TECHNICAL PAPER

Criteria for Selecting Connectors for LED Lighting/Industrial Apps

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Abstract

Connectors used in industrial and solid-state lighting applications pose uniquely challenging design constraints on power density and form-factor while simultaneously demanding the highest reliability under harsh environmental conditions. As a designer in these spaces, one cannot simply prioritize piece cost in the connector selection process. The true value of a connector is much more nuanced and must include the amortized costs of manufacturability, reliability, and safety. Eliminating hand soldering, ease of use, and good yield are not free. Avoiding field failures and product recalls are not free. Regulatory compliance is not free. To best address these hidden costs, designers should choose connectors from suppliers that have already engineered them out. For this very reason, in addition to electrical and mechanical performance, AVX's portfolio of connectors contains many options perfectly suited for industrial and solid-state lighting applications.

KYOCERA AVX

CRITERIA FOR SELECTING CONNECTORS FOR LED LIGHTING/INDUSTRIAL APPS

INTRODUCTION

Connectors used in industrial and solid-state lighting applications pose uniquely challenging design constraints on power density and form-factor while simultaneously demanding the highest reliability under harsh environmental conditions. As a designer in these spaces, one cannot simply prioritize piece cost in the connector selection process. The true value of a connector is much more nuanced and must include the amortized costs of manufacturability, reliability, and safety. Eliminating hand soldering, ease of use, and good yield are not free. Avoiding field failures and product recalls are not free. Regulatory compliance is not free. To best address these hidden costs, designers should choose connectors from suppliers that have already engineered them out. For this very reason, in addition to electrical and mechanical performance, AVX's portfolio of connectors contains many options perfectly suited for industrial and solid-state lighting applications.

CONNECTOR ELECTRICAL PERFORMANCE

First and foremost, the electrical characteristics of a connector must be suitable for the intended application. A brief overview of common electrical specifications is shown below.

RATED VOLTAGE

The voltage rating, also called the working voltage, is the maximum voltage the connector can withstand without deformation or electrical failure during regular operation. It is a function of insulation material type and contact pitch distance.

PROOF VOLTAGE

Proof voltage is a measure of the highest voltage a connector can withstand before it breaks down electrically. The connector is tested near this "breakdown voltage" to ensure it can be safely used below it without surface arcing. A higher proof voltage corresponds to a lower probability of surface arcing failure. It is important to remember that the application environmental conditions can affect the results and is dependent on insulator material, clearance distance, and creepage distance.

CURRENT RATING

Current rating, also known as working current, is the current below which the connector is guaranteed to work normally. It is dependent on the contact material and the contact resistance at the mating surfaces of the conductive elements. Current rating is also affected by operating temperature. When designing a connector implementation, the rated current must be chosen to meet the environmental temperature and heat dissipation requirements.

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CONNECTOR ELECTRICAL PERFORMANCE

CURRENT DERATING

Derating current is a common practice when selecting connectors. The purpose is to restrict temperature rise inside the connector as an extra measure of prevention against exceeding maximum operational limits and, in turn, catastrophic failures. Many manufacturers will provide a current ambient temperature characteristic chart to help the designer determine if the product meets their requirements. A minimum of 20% of additional derating of the operating current is advised.

CURRENT RATING

Continuous current rating @ 25° ambient.

Standard 1, 2, and 3 way 9176 connector 10A

Note: Figures given are for the connector; maximum wire current ratings are still applicable.

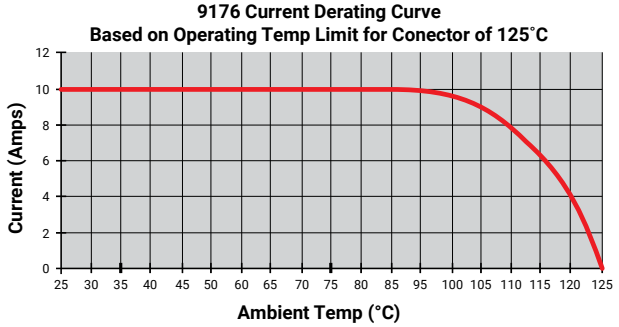

Figure 1: An example of the Derating Curve on AVX IDC 9176 Series Connector

CONTACT RESISTANCE

Contact resistance is defined as the electrical resistance at the joint of two mated conductive elements. For most metals, including copper, the bulk material's resistance is relatively small compared to its contact resistance. It is dependent on contact material, normal force at the joint, and surface treatment of the two conductive elements. Lower contact resistance produces less heat and can be achieved with a tight joint and clean surface treatment without oxidation and pollution.

INSULATION RESISTANCE (IR)

When applying a voltage across the body of a connector, there will be some measurable leakage current through the weakest point of the insulation. Quantification of this weakness is given as the insulation resistance. It is dependent on insulation material, operating temperature, environmental humidity, and environmental pollution.

OPERATING TEMPERATURE

Operating temperature is the specified maximum temperature below which normal operation is guaranteed. Above this temperature, damage will result such as melting of insulation and plastic housing, physical deformation, and even contact damage due to fatigue, oxidation, and plating failure.

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CONNECTOR MECHANICAL PERFORMANCE

Of equal importance to electrical performance is the mechanical performance of the connector. This is especially true in industrial and solid-state lighting applications, where environmental conditions and variability tolerance may be very stringent. The following characteristics are often considered when evaluating a particular connector implementation.

TERMINATION / CONTACT VARIATION

A variety of options exist for contact terminations, including crimped wire, insulation displacement connector (IDC), low insertion force spring contacts, and screw terminals. The designer must determine the effectiveness of the various termination systems available to them and select one that is most suitable for a given application.

WIRE GAUGE

Wire gauge is typically given as a range of wire sizes that wire-to-board and wire-to-wire connectors can accept. The wire gauge will determine the wire's maximum current carrying capability. The designer must clearly define the wire gauge that is safe for their application and ensure adequate derating is considered when selecting the wire gauge to be used.

INSERTION / WITHDRAWAL FORCE

This specification describes the force to mate/separate two paired connectors. The withdrawal force is also referred to as the pulling force. Both insertion and withdrawal force is affected by the connector design, including locking features, wire gauge, crimping contact design, and crimping quality. Withdrawal force also directly affects shock and vibration performance in harsh environments.

DURABILITY

A connector's durability is measured as the maximum number of cycles of inserting and withdrawing the paired connector without failure. All characteristics of the connector should remain within the specified range when the total number of operating cycles is below its durability.

FORM FACTOR

Often, the physical shape and size of the connector become a critical design decision. Solid-state lighting is an excellent example where connectors with large z-heights can create shadows and unevenness in the luminaire's output. For example, AVX offers a line of "naked" connectors with no housing to minimize z-height. This lack of insulative housing also allows for higher current carrying capacity because of improved dissipation of heat, which is often a reliability concern for industrial and lighting applications.

Figure 2: An example of "Naked" wire-to-board connector on LED Lighting arrays

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CONNECTOR RELIABILITY AND MANUFACTURABILITY

In addition to the electrical and mechanical performance of a connector, it is critical to ensure reliability throughout a design's lifetime. Connectors must also perform repeatably throughout the manufacturing process with minimal manual labor, rework, and testing.

HAND SOLDERING ALTERNATIVE

One of the most common pitfalls to avoid when deciding to transition from hand soldering to connectorization is focusing on the connector's cost. Manual soldering of wires to a PCB comes with an inherent labor cost. The usage of a connector eliminates this time and cost and improves the quality and consistency of the final connection. This, in turn, reduces the amortized long-term cost of yield, rework, and product failure.

Figure 3: Example of a one-piece connector replacing hand soldering

The typical expectation of connectors for industrial and solid-state lighting applications is that they are surface mount compatible and easy to assemble in production without complicated and expensive tooling. A popular option is to use a one-piece connector solution. See figure 4 for a brief comparison of the various Wire-to-board solutions' pros and cons compared to hand soldering.

	Hand Soldering	2 Piece Crimping	1 Piece Poke Home (AVX)	1 Piece IDC (AVX)
Assembly Cost (Labour + Material + Productivity)	*** (No Connector, Manual soldering-low productivity)	* (Need preassembly, 2 connector cost)	*** (One contact, wire insertion)	*** (One Connector, wire insertion)
Repeatability Speed of Assembly	* (Poor-slow: manual soldering time)	*** (Fast-quick hand insertion)	*** (Fast-insertion tooling needed)	** (Fast-insertion using tooling)
Reliability	* (Hand soldering quality is people dependent, inconsistent quality)	* or *** (Reliability depending on proper connectors matching and crimp process quality)	*** (High spring force contact, good wire conductor grip)	**** (Solid gas tight contact, good insulation grip, automotive grade reliability)
Repairability Ease to Rework Wires	* (Tidious desoldering and resoldering)	* (Wire crimp hand to remove and rework)	*** (No tooling required; twist and pull removal and reinsert)	* (Pull out with pliers, and reinsert)

Note: **** = Superior
*** = Excellent
** = Good
* = OK

Figure 4: Table of Wire-to-Board Solutions: The Pros and Cons of Hand Soldering vs. Connector Options

Poke home single piece connectors are excellent wire-to-board and wire-to-wire products if repair or replacement may be required. The IDC (Insulation Displacement Connector) technology is the best design for long-term reliability and resistance to environmental changes and conditions.

CRITERIA FOR SELECTING CONNECTORS FOR LED LIGHTING/INDUSTRIAL APPS

CONNECTOR RELIABILITY AND MANUFACTURABILITY

ELIMINATING BROKEN WIRES

Soldering wire directly onto printed circuit boards is considered the most cost-effective solution, but this method doesn't come without risk. Cold solder joints are the main cause of failures associated with hand soldering. If wires are mishandled within the circuit boards, the wires can break. Even if the cable/board assemblies are handled well during manufacturing, the blame is not on the customer for mishandling them, which is why it's essential to design against these types of failures.

When soldering directly onto a circuit board, the wire's strength depends solely on the center core copper wire and the solder. The copper wire is a soft metal and is prone to stress crack or breakage when subject to improper handling forces. This is especially sensitive on thinner wires.

Insulation Displacement Connector (IDC) is an excellent solution to address the broken wire issue. The AVX IDC is an SMD connector designed for reflow soldering — when the wires are pressed onto the IDC, it locks the wire's insulator. This locking results in a high pull strength. It also has additional benefits of gas-tight contacts between IDC and wire interface and is excellent for high humidity and aggressive vibration requirements.

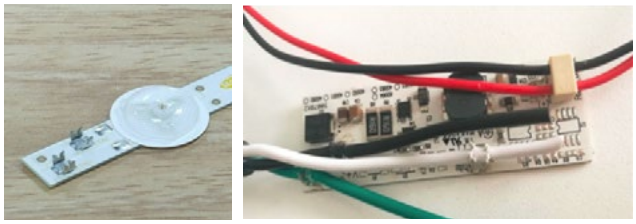

Figure 5: Examples of IDCs in LED lighting applications

COST SAVINGS

To minimize the challenge of cost, AVX developed "Stript" contact technology and tooled a specific product called "Naked" connectors. "Strip" technology is generally understood as removing or stripping the housing body of a connector. They perform the full connector functions while offering low cost, high reliability, and UL approval. These naked connectors are excellent for downsizing and better heat dissipation performance than regular connectors with conductors and insulators.

AVX is currently the pioneer and technology leader in strip contact technology.

Figure 6: Examples of AVX "Naked" Connectors: Connectors without housing

Figure 7: An example of AVX board-to-board connector use: Low profile = shadow effect

EASE OF USE

The AVX poke home is a 1-piece connector product that offers a reliable and straightforward wire-to-board or wire-to-wire connection. This connector only requires that a pre-stripped wire exposing the copper conductor be inserted into the connector. It also has a low insertion force for the wire resulting in its easy installation, and wire removal is tooling-free, meaning it can be removed by simply twisting and pulling the wire. The high spring force contacts provide maximum wire retention to achieve industrial level reliability at temperature and vibration.

The poke home design offers a simple one-hand installation of wire with a one-piece connector. It is widely used to eliminate the hand soldering and gluing process as it improves manufacturing productivity and eliminates quality issues associated with soldered intermittent and broken wires.

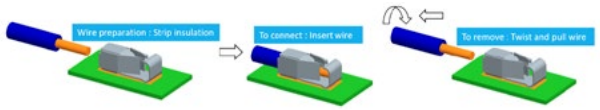

Figure 8: The installation and removal of wires on poke home connectors

CONNECTOR RELIABILITY AND MANUFACTURABILITY

Figure 9: An example of poke-home connectors on wireless charger coils

A ONE-PIECE CONNECTOR SOLUTION

Suppose the final product is shipped to intermediate customers, and mating connectors are used to connect to another assembly. In that case, one must ensure that the male and female mating connectors should be from the same manufacturer with the specified MPNs to prevent potential matching and intermittent contact problems. Alternatively, more innovative single-piece connectors can be used to create a more reliable connection in a more straightforward, cost-effective package.

With the single piece mating solution, only one connector is used to mate directly to a wire, meaning just the gauge of the wire used must be defined. One such example is the use of IDC board mount contacts to daisy chain LED lighting. The power wires are simply pressed into the IDC slot, and a reliable, gas-tight connection is created. No mating connectors, soldering, or crimping is required.

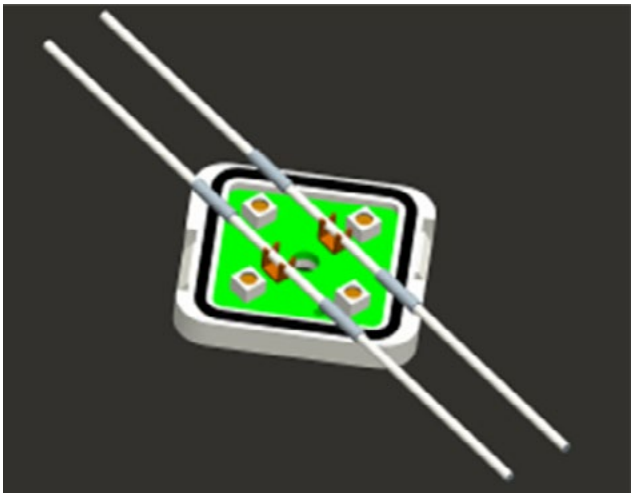

Figure 10: An example of IDC "naked" connectors with wires in daisy chain

Another innovative solution particularly well-suited to LED lighting is the SMD board-to-board connector, which can connect a power PCB to an aluminum array PCB vertically. As shown in figure 11, a rectangular slot is cut into the array to accept the ultra-low profile connector, which is soldered using traditional pick and place equipment. The power PCB is then inserted into the vertical connector to eliminate any lighting shadow and minimize total physical volume while creating a simple, reliable manufacturing operation.

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CONNECTOR RELIABILITY AND MANUFACTURABILITY

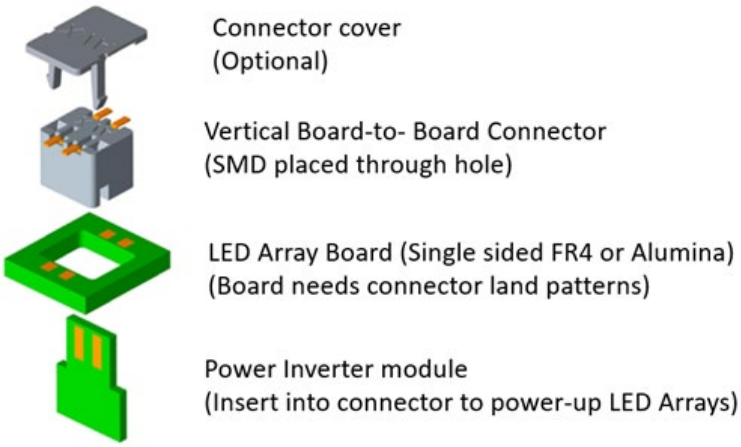

Figure: 11: Installation of a vertical board-to-board connector

This vertical mating solution has been the key to creating LED lighting solutions in traditional bulb-shaped form factors.

Another popular one-piece solution is the vertical poke-home connector, which connects wires on circuit boards with the limited surface area available for component placement. This small footprint vertical poke-home connector requires very little space on the circuit board and is widely used to connect wires from a power supply to the main application circuit board.

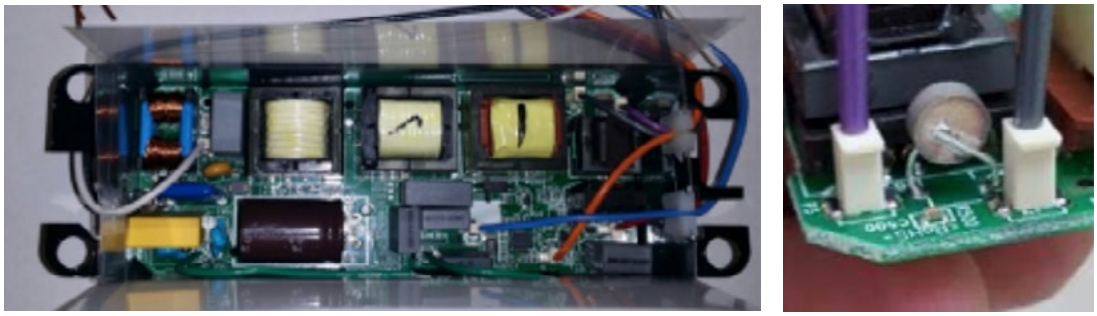

Figure 12: Examples of circuit boards that use the vertical poke-home connectors

CONCLUSION

When considering the connection of PCB's to wires or each other, a myriad of factors must be considered to choose the optimal components. Often, the bill of materials impact the component itself and play a large part in the decision process. In industrial and solid-state lighting applications, however, designers need to be more holistic in their thinking. Once reliability, manufacturability, and performance in harsh environments come into play, one can find innovative and creative solutions that simultaneously optimize all aspects of the connection method. AVX offers various solutions that allow the designer to rely on world-class connector engineering and years of proven performance to guide their decision-making. To learn more, visit AVX's website.

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