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APPLICATION NOTE

Cu connection technology

RJ45 – The standard-compliant all-round plug for requirements in industry and buildings

P | Cabling

RJ45 – The standard-compliant all-round plug for requirements in industry and buildings

From telephone plug to high-tech plug system for future applications

Management Summary

The RJ45 plug is a technically decisive component within "structured cabling". Designed for the ambient requirements and adapted to the physical properties of the cabling, it contributes to the performance of the entire network. Industrial Ethernet and use in building automation presents entirely new tasks for the plug, which has now become an essential part of office communication.10-GBit-compatible and compliant with the requirements of cabling in industry, it has already become a small piece of high tech today. It makes a decisve contribution to the reliable functioning of the entire network and thus offers reliable investment protection over many years.

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RJ45 from telephone plug to high-speed plug system

The RJ45 has maintained its position for more than 30 years as the allround plug for data transmission systems.
In addition to cable, outlet and distributor, it is an important part of the "application-neutral communication cable systems" defined in the European standard DIN EN 50173. In contrast to requirements cabling, with which the cables are laid as they are currently required, this cabling takes into account all potential applications over years and keeps reserves. It is also referred to as "structured cabling" and is an integral part of a modern property. To meet the requirements of "structured cabling", the features of the RJ45 plug systems must also be ideally adapted to the features of the cables.

Since its first days, its outer form, which is defined in the DIN EN 60603-7-x, has been unchanged.
It has a very compact constructional design and offers 8 contacts and a screening. With standard RJ45 plugs, cables are connected by means of the piercing contact technology using a so-called crimping tool.
Modern plugs opt for the insulation displacement termination technique that offers much greater contact reliability. As a result of these and many other technical further developments and optimizations, it has remained the top-notch solution in data transmission to date.
The RJ45 is the standard plug for 4-pair (8-wire) data cables. It has been primarily used in office communication up to now but more and more applications are using it. Reason enough to examine the RJ45 and its environment more closely, to dispel wrong ideas, highlight new scenarios for us and to take a look at the latest technical developments.

Fig. 1: RJ45 connector plug

The outlet legacy

Up to now, it has always been assumed that every network device requires a wall outlet. This is also assumed by the relevant standards. But a new class of devices is taking over the building network – Devices that are firmly installed and no longer require an outlet as a mandatory measure.
When a device is to be connected to a LAN, the first thing that the fitter looks for is the wall outlet.
Each terminal connection (TA) should have its own outlet! This is how it is defined in the DIN EN 50173-1 standard. First an outlet is set as a hand-over point and then the final cabling is laid to the end device – This has been the generally valid standard in structured cabling since the introduction of the 1995 standard and is not in question.
This procedure originates from power cabling. Here, it is also necessary to avoid risks to people and machines and to be able to disconnect a device safely from the network - in the simplest case by pulling the mains plug.

These safety concerns do not apply to Ethernet. The setting of installation outlets, however, is also justified there. For instance, PC workstations in offices are not always fixed to one place. In the course of the usage of such rooms, the connection points move so that it is easier to provide a fixed installed wall outlet from which the PCs are then served with flexible patch cables. The temporary connection of mobile end devices is also then easier to handle.

Only one connection cable is needed for connection and this can be simply removed again after use. But it has to be asked whether this use of outlets is worthwhile in every case.
Network cabling today is no longer used just to connect office communication devices. An increasing number of application areas for communication connection via Ethernet are being opened up.Application areas in which the end devices are not flexible geo-

Fig. 2: RJ45 connector plug

graphically and are also not connected temporarily. For this class of devices, a fixed place of installation is envisaged to which mostly only one installation cable is also laid. An installation outlet could be saved here.
A point that is regularly mentioned in this context is that the setting of outlets is prescribed in this way in the standard. This is initially also correct. In the relevant standards DIN EN 50173 and DIN EN 50174, the connection points (TA) are defined as end points of structured cabling. A copper cabling must involve a socket with eight contacts pursuant to DIN EN IEC 60603-7x. Nevertheless, the standard is sufficiently open in order to permit a RJ45 plug as an end point of the structured cabling in the building. That is already defined for the industrial area in the EN 50173-3 standard.

Connection-free transmission routes

A new philosophy in cabling is being adopted. Scenarios from industry and building technology.

For the foreseeable future too, conventional office cabling will also be one of the main areas of usage of structured cabling. However, use is increasingly spreading to other areas such as industry and building automation.

Installation of WLAN access points

WLAN access points are becoming ever more popular. Whether it is for equipment in private households or in offices, with public hot spots or in the works hall - any area without WLAN access points for the cable-free connection of mobile participants or to open up areas that are difficult to reach by cable is now unthinkable.
In the installation of the devices, the ideal place of use to meet the functionality is first determined. In very few cases, direct access to an existing LAN is then also possible there. This means that usually an additional installation cable specifically for this device has to be drawn to connect a WLAN access point. In this case, you therefore have a cable and precisely one device that has to be connected to this cable. Here, preference is then given to installation without wall outlets. For this purpose, a RJ45 plug is simply installed directly on the installation cable, thus enabling a direct connection of the access point.

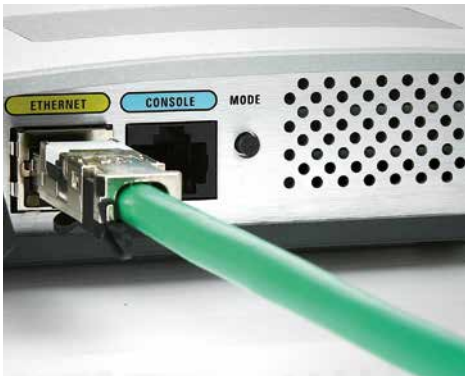

Fig. 3: Direct connection of a network device

Building automation

Building automation with its potential for saving energy and its diverse and convenient functions is moving increasingly into the field of interest of building operators. Automatically controlled ventilation, the monitoring and regulation of the air conditioning, the lighting and blind system, and the central access control require the fixed installation of additional devices, actuators and sensors in each room of the building.

Fig. 4: Direct connection in building automation

Most of these devices are firmly installed behind wall and ceiling claddings or in the flooring and thus invisible to users of the room. In most cases, so-called room operation devices are the only indication of all the hidden technology in use. The communication between the devices is done mostly via building automation buses, such as LON, BACnet or also KNX. More and more manufacturers are changing over to integrating an Ethernet RJ45 connection in their devices, alongside the communication interface for the corresponding bus. They are thus opening up for themselves the integration in the IP communication of the LAN, which facilitates external access

to room regulators or even sensors and actuators. Remote maintenance via the Internet or a simple PC-based control, regulation, monitoring and visualization of process data are just two examples of applications that are conceivable in this manner. The complete communication of the devices among themselves can also be done on a TCP/IP basis. An additional bus cabling would then be obsolete. Here too, each device has its fixed place that is often defined by the application. Even if the device is replaced by another, the place of installation remains. If it is to be integrated into the LAN, an extra cable normally has to be laid to the device. The setting of an outlet does not make any sense. The direct installation of a RJ45 plug onto the installation cable is the procedure of choice in order to connect the device in a cost-efficient and safe manner.

Home automation

However, another class of devices is also found in buildings. So-called white goods, such as a refrigerator, washing machine, dishwasher, or stove. Although the market is not that large yet, there are already initial types of household devices that report their status or which can be controlled remotely via the network interface. Switching on the coffee machine via the Internet using your mobile phone or simply determining and monitoring the temperature of the freezer – all this will be possible in future. With fixed devices, outlet-free installation can indeed make sense.

Industry (Industrial Ethernet)

In a very different area too, the Ethernet communication and thus the RJ45 plug is gaining an increasing share – in industrial automation and production. Like building automation, special field buses such as CANopen, Interbus or Profibus dominate here. Through the integration of Ethernet interfaces, these intrinsically closed systems open up and permit a consistent communication from the office to the individual machine for the first time. Communication of the individual machine parts is the basic requirement for the actual task of automation. To ensure the smooth running of the control system, actuators must react in a foreseeable time. The communication must be strictly deterministic and thus capable of working in real time. Ethernet with the TCP/IP protocol is initially not envisaged for this. Nevertheless, it appears attractive to use low-cost Ethernet mass ware and to benefit from the huge bandwidths of up to 10 GBit/s. Various approaches have developed over the last years to make standard Ethernet capable of real time which are all to be assigned under the generic term "industrial Ethernet". The most well-known examples of this are Profinet, Ethercat, Ethernet/IP and Ethernet Powerlink. Although they are fundamentally different, these systems make one thing possible: IP communication between machines and control units of industrial production. Here, giving each communication participant its own wall outlet today is an impossibility not least due to the restricted space available. The direct connection of the installation cables is the one useful approach.

Fig. 5: Direct connection in the industry distributor

Locations with restricted space available

The lack of space also leads to alternative approaches in network installation in other application fields. For instance, it is necessary in ships and aeroplances to forgo not only outlets but also patch panels. Here, the installation cables are guided directly into the switches; – this not only saves space, it also saves weight. These usage scenarios show: Ethernet and the RJ45 plug are not only at home in office communication. The trend to equip devices and machines with Ethernet connections will continue over the next few years. When we just think of building system technology, it is already foreseeable today that the number of fixed installed devices in the LAN will overtake the number of conventional network participants. One constant in this is the RJ45 plug. But to meet these new requirements, new technical developments need to be made that make it fit for successful use also in the future.

New requirements of an "old" plug.

How a proven technology is made fit for the applications of the future with Cat. 6 and 10 Gigabet Ethernet, simplest and most secure installation and innovative connection technology.

An important main requirement is already visible from the exemplary scenarios on the use of the RJ45: It must be possible to install it directly on the installation cable.

The wire strength

Conventional RJ45 plugs are designed for cables with a maximum wire diameter of approx. 1 mm. This is insufficient for many applications. With installation cables, wire strengths of 1.6 mm can indeed be used. Of these, 8 wires next to one another must fit in a plug. 8 wires wiht a diameter of 1.6 mm next to one another in one plug that may be only 11.63 mm wide according to DIN EN 60603-7-1 – Here, it is no longer possible from a purely mathematical perspective to place all wires parallel to the connections.

Modern RJ45 plugs incorporate the wires for this at two levels. 4 wires each are guided in one level to their connection points. A circuit board integrated in the plugs then combines the connection points with the contacts of the plug. There is thus an integrated wire management in these plugs which also facilitates the packaging for the fitter.

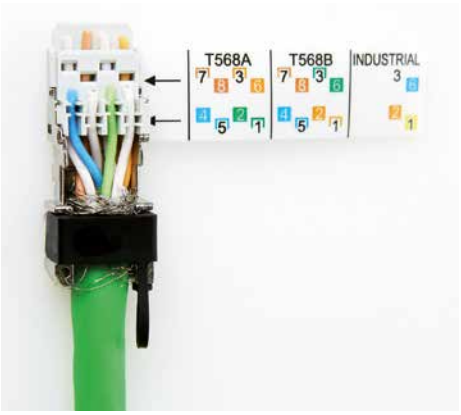

Fig. 6: Modern RJ45 plug with wire management

The cable sheath

In particularly rough environments, particular requirements are also placed on the safety of the entire cable. Total cable diameter of 8.5 mm, in some cases even up to 10 mm, are commonplace.

In cramped conditions, cables with such dimensions, along with the plugs, must also remain compatible with Harmonica Jack. This means in cabling without patch panels, with which the installation cables are laid directly to a switch, those switches must also match next to one another and above one another.

For this purpose, the entire geometry of the plug has an highly streamlined design.

The transmission rate

The requirements of the transmission rate are increasing in all areas. The demands for GBit Ethernet or even 10 GBit Ethernet are growing ever louder, not only with the transmission of multimedia data in consumer electronics devices but also in Industrial Ethernet.

To meet these high requirements, a RJ45 plug must comply with the future standard DIN EN IEC 60603-7-51. In it, the design types for shielded free and fixed plug connectors for data transmission rates up to 500 MHz are specified. These transmission rates can only be achieved with a RJ45 under ideal conditions. This means all contacts must be produced in a simple way and the losses resulting from reflections, insertion damping and overspeaking must be minimized.

Cross-talk

Close ancillary talk proves to be particularly problematic with the required frequencies of up to 500 MHz. Cross-talk between two neighbouring wires result. This is suppressed in the cable by the symmetric drilling and corresponding shielding. In the plug, however, the symmetric drilling and the shielding are no longer available. In the plug, the undrilled and unshielded length of the wire pairs must be kept as short as possible.

Another bottleneck remains, however: the very tight distances between the contacts based on the geometry. Through the specified plug occupancy, the wires of the pairs (3-6) and (4-5) lie unfavourably above one another. Capacitive and inductive couplings result which can be combated by a sophisticated compensation in the interior of the plug.

Simplicity / Contact reliability

The most sophisticated compensation and the best geometry are doomed to failure if there is no correct and permanent connection between cable and plug. In industrial production, the assembly of RJ45 plugs on the patch cable is a fully developed process that is ideally done under permanent quality control. This makes it possible to retain the transmission properties of the cable. The fitter in the field must attach the plug by hand to the cable. Although he normally uses special tools such as RJ45 crimping tools, the plug and tools can come from different manufacturers and are therefore not perfectly aligned to one another. Only crimping tools that match the plug ensure the right "press-in depth" of the contacts in the plug. If it is not pressed in enough, it can result in loose contacts; if it is pressed in too much, the contact can be lost entirely.

During crimping, it is therefore important how firmly and how far the tools are pressed together in order to thus establish the connection between the wires and the connections. A process that is difficult to calculate and which may not offer any contact reliability. In addition, cramped work conditions and also dirt restrict the work of the fitter. In order to guarantee contact reliability, it must be possible for the installation to be implemented as easily as possible for the fitter and without special tools. A field-assembled plug is now used here. This is characterized by optimized insulation displacement connectors (IDC) and simple laying of the 8 wires.

The contact is generated by simply pressing together the two-part plug unit with tools or simply also by hand. This pressing together is done up to a fixed stop, thus ensuring that the wires are pressed into the terminals down to the precisely correct depth.

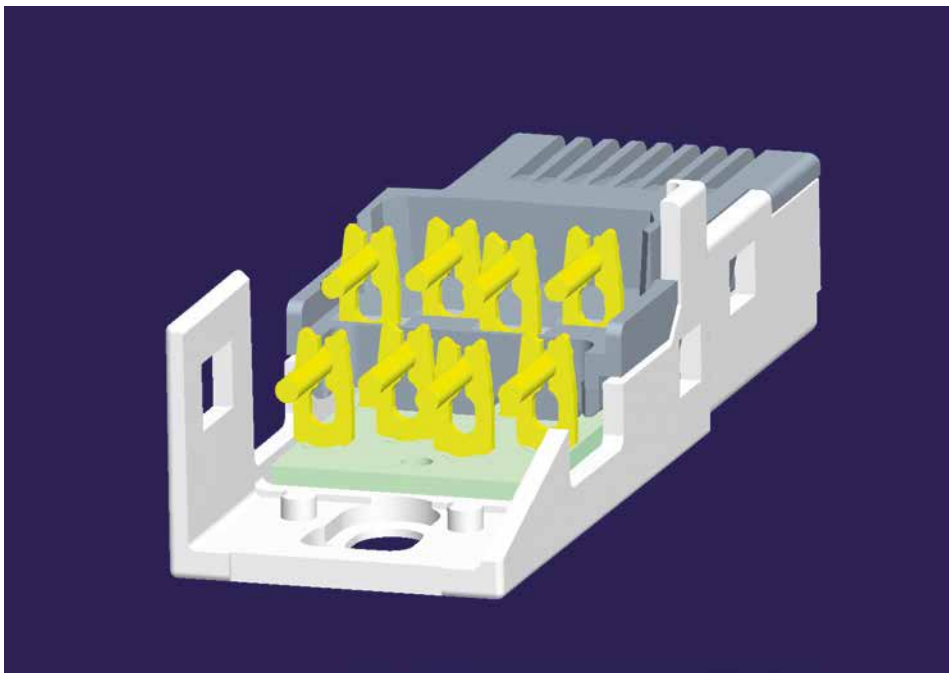

Fig. 7: Insulation displacment connectors (IDC)of a field-assembled RJ45 plug

Conclusion

The RJ45 plug still has a long time to go before it has served its use. Through the penetration of Ethernet into new areas such as building automation and industry automation (Industrial Ethernet), very different requirements are placed on it. With outlet-less installation, it has to adapt to the installation cables. For this purpose, new innovative wire management systems are integrated into the plugs in order to be able to house all 8 wires in the first place. The procurement of all 8 wires (4 wire pairings) again makes the full use of the performance of current cables of the category 6 and 7 possible in the first place. To meet the need for every greater data transfer output of up to 10 GBit, the geometry of the wire contacting was optimized. Elaborate inductive and capacitve compensations integrated in the plug compensate for the unwanted couplings which occur increasingly with the required frequencies of up to 500 MHz and produce the ideal symmetric conditions for the signal transfer.

These high requirements also necessitate an optimized installation technology which makes work easier for the fitter and also guarantees the transmission reliability.

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