIRNS technicians utilise ENA network analysers that provide accurate and repeatable decibel loss and voltage standing wave ratio (VSWR) measurements

in the 300kHz to 20GHz test frequency range. For its advanced inspection protocols required for hybridised connector solutions, BIRNS uses digital inspection equipment, like a Mitutoyo, Japan, DCC CMM (coordinate measuring machine) and Mantis 3D binocular scopes with digital imaging, and all digital precision measuring instruments. BIRNS also uses an advanced video measuring system, which combines the capabilities of an optical comparator with digital video, high-resolution cameras, telecentric optics and LED lighting.

BIRNS continues to lead the industry in the development of new ways to hybridise connectivity. Whether it is inventing new coaxial contacts or combining multiple types of different contacts in high density pin configurations, the path to advancement lies in innovation and precision. The result will be even more sophisticated, robust connector solutions manufactured to exacting tolerances and rigorously tested, all capable of pushing the boundaries of performance in one small package. ■

