element14 ESSENTIAL

Connectors IV: Sealed Connectors

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1. Introduction

The need for compact connectors has grown in recent years as products have become increasingly smaller and the space available for all the necessary electronic components has become challenging. High-current applications also create the need for larger-gauge wires, compromising compactness. Many industrial and commercial applications experience wet conditions in washdown or other harsh environments, so compact sealed connectors take on a greater role in overall electronics packaging. Moreover, there is a growing trend to draw more power from a smaller, more durable, IP67-rated connector. This learning module will discuss the concepts, characteristics and design of sealed connectors used today in space-constrained applications, as well as introduce you to the Molex Squba Wire-to-Wire connectors.

2. Objectives

Upon completion of this learning module, you will be able to:

- Discuss the difference between a sealed and an unsealed connector.
- Explain the important elements of connector design.
- Understand the IEC/EN 60529-based ingress protection (IP) rating system.
- Describe the primary sealing techniques of electrical connectors.

3. Scope

A connector is a device that consists of a housing and contacts used to create a separable low resistance electromechanical interface. Connectors must be durable to withstand the mechanical forces of the application, and they must resist the corrosion that may occur and deteriorate the connection over time. While there are many types of connectors, ranging from component-to-board, board-to-board, wire-to-board, and wire-to-wire, etc., when categorizing connectors based on environmental application (e.g. washdown, high-temperature, dust, etc.), there are two broad categories to consider: unsealed connectors and sealed connectors.

- **Unsealed connectors:** Unsealed connectors are used in applications that do not require the level of environmental protection that would be necessary in harsh environments that include vibrations, dust, water, or debris. Unsealed connectors will often be applied within interior electronic modules, appliances, or in controlled environments within an enclosure.

■ **Sealed Connectors:** Environmentally sealed connectors are typically used in heavy-duty and harsh-environment applications. They are specified to fit a wide range of uses that require ruggedized sealed plugs, receptacles, and power connectors, offering IP67/IP68 ratings, along with space savings. Like unsealed connectors, sealed connectors offer additional features, including a positive lock for secure mating and polarization. Some sealed connectors have a spring-beam terminal design for high pressure and high-vibration applications.
The scope of this learning module is to focus on the basic concepts and operation of sealed connectors.

4. Basic Concepts

Connectors are one of the most important components in an electronics product design. They are the pathway by which electronic signals are routed through the sub-components of the systems or between sub-systems in a complex product or machine such as automation machinery, a robot, or a process control system. Connector performance depends not only on the specific design of the connector, but also the operating environment and the number of cycles the connector is inserted/removed from its socket/receptacle. Beyond the apparent connector design, the choice of contact material influences connector performance. Connectors that are intended to operate in harsh environments (i.e., corrosive, wash-down, high-pressure, high-temperature, etc.) are usually sealed to ensure the contact interface is not contaminated.

- 4.1 Review

Let us briefly review the three important factors to consider when designing a connector: voltage/current, contact metallurgy, and housing design.

■ **Voltage and Current:** Voltage and current levels are perhaps the two most important factors to consider when designing a connector. A signal connector is generally rated for less than 1 amp, while a power connector is usually rated for more than 1 amp. The temperature rise is heating due to current flow through the connector's contacts, above that attributed to the ambient temperature of the environment. A 30°C temperature rise is the generally accepted maximum value as stipulated by the standards organization Underwriters Laboratories, based on safety considerations, but this recommendation depends on the application. Signal contacts are typically gold plated to minimize contact resistance. Signal contacts are used in low voltage applications, while power contacts can handle high voltage applications; in both cases, this is due to voltage separation requirements and safety considerations. Not only must continuous voltage and current be considered, but also surges and EMI.

■ **Contact Metallurgy:** The choice of the contact material depends on a combination of concurrent factors such as cost, mechanical requirements, electrical requirements, and size limitations. Copper alloys are used in a wide range of contacts. Brass (copper-zinc alloy) is commonly used because it balances conductivity (electrical), strength (mechanical), and cost requirements. But brass corrodes, so a plating system is usually required. Phosphor bronze (copper-tin-phosphorous alloy) is used in electrical contacts for its strength, corrosion resistance, and spring properties. Beryllium copper is used in electrical connectors for its hardness, electrical and thermal conductivity, corrosion resistance, and resistance to stress relaxation. Tin, nickel and silver plating are part of the non-noble group. While less expensive than gold, they do suffer from corrosion. Oxides form on non-noble platings, which can cause fretting corrosion and thereby increase the resistance of the contact interface, creating a

potential reliability issue. In signal connectors, an increased contact resistance prevents conduction of the electrical signal, while in power connectors, heating can lead at some point to total failure.

- **Connector Housing:** Connector housings provide the necessary insulation between contacts in a connector, termed as Dielectric Withstand Voltage rating. They also provide a mechanical function by ensuring the contacts in each half of the connector-socket system mate properly. The housing determines creep and clearance between the contacts. Finally, the housing typically includes an environmental protection function in order to protect the contact interface.

- ***4.2 Environmental Protection***

As mentioned in the previous section, the connector housing serves the important function of preventing contamination of the contact interface. Contamination is prevented by incorporating sealing devices within the housing. Sealing devices typically comply with the internationally accepted ingress protection (IP) rating classification system as per IEC 60529 (European Equivalent, EN 60529). The first digit is applied to protection from solid objects, while the second one applies to moisture. It also should be noted that EN 60529 does not specify sealing effectiveness against mechanical damage of the equipment, risk of explosions, condensation, corrosive vapors, fungus, etc.

First Digit	Solid Object Protection	Second Digit	Moisture Protection
0	Not Protected	0	Not Protected
1	Protected against solid object greater than 50 mm	1	Protected against vertical falling drops of water. Limited ingress permitted.
2	Protected against solid object greater than 12.5 mm	2	Protected against falling drops of water with enclosure tilted up to 15°. Limited water permitted.
3	Protected against solid object greater than 2.5 mm	3	Protected against sprays of water up to 60° from the vertical. Limited water permitted for three minutes.
4	Protected against solid object greater than 1 mm	4	Protected against water splashed from all directions. Limited water permitted.
5	Protected Against Dust. Limited ingress of dust permitted. Two to eight hours.	5	Protected against currents of water. Limited water permitted.
6	Dust Tight. No ingress of dust. Two to eight	6	Protected against powerful jets of water. Limited ingress permitted.

First Digit	Solid Object Protection	Second Digit	Moisture Protection
	hours.		
		7	Protected against the immersion in water between 15cm and 1m for 30 minutes.
		8	Protection against submersion for long periods of time.
		9k	Protected against close-range high pressure, high temperature spray downs.

**Table 1: IP Ratings. Note example, IP67: Provides dust tight protection and protection against the immersion in water between 15cm and 1m for 30 minutes.*

The IP rating system defines protection against both solid objects and different levels of moisture and/or sprays. Solid objects include hands and fingers. In other words, environmental protection design includes the prevention of human beings from touching electrical contacts, which could be a safety issue when live circuits are involved. To protect against solid objects, connector housings can have recessed contacts or enclosed arc chambers to provide a physical barrier to fingers touching the live contacts. For connectors that will be used outdoors, housings will have a UV rating. For connectors used in harsh environments where mechanical shock or impact is likely to occur, the housing will either be metal or will be fortified with a special polymer material. For high ambient temperatures, housings will be made of thermoset material, as required.

- ***4.3 Sealing Techniques***

There are a wide variety of seals and sealing techniques, including but not limited to: static, rotary, mechanical, magnetic, reciprocating and high-pressure seals. There are two types of seals used in applications that are the focus of this learning module: hermetic and environmental sealing.

Hermetic seals are typically used in vacuum applications that require not only tightness, but also do not allow detectable leaks through the seal. Glass-to metal hermetic seals are common in electrical connectors. These seals are made of a metallic housing, sealing glass, and a contact. Hermetic compression connectors are designed by using a metallic housing that has a higher coefficient of thermal expansion than the sealing glass. During manufacturing, the housing contracts around the glass to create a compressional seal. Besides electrical connectors, hermetic seals are often used in thermostats, optical devices, and switches. Environmental seals are used in outdoor and commercial applications, including exposure to water and sprays, rain, dust and debris, etc. While not airtight, the function of environmental seals is the same: to protect the contact interface. For reliable mating and un-mating operations, environmental seals are typically manufactured with fluoropolymers or ethylene propylene rubber. They are classified with the IP ratings established by IEC, NEMA, or other standards organizations. The value of the IP rating systems is that it tells the conditions by which a connector can be used safely, as well as the limitations of the connector.

5. Analysis

The miniaturization of electronic components, from semiconductors to passive devices, has recently driven much of the product development in portable computing devices, appliances, and the general category of space-constrained devices (e.g., handheld test equipment, computing tablets, digital assistants, etc.). As electronics packages respond to this trend, so must connectors.

Combining a low-profile with high current carrying capability and a high level of environmental protection can be a complex design scenario. Molex Squba sealed wire-to-wire connectors fulfill these requirements in offering a connector that can be used for a wide range of space-constrained applications, along with high current ratings, and an IP67 rating. With their wide variety of inserts and housings, these connectors are suitable for applications involving signal or power transmission. In this section let us examine (or teardown) a Squba sealed connector to see how it is designed.

Squba Sealed Wire-to-Wire Connectors are designed with an IP67-seal rating when mated and carry up to 14.0A of current to deliver signal and power. They are available in 2 to 10 circuits, with an operating temperature range from -40 to +105°C. They use copper terminals with a tin plated contact interface that's terminated with 22 to 24 AWG wire using Molex crimp technology. They are typically used in applications such as consumer, industrial, commercial vehicular, and the connected home.

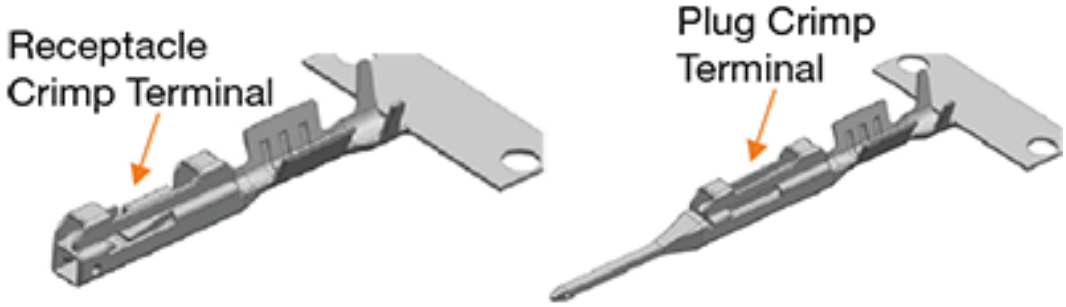

Figure 1: Connector Terminals

Their higher performance rating, which gives the ability to transmit a higher current rating over a smaller gauge wire, is achieved through the strength of the female contact. The terminal features two contact points and two serrations in the conductor crimp area to provide better electrical and mechanical performance.

Figure 2: Low-profile, positive locking, thumb latch

The connectors offer a number of mechanical features in the overall housing assembly that facilitates its use in space-constrained applications. A protected, low-profile, positive latch

prevents wires from getting caught or damaged, and ensures full mating and prevents accidental un-mating during normal operation. A wraparound insulation crimp provides security against seal punctures. Clean-body terminals also avoid seal punctures. A primary lock enables 30N terminal retention to enhance reliability and withstand vibrations. A polarizing rib ensures proper orientation during mating. A light audible click is heard to indicate fully mated connectors.

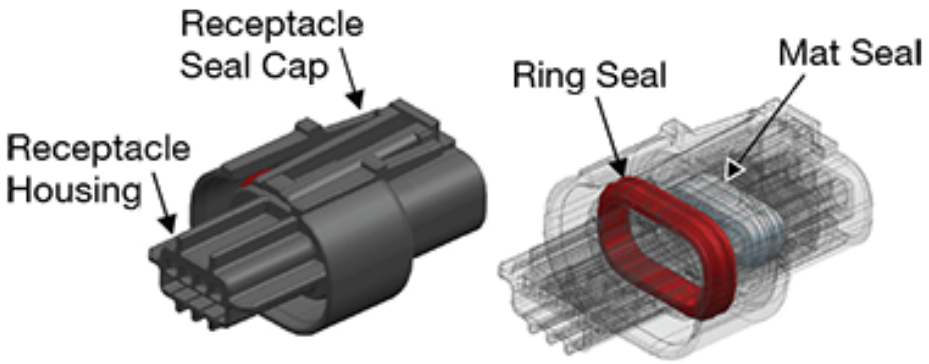

Figure 3: Connector Assembly

The Squba connector consists of a plug housing, plug seal cap, ring seal, and mat seal. Sealed components delivers an IP67-sealed rating when mated to prevent ingress of dust and water. The terminal and housing are designed with silicon seals and other features that will provide some light resistance during insertion as well as retention.

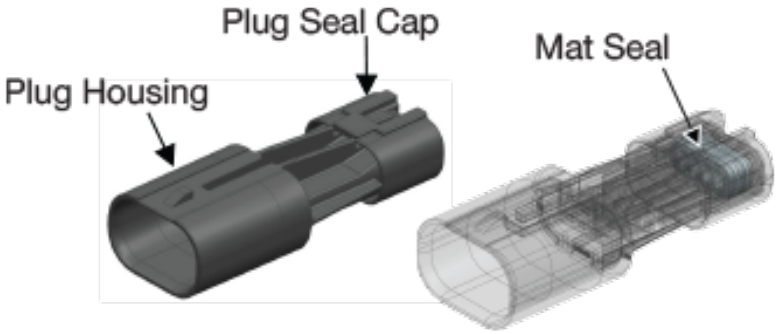

Figure 4: Plug Assembly

They are designed to take into account the probability of seals being damaged during assembly, handling, or shipping. To prevent this from occurring, they have caps to protect seals. Caps guide terminal insertion to protect the seal from being punctured by terminals during assembly. Specially designed caps provide sensors, lighting, and commercial equipment with a durable barrier to protect products from moisture and dust.

6. Glossary

- **Contact interface:** the point or zone where both halves of an electrical connector-socket system are mated and where current flows through.
- **Corrosion:** the deterioration of a metal as a result of chemical reactions between the metal and the environment.

- **Enclosed arc chambers:** a safety feature of an electrical connector's housing that shrouds the live contacts and isolates them from human contact during opening or closing the circuit.
- **IEC 60529:** the International Electrotechnical Commission (IEC) standard for Ingress Protection. It defines the degrees of protection provided by enclosures as it is applied to commercial products.
- **NEMA:** The National Electrical Manufacturers Association. A US-based organization that represents nearly 325 electrical equipment and medical imaging manufacturers that make safe, reliable, and efficient products and systems.
- **Noble material:** chemical elements that have a very high level of resistance to oxidation. The noble group includes rhenium, ruthenium, rhodium, palladium, silver, osmium, iridium, platinum, and gold.
- **Plating:** a manufacturing process by which a thin layer of metal coats a substrate.
- **Polarization:** a connector design technique used to assure that connector halves mate properly.
- **Seals:** a device that is used to join two components while at the same time preventing leakage.
- **Space-constrained:** a term applied to a very low profile electronic package that requires either miniaturized components or a downsizing of the number of components.
- **Temperature rise:** the increase in temperature as a result of current flowing in a conductor.
- **Washdown:** high-pressure cleaning conducted in the food/beverage and pharmaceuticals industries.
- **Wire gauge:** the apparent measure of a wire's diameter. It determines the amount of current that can be safely conducted through the wire.

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