CAN Newsletter Online

CAN NEWSLETTER MAGAZINE

Selecting a connector system for harsh environments

This article gives a deep insight into the aspects to be considered when selecting a connector for use e.g. in mobile working machines. These include the connector's CAN connection, IP protection, wire sealing, contacts, mounting, flammability, etc.

(Source: Adobe Stock)

The complete article is published in the September issue of the CAN Newsletter magazine 2020. This is just an excerpt.

The world is full of different connectors. Connectors are available in many different shapes, sizes, materials and colors. It might seem that selecting a connector sys- tem to suit perfectly in the intended application is a trivial task. But there is a lot more to it.

Most connectors are located in such environments that do not pose too strict requirements for the connector system in terms of size, shape, current throughput, ingress protection levels, vibration performance and so on. But when you start to list the requirements of a mobile working machine environment, the options to choose from narrow down drastically. Connector systems should support the design of a high-quality system built on top of a machine and therefore there is a lot more to a high-quality connector than just high ingress protection level. From system architecture and harness design point of view, the right amount of contacts is important so that the harness stays simple and easy to assemble and service. The ability to withstand vibration and high acceleration mechanical shocks is vital. Also, extreme temperatures are often to be found in mobile ECU (electronic control unit) operating environments.

Connectors are obviously not the only components in the control system that must withstand harsh environments, so the connector design must support high quality ECU and wire harness design. Manufacturability of wire harness or ECU is crucial when electronic systems get more complex and the price must be kept in control.

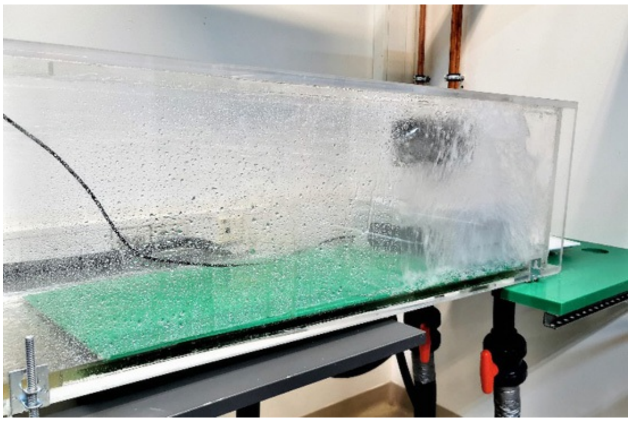
This article has been written to help a mobile working machine builder, electronic control system integrator, system architect or an ECU design engineer in their job by providing important points that should be taken into consideration when selecting a connector system for demanding applications.

System architecture

To begin with, a simple question is how many wire connections per connector is suitable for the application. If you have a single unit that controls several small auxiliaries all over the machine, you probably want to have a lot of connectors with small amount of contacts in order to keep the harness simple. On the other hand, you might want to keep the assembly and unit change simple and go with one connector with the cost of more complex wire harness design. A common way to build machines is to dedicate one medium to high I/O (input/output) unit for one section of a ma- chine. This often provides room for some auxiliary device expansions.

Equally important is to determine if the communication buses are routed through the same connectors as sensor inputs and control outputs or if they have their own connectors. Traditional communication protocols such as CAN and serial protocols such as EIA-232 and EIA-485 can be routed through almost any kind of connector with no need for uninterrupted external shielding or only short untwisted section of a twisted pair cable. High-speed communication protocols such as Ethernet or USB (universal serial bus) are widely used in mobile machinery today. These kind of communication protocols need external shielding for cables and are quite sensitive to untwisted and unshielded sections. So, in order to use such protocols, a separate high-speed connector or a hybrid connector needs to be used. Since these signals not only require specialized connectors but also the cables need to fulfill certain

Typical operation environment for an ECU (Source: Epec)



IP65 test performed inside acrylic tube (Source: Epec)

requirements, often off-the-shelf cables are preferred. When using a hybrid connector, it should be noted that these cables are routed within the power and IO-cabling.

CAN design considerations

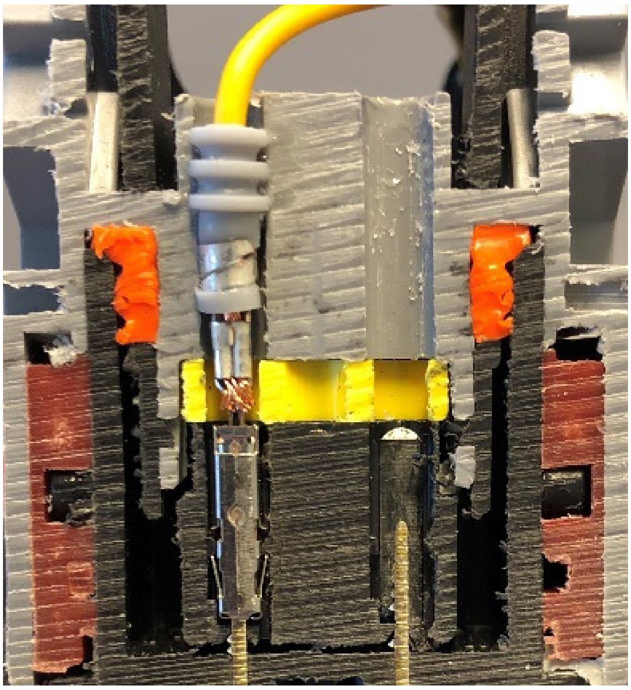
Electronic control units in mobile machinery communicate with each other with almost no exceptions via a field bus. CAN has established its place as the industry standard for more than 20 years now. As the amount of data increases, Classical CAN is also evolving from maximum bit-rate of 1 Mbit/s to CAN FD (Flexible data rate), which can reach up to 5 Mbit/s. Also, next evolution versions of CAN are in sight, CAN XL will someday reach the bit-rates up to 10 Mbit/s.

What kind of requirements does CAN set to the connector system? CAN is a robust and fault-tolerant field bus, and especially at bit-rates below 500 kbit/s it is not too picky on the cable nor the connector. But when the bit-rate increases from 500 kbit/s up to 1 Mbit/s or even higher, the significance of a proper signal path provided by the cable and the connector system becomes more relevant. Even more so, when the environment is critical in terms of EMC (electromagnetic compatibility) and the CAN emissions must be kept low and the tolerance against external electromagnetic fields high. For most demanding applications, a tight twisted pair with 360-degree shielding is the way to go. The connector system must support this with short untwisted length of the signal pair and secure the cable shield connection.

CAN bus uses a differential, single twisted pair signal that has a characteristic impedance of 120 Ohm. The bus must be terminated with 120-Ohm resistors from each end of the bus. Also, a ground return path shall be pro- vided between nodes, and, if cabling incorporates shielding, this should be able to connect to the connector also. To connect CAN sensors to the system, a supply voltage to the sensor is needed too. So, to take all scenarios into account, it is required to have five connector pins for a single CAN interface. For sensors, a 5-pin A-coded M12-connector is the choice of most manufacturers, since it serves almost all features a properly cabled CAN would need. The only downsides are bulky (and costly) cables and cable branching. For a more common ECU connector (rectangular plastic connector) a perfect design would incorporate the following features:

- CAN bus cables separated from I/O cabling,
- inbuilt selectable bus termination resistor, and
- the possibility to branch the bus to the next ECU or sensor.

Designated ground and shield pins for each CAN bus are very useful as well. Sometimes the service technician will want to connect a diagnostics tool to the CAN bus. A perfect connector design would make this both easy and simple.



Single wire sealing (SWS) example featuring TE Connectivity's Leavyseal connector (Source: Epec)

Protection against environment

Anyone who has been dealing with harsh environment systems is usually familiar with most common IP (ingress protection) classes. But what distinguishes these different protection classes from each other? Here we focus only on dust tight IP6x classifications since these are the most common ones to appear in waterproof connectors. Both, IP65-rated and IP66-rated devices have to withstand 3-minute water spray tests from 2,5 m to 3 m distance, with different nozzles and water flow. In IP65, the nozzle diameter is 6,3 mm and water flow 12,5 l/min. These figures add up to approximately 0,3 bar pressure. For comparison, IP66 water flow is significantly higher, 100 l/min from a 12,5-mm nozzle. That is almost two times the diameter of an IP65-nozzle, and the pressure for IP66 is around 1 bar, more than three times higher as the pressure of IP65. Both tests are normally made with roughly room-temperature water, the deviation between EUT (equipment under test) temperature and water should be kept smaller than 5 °C. IP67 is probably one of the most recognized tests, a static immersion test in 1-m deep water for half an hour.

IP68 is also a static immersion test, but in this test the depth and the immersion time is specified by the manufacturer. So, if one sees the IP68 classification, it should always be accompanied with specification for immersion depth and time. Currently the highest classification IP69/ IP69K represents equipment that is protected against high-power steam washers. In practice, there is quite minimal difference in the testing procedure between IP69 and IP69K. IP69 is specified in the IEC 60529 and IP69k in the ISO 20653 standard. Both are generally used, but ISO 20653 is more often used in the automotive industry. When one looks at a sealed connector, there is one big difference between IP69-/IP69K-rated connectors compared with the lower classifications. In IP69/IP69K the sealing material (silicone in most cases) is usually protected by harder material (plastic/metal) since the water spray is so intensive that the seal would easily fail if a direct water spray hits it. To give a rough idea of the IP69 tests compared to lower classification spray tests, here are the important figures: 15 l/min, 100 bar pressure with water temperature of 80 °C.

Also, one important note is that IP classes are only cumulative up to IP66. This means that if a device fulfills IP67 it does not automatically gain IP66 classification, if it is not tested separately. A device designer or system designer should also take into consideration that most of the weatherproof connectors fulfill their ingress protection classification only mated with a corresponding connector. Some connectors can have different ratings for mated/unmated connectors, but if the manufacturer does not specify this accordingly, the assumption should be that the rating is for a mated pair only. So, if some connectors are left unconnected in a system, cap/sealed empty connector must be used to provide for the proper protection of the whole system.

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