SIERRA CIRCUITS

How to Select Connectors

DESIGN GUIDE

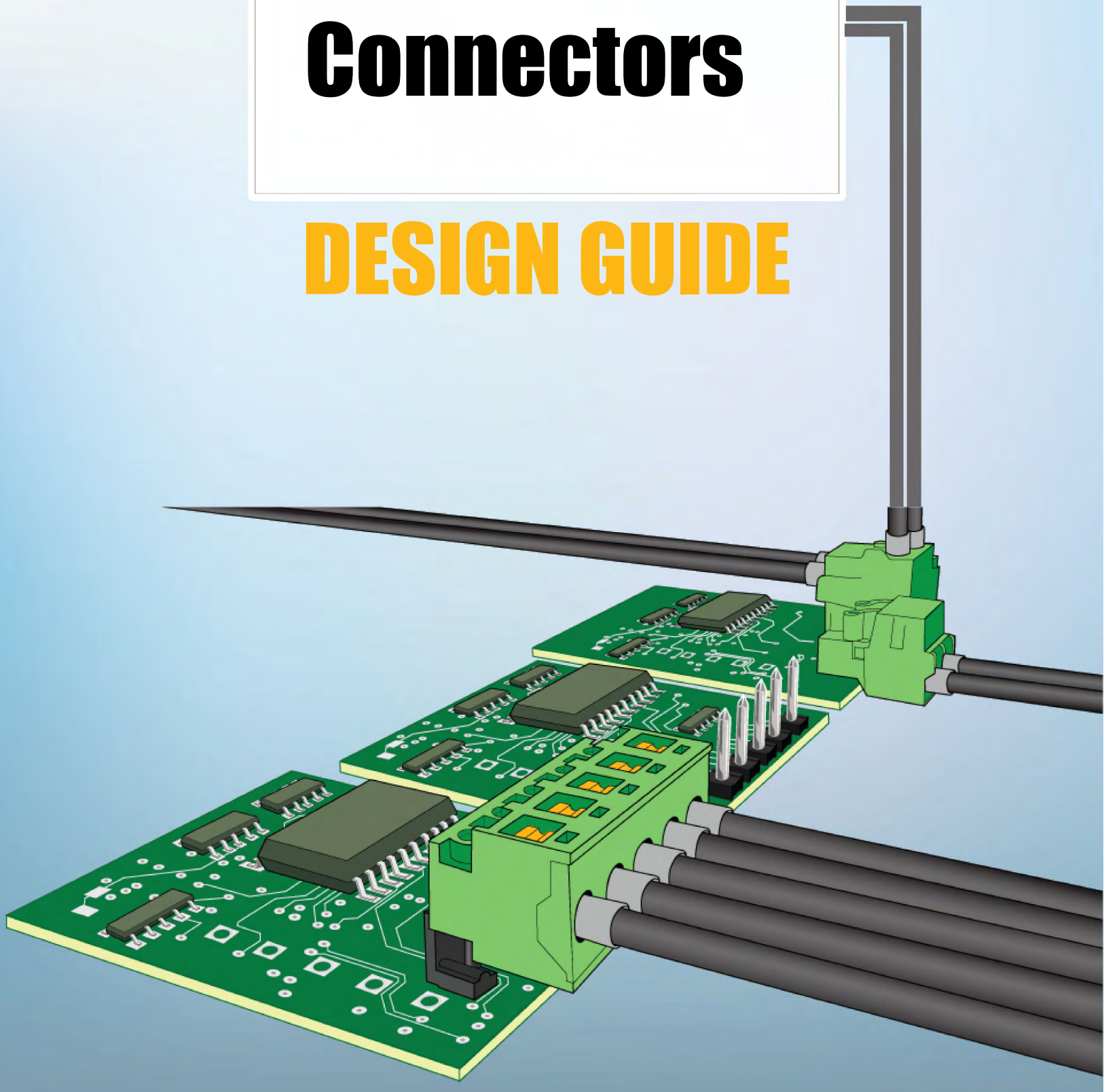


Table of Content

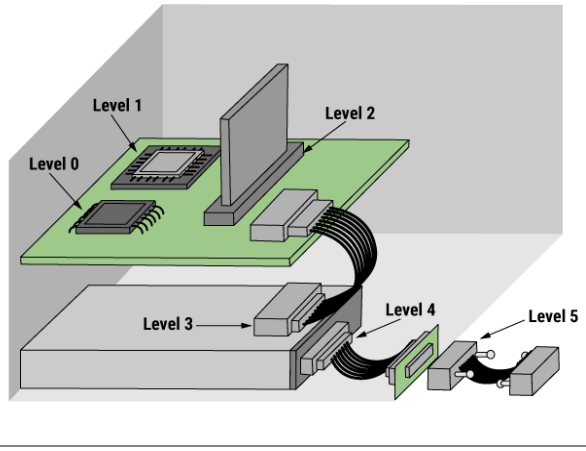
Table of Content

Introduction

When selecting a connector for any application, the first consideration should be what is being connected and what is the end application. Is it required to connect two PCBs or more, or is a cable/wire involved - board to board, wire to board, or wire to wire? This will surely help to decide the type of connector required. PCB connectors can be of different types (shapes and sizes), and their selection depends upon the final application requirement like signal types, power, size, and weight. Connectors carry signal and power from one board to the intended electromechanical component and vice-versa.

An electronic system is a hierarchical interconnection network that enables communication among different electronic devices. Several interconnects are required for signal transmission and power distribution to ensure the correct operation of electric products. Electrical connectors are classified into three types with regard to their termination ends: board-to-board (B2B) connectors, wire-to-wire (W2W) connectors, and wire-to-board (W2B) connectors. The connectors are also classified based on the application like signal connectors, RF connectors, and power connectors. Signal connectors can be further classified as general-purpose, low-frequency, and high-frequency connectors such as USB, PCIe, etc.

Six levels of interconnection (refer to the diagram given below) can be seen in electrical connectors.



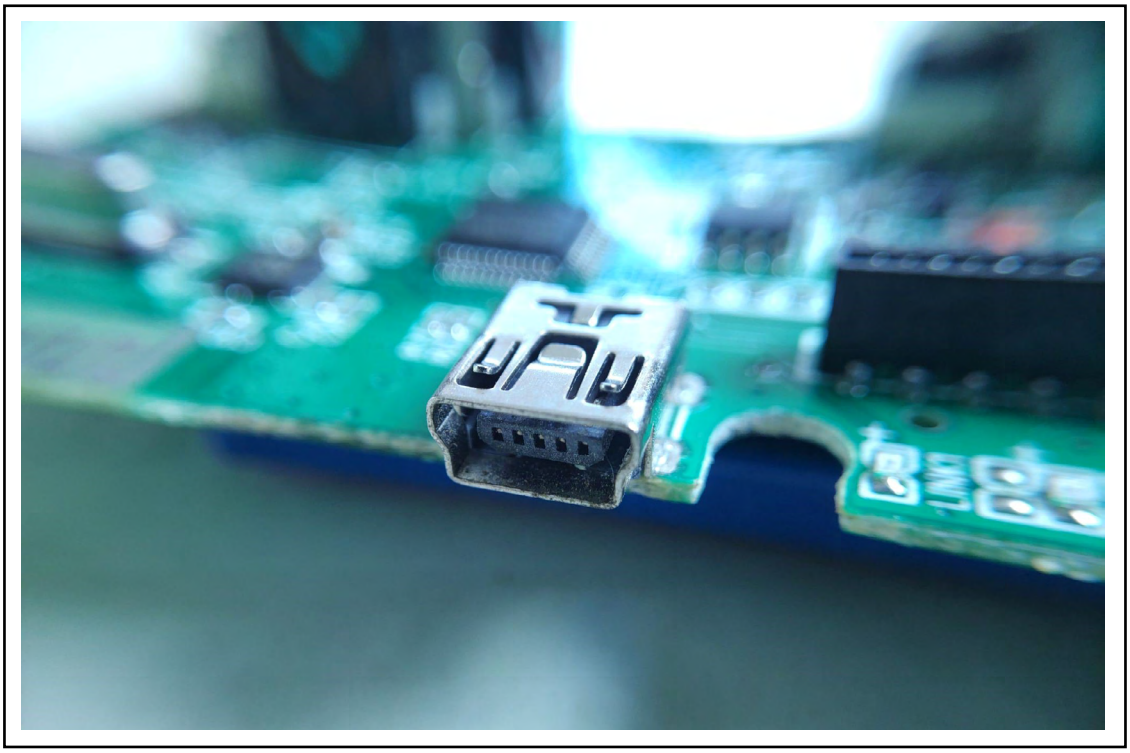
Level of interconnections seen in electrical connectors

- **Level 0** represents the connection between an essential circuit element and its lead, such as the link between a semiconductor chip and the lead frame.
- **Level 1** represents the connection between a component lead and a PCB, exemplified by chip carrier sockets, dual inline package (DIP) sockets, and switches.
- **Level 2** represents the connection between two or more boards. A motherboard–daughterboard connection is typical.
- **Level 3** represents the connection between two subassemblies, such as a power supply and an associated subassembly.
- **Level 4** represents the connection from a major subassembly to the input/output (I/O) port of the complete system.
- **Level 5** shows the connection between physically separated systems.

Selecting the correct connector type is the prime objective when it comes to a reliable system operation. A suitable connector can make your system smaller, lighter, and easy to handle. A connector contact must support the selected conductor size. A non-compatible conductor may lead to overheating issues hence premature connector failure. To avoid future repair costs, perform adequate research before starting the system design process.

1. Connector basics

1.1 What is a connector?



A charging port connector mounted on a PCB.

A connector is a device that provides a specified electrical or mechanical interface between a PCB and an interconnection wiring or between board assemblies without compromising the performance. Typically, circuit board connectors are used to transfer signals or power from one board to another or from another power source within the PCB unit. They provide an easy method of design for manufacture (DFM), as boards are not hard-wired to each other and can be connected together later in the production process.

The connector type, mounting style, and contacts with the leads are decided based on the application. A small connector footprint makes the PCB design less complicated and reduces the cost as well. It also reduces the losses associated with transmission lines while making connections. Connector functions, methods of attaching it to the board, and maintaining enough clearances are major factors to be considered in PCB design.

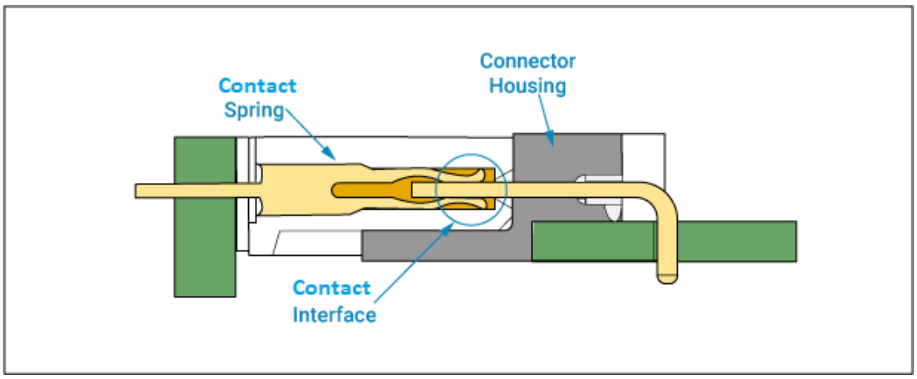
Key point: Connectors are entry and exit points for electrical signals from a product or system. They also act as entry and exit points for unwanted EMI that affects the system or nearby systems badly.

1.1.1 Functions of a connector

- Carry power and signals between circuit boards with minimum losses and reflections
- Provide fast and repeatable mating/plug-in and demating/plug-out

1.1.2 What are the components of a connector?

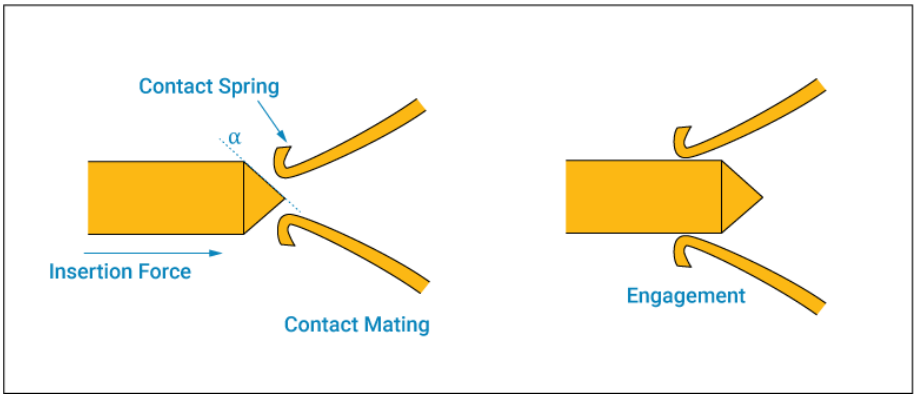
The main components of a connector are the **contact springs**, **contact finish**, and **connector housing**. The contact interface is the physical-electrical connection of the connector parts that are mated and it also determines how well the connector performs.



Schematic illustration of a typical connector.

Contact spring:

It provides the path for the transmission of signal, power, and/or ground between the circuits that the connector connects. Insertion and extraction force, contact force, contact retention, and contact wipe are some of the key mechanical requirements of the contact spring.



Connector engagement with adequate insertion force.

Contact resistance, current rating, inductance, capacitance, and bandwidth are the electrical requirements of the contact spring. A receptacle and a plug are the two sorts of contact springs. A receptacle is usually a spring component, whereas a plug is stiff and offers a means for the receptacle spring to be deflected to generate the contact force.

Contact plating:

Contact plating (finish) protects base metals from corrosion and also improves the mechanical and electrical characteristics of contact surfaces. Contact plating can protect copper alloy base metals against environmental attacks, prevents the formation of an insulating layer on the contact interface, and ensures its electrical stability.

Contact plating improves the endurance and wear resistance of connection contacts by providing a protective coating. Choosing the right plating material and thickness may control the mechanical and electrical characteristics of the contact surface.

Connector housing:

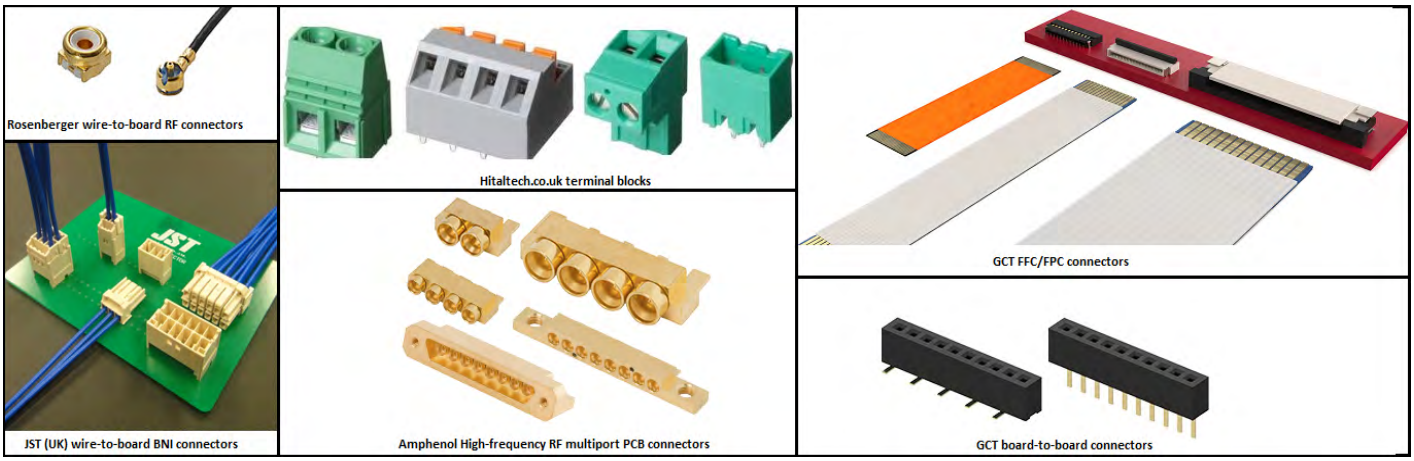
A connector housing supports the contact members mechanically, electrically insulates them, and aids in the exertion and maintenance of contact pressure to guarantee a good electrical connection. The mechanical characteristics of the house must be assessed. The housing should be evaluated based on its mechanical properties. These include elastic modulus, flexural strength, tensile strength, compressive strength, impact resistance, deflection temperature, coefficient of thermal expansion (CTE), and hardness.

1.1.3 Challenges of incorporating connectors in a system

Increasing signal speed and switching frequency demands stringent requirements from connectors. Primary issues while dealing with connectors are electrical length, need of a larger assembly area, compatibility with new technologies, and reliability.

- A connector introduces an extra electrical path that can lead to added propagation delay and electrical noise, such as crosstalk.
- A connector also raises concern for reliability, because degradation of the contact interface can lead to an increase in contact resistance, resulting in signal distortion, heating problems, and power loss. These losses increase due to contact resistance, which depends on the material properties of the connectors, environmental conditions, and mode of operation.
- Additionally, since a connector occupies more area than a simple solder or adhesive, the use of connectors might be difficult in applications that have limited space.

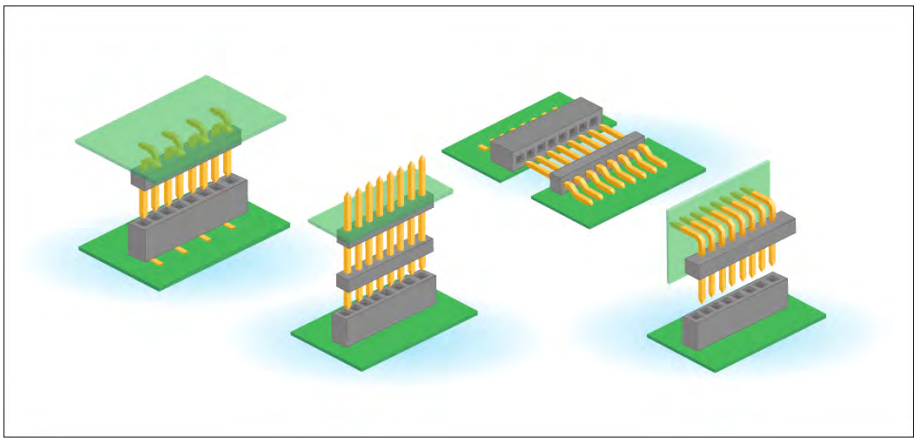
1.2 Types of PCB connectors



PCB connectors from different manufacturers.

Being a multi-pin connection system, male PCB connectors are referred to as pin headers, as they are simply rows of pins. Female connectors are called sockets, receptacles, or header receptacles. A mating pair of board connectors will either be for board-to-board or cable-to-board (wire-to-board).

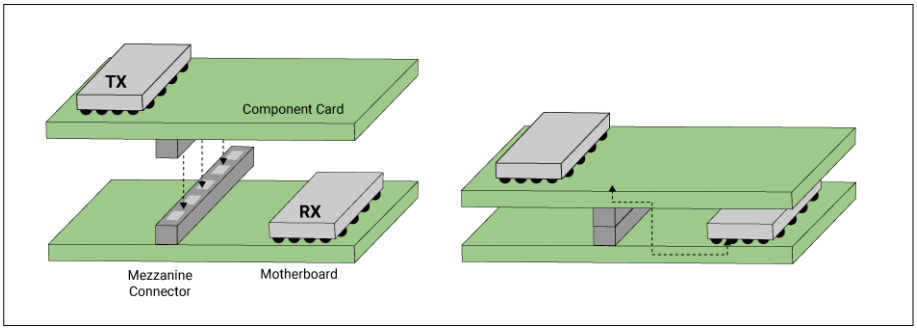
1.2.1 Board-to-board (B2B) connectors



Board-to-board connectors with different orientations.

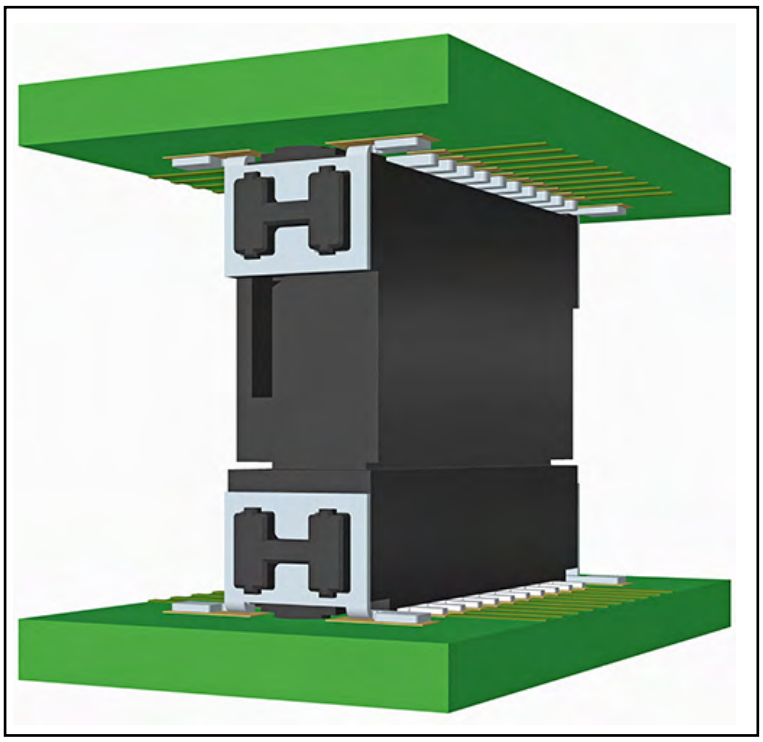
Board-to-board connectors are used to connect different PCBs together without using a cable. They consist of two connectible parts in which one part having pins is attached to the first board, and another part with receptacles is mounted onto the second board. And finally, circuit boards are connected by mating these two parts of the connector.

Board-to-board layouts offer a range of PCB connection orientations, all based on 90-degrees increments:



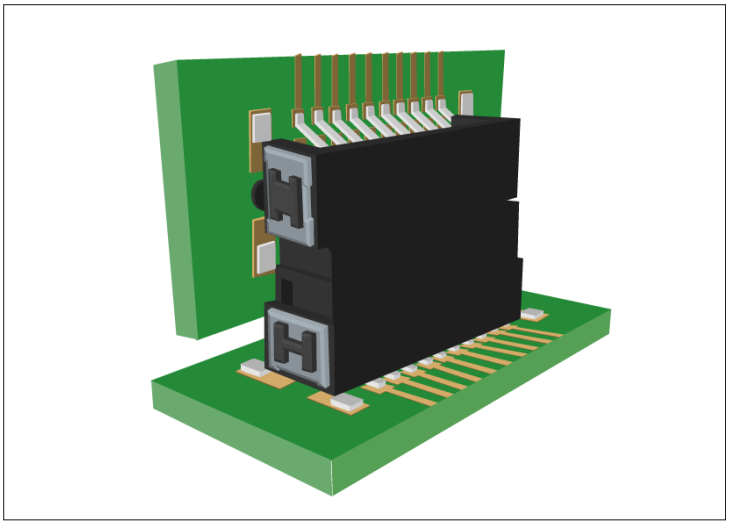
Parallelly arranged board-to-board mezzanine connector.

- Parallel or mezzanine, where both connectors are vertically oriented. **EIA 700AAAB** is a standard for mezzanine connectors.



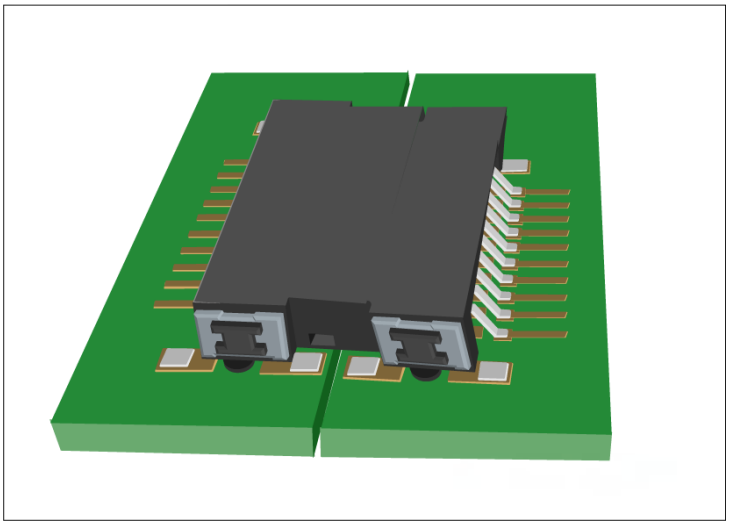
Parallel or mezzanine connector orientation.

- 90 degrees, right-angle, motherboard to daughterboard, where one connector is vertical and one is horizontal



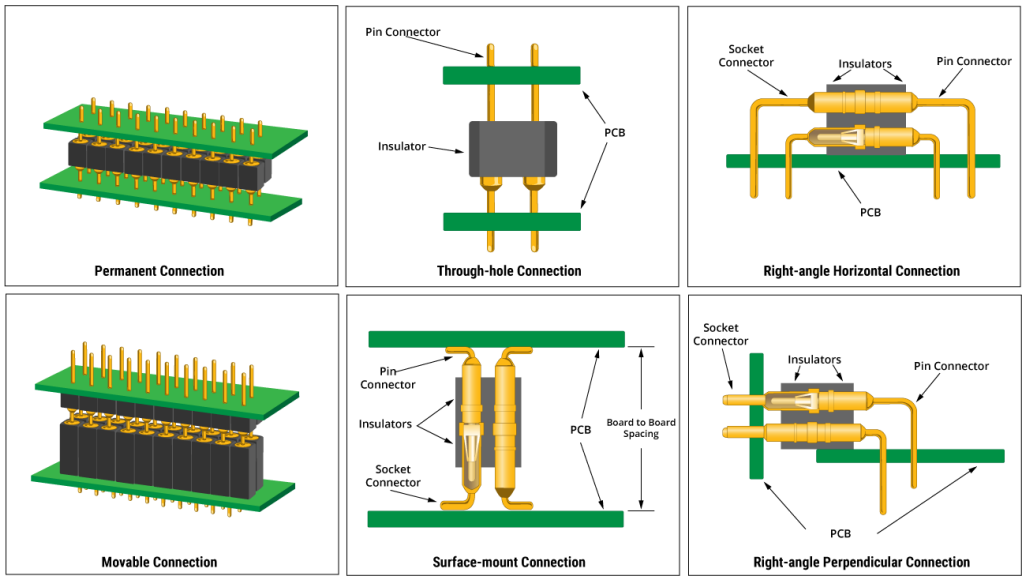
90 degrees connector orientation.

- 180 degrees, coplanar, edge to edge, where both connectors are horizontally oriented.



180 degrees connector orientation.

Board-to-board connectors can make use any of permanent, movable, through-hole, surface-mount, right-angle horizontal, or right-angle perpendicular connection types.



Connection types for board-to-board connectors.

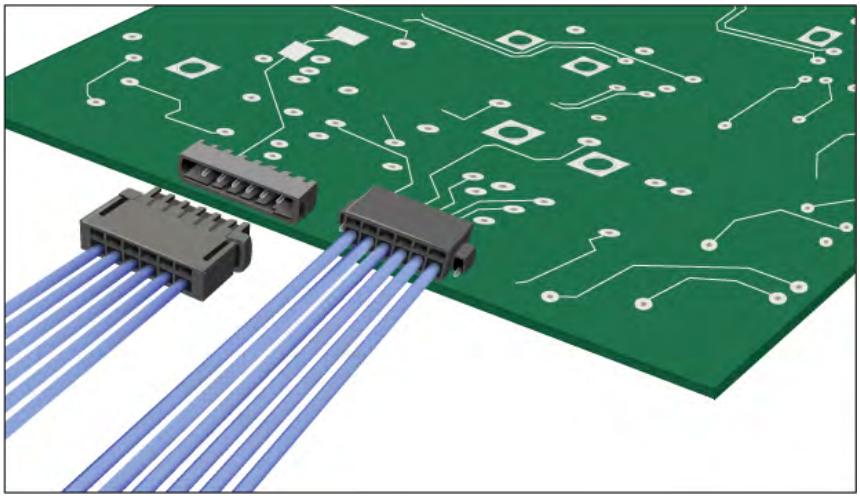
Examples of board-to-board connectors: PCIe, Euro, Mezzanine, edge connectors

Advantages:

- Improve signal integrity and crosstalk
- Provide multiple add-on board options
- Easily upgradable to accommodate future design changes
- High input/output density and space-saving
- Suitable for systems with limited space

Applications: Microminiature, high-speed, high-density, and high-power applications such as telecom switches, aerospace, medical, servers, and military and defense, etc.

1.2.2 Wire-to-board (W2B) connectors



Wire-to-board connector.

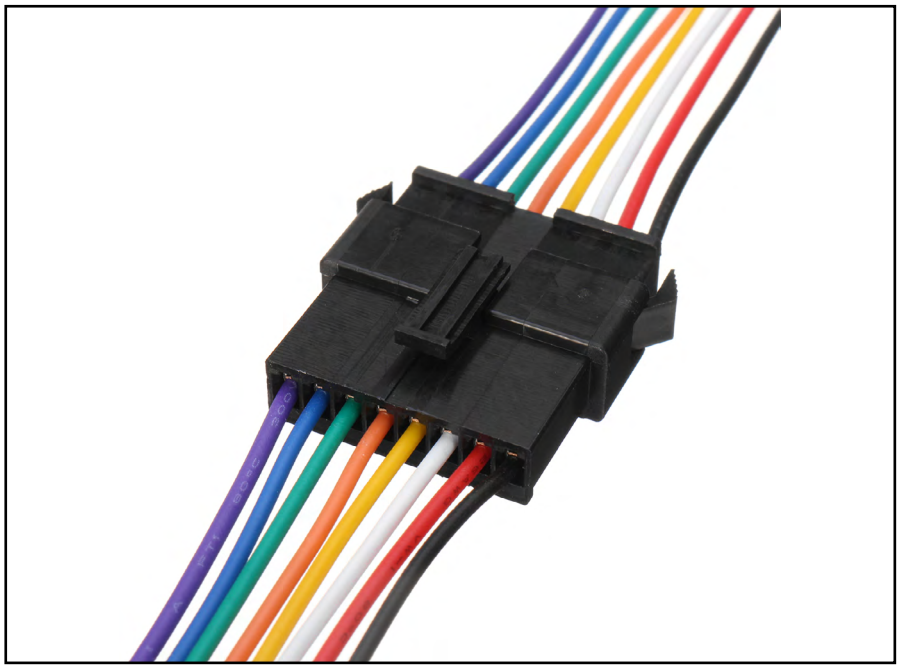
Wire-to-board connectors are used to connect a PCB to wires. These connectors are used to fix connections onto the conductor board. Primarily, the male connector named 'PCB header' is fixed with the conductor board and the female connector is linked to the wiring harness.

Advantages:

- Easy maintainability as the cables can be disconnected easily from the board
- Good reliability
- Easy mating and unmating

Applications: Medical equipment, aerospace, military and defense, computers, and consumer electronics, etc. They are also used to connect control units to the power harness.

1.2.3 Wire/cable-to-wire/cable connectors

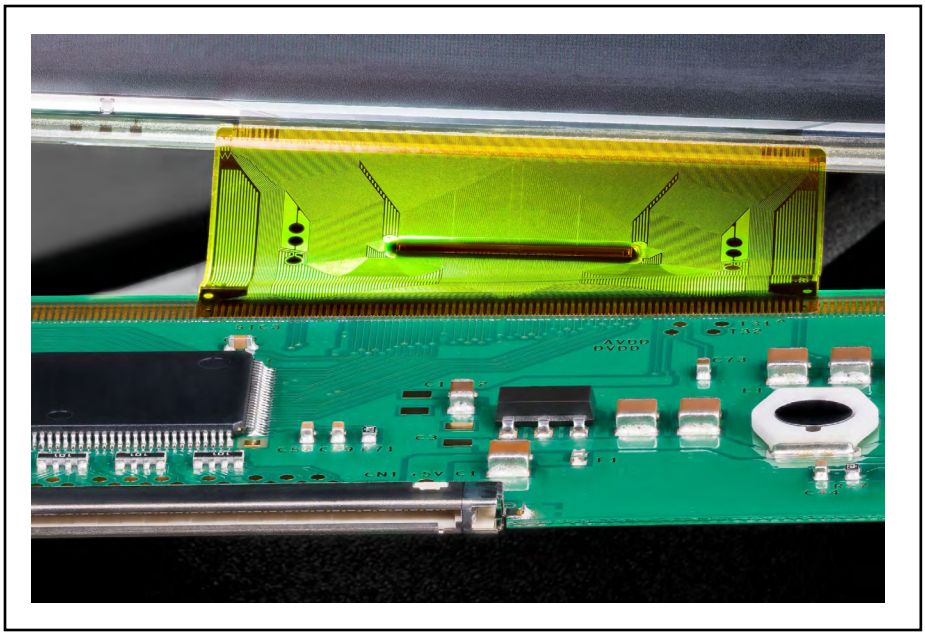


Wire-to-board connector.

As the name implies, wire-to-wire connections link two wires. One end of the connector is permanently connected to the wire. The connector's opposite end provides a detachable interface. Crimping or insulation displacement contact (IDC) can be used to make a permanent connection. The IDC method forms a connection by inserting the insulated wire into a slot in a sharpened metal beam. The beam's sharp edges pierce the insulation wire forming a hard metal-metal contact between the wire and the beam.

Wire-to-wire connectors come in a wide variety of housing geometries, including rectangular and circular with polymer housings made from a wide variety of polymers, and metal shells, primarily for military-grade PCB applications.

1.2.4 FPC and FFC connectors



FPC connector.

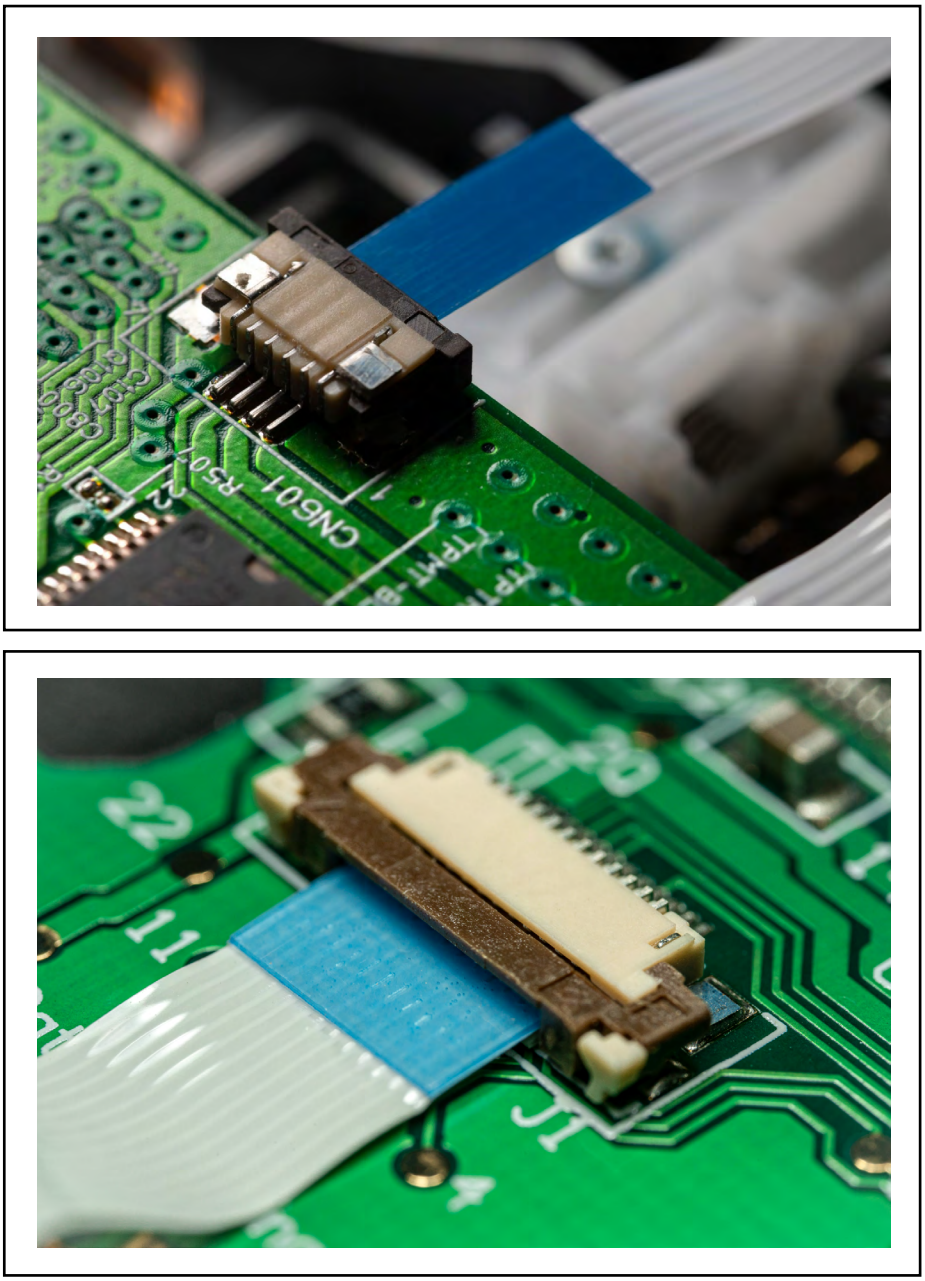
FPC stands for flexible printed circuit connectors. These are like wire-to-board connectors where a flexible PCB is used to connect two circuit boards instead of a cable. FPC connectors have been designed to meet the miniaturization challenges that require smaller pitch spacing and lighter interconnect solutions.

Advantages:

- Offer multiple centerline spacing options
- Available with top and bottom contacts
- No tooling required
- Prevent solder bridges

Applications: Medical, consumer, automotive, and industrial equipment

Flexible flat cable (FFC) connectors are ribbon-like connectors composed of flexible plastic, polymers, films, or engineered rubber with a metallic connector inserted parallel to the base at the end. FPC, on the other hand, has printed or integrated circuitry on the cable plane, allowing it to operate as a flexible PCB.



FFC connector.

Advantages:

- Suitable for sleek applications
- Provide exceptionally high density and hence suit numerous complex applications across various market areas, thanks to their ultra-thin form factors and unrivalled flexibility

1.3 Factors affecting the performance of a connector

- **Electrical:** The real electrical performance depends on the performance of the attached cable, cable entry, geometrical connector dimensions, inner conductor captivation, etc.

- **Mechanical:** It is best practice to use a connector type that does not rely entirely on solder connections for mechanical fixing (on to PCBs) in situations where significant mechanical loads are expected. This is particularly true with surface mount devices. Many connections, such as bosses and threaded inserts, feature characteristics that enhance mechanical stiffness, allowing them to be attached securely.

- **Environmental:** If the connectors have to be used in harsh operating environments, check the manufacturer's IP (Ingress Protection) rating for sealing to dust and water at various depths and operating time frames. Make sure you understand the end environment for your connectors and then compare that with the details under the manufacturer's IP rating.

- **Material:** The voltages in the system have an impact on the material selection; if there are high voltages, an insulator material with good insulation characteristics may be required.

- **Economic:** Select the connector material wisely as this may impact reliability, weight, and cost. Knowing exact application requirements can save future costs and time.

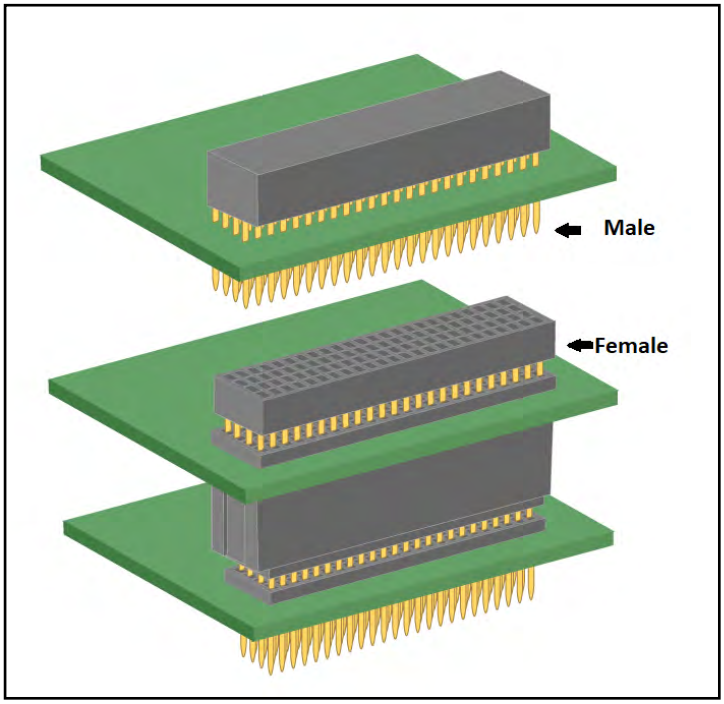
Note: Chapter 3 discusses the above factors in detail.

2. Connector terminology

Some of the common connector terminologies one should know before implementing connectors in their system are:

2.1 Gender

The gender of a connector signifies whether it plugs in (male) or is plugged into (female).



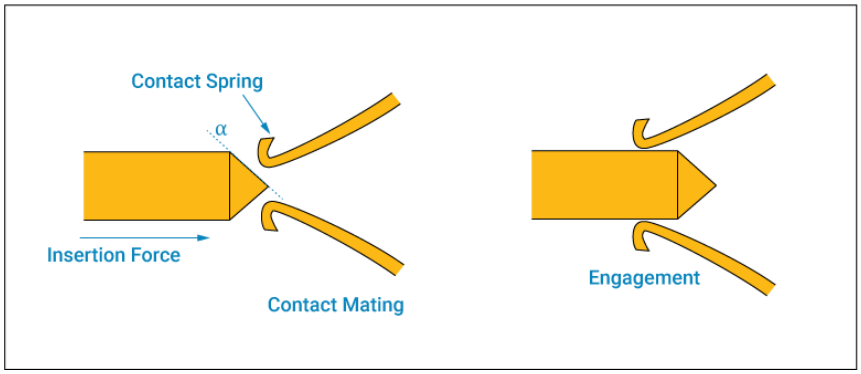
2.2 Polarity

The majority of connectors can only be connected in one direction. This property is called polarity. Additionally, connectors come with some means to prevent them from being connected incorrectly. For instance, male and female connectors are designed in such a manner that they can mate in only one way.

2.3 Pitch

Many connectors are made up of a series of contacts that are arranged in a pattern. The pitch of a connector refers to the distance between the centers of one contact and the next. Many contact families have similar appearances but may differ in pitch.

2.4 Mating cycles/Duty cycles

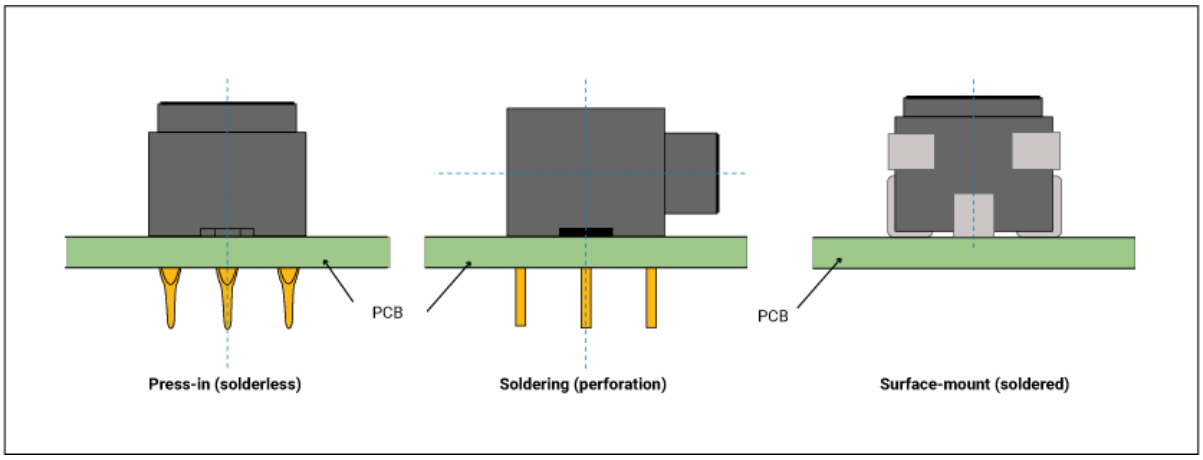


Connector engagement with adequate insertion force.

The lifespan of a connector is dependent on the number of mating/demating cycles it is subjected to. The maximum mating cycles the connection can sustain are generally listed on connector datasheets. The number of mating rounds varies depending on the technology. A USB-based connector can have tens of thousands of mating cycles, but a board-to-board connector designed for use within a consumer electronics product could have only ten mating cycles.

2.5 Mounting style

The mounting style of a connector refers to how it is installed (for example, panel mount, free-hanging, or board mount), the angle at which it is connected (for example, straight or right-angle), and how it is mechanically attached (e.g., solder tab, surface mount, or through-hole).



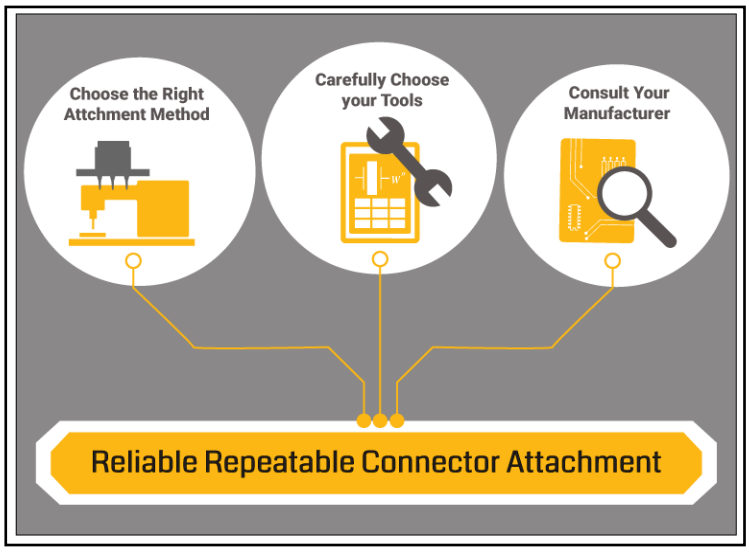
Ways to attach a connector to the PCB

When mounting a connector, it is important to know the influence of forces such as engagement, disengagement, and mounting methods such as pressing or soldering. The three mounting methods (shown in the above image) are frequently used in PCB applications. First is the press-in method, which means that the PCB connector with press-in legs is inserted into the defined plated-through holes. Compared to the traditional soldering method, press-in mounting guarantees the same electrical and mechanical performance. It also makes a more secure contact and is easier to assemble than with soldering.

The soldering method is used for three different types of connectors, the print socket with solder legs, the surface mount, and the edge-mount connector with solder leads. The print socket perforates the board with legs similar to the press-in type, with the surface-mount or edge-mount being soldered on the surface of the print (shown on the right side in the image). The surface mount solder method generally does not ensure a higher contact quality because of lower resistance to vibrations, shock, and forces when compared to press-fit and soldering (perforation).

How to achieve a good, reliable, and repeatable connector attachment?

- Choose the attachment method based on the application requirements (electrical, mechanical, and environmental).
- If a tool is needed for assembling, carefully consider the advantages and disadvantages of the available tools.
- Recommended tools are those with calibration sets and guaranteed repeatability. Follow the enclosed assembly instructions step by step.
- Check the results carefully. If in doubt, consult the manufacturer for help.



2.6 Strain relief

When a connector mounts to a board or cable, the electrical connections tend to be somewhat fragile. That is why it is typical to provide strain relief to transfer any forces acting on that connector to a more mechanically sound object than the fragile electrical connections. For example, some strain-relief connectors use a nylon gripper that squeezes down on the cable or cord as the nut is tightened, latching it firmly in place.

2.7 Connector labeling

Always mark connectors that will be linked to the outside with descriptive names. Add names for each pin on a pin header. Connectors are normally given references starting with 'J' such as J1, J2. Sometimes they are CONN1, CONN2.

3. Connector selection and layout rules

3.1 Connector selection parameters

- **Voltage and current requirements:** Defining how much electrical voltage and current each contact will carry is the first step to selecting a connector for any device. Ensuring the right number of contacts for a connector is not alone sufficient but whether the contact would fulfill the power demands of your application is equally important.

  The current-carrying capability of a contact depends on its size and the wire. And the voltage rating depends upon the contact spacing, insulation materials, and the geometry of the insulator used to isolate the contacts. For an adequately designed connector, how a manufacturer specifies the current ratings and operating voltages for that connector plays a vital role. You can always ask the manufacturer regarding the test standards followed and how it is performed since everyone doesn't follow the same testing method.

  When reviewing current ratings, make a note of the temperature rise specification. This specification tells how much heat will be dissipated at a specific current value.

- **Reliability requirements:** Figure out how many times you will be connecting and disconnecting the device over its lifespan. In case you require a high number of mating cycles, choose a connector with 5000 to 10,000 mating cycles. Why is it important? Because a failed connection can put lives under threat, such as military and medical environments. Nowadays, many connector solutions use blanked pins or a specific feature molded into the housing to ensure correct mating.

  For safety reasons, female receptacles use scoop-proof sockets, where they are housed deeper within the socket. It thereby avoids the chances of high voltage contacts being touched accidentally by a user. Another requirement to investigate is whether the connector would be able to stay stable in harsh/extreme environment conditions. For example, many connectors work well indoors and lose performance in harsh outdoor scenarios.

- **Termination type:** The assembly process and the ability to seal a connector are affected by the type of termination used. Connectors with solder are usually simpler to seal against moisture ingress. On the other hand, crimp contacts offer better field repairability. The final decision regarding the termination type is based on manufacturing and design. It's crucial to understand exactly how and where the connector will be used and whether field repairability is a necessity.

- **Make use of hybrid functions:** Determine which extra functions can be added to your connection after ascertaining the current and voltage requirements. Hybrid connections are often custom-designed, but if you have the time to work with a manufacturer to build a hybrid connector that is tailored to your unique needs, it may be worthwhile. The results will provide the end-user with fewer connections and cables to manage. If you can find a single connector that can transport more than one of the following: power, signal, coax, fiber that would be ideal.

- **Check for operating environment rating:** Check the manufacturer's IP (Ingress Protection) rating for sealing against dust and water at various depths and operational time periods. Make sure you know where your connectors will be used(environment), and then compare it to the specifications of the manufacturer's IP rating.

  Most IP classifications have specific conditions, although the IP68 rating may be specified differently by each manufacturer. Inquire about how the manufacturer's IP68 rating is calculated while looking for a connection with an IP68 sealing rating.

- **Connector material:** The voltages present in the system also affect the choice of material; if high voltages are present, then an insulator material with strong insulation properties would be required.

  Choose the connector material carefully since it might impact the connector's durability, weight, and cost. Brass connectors with nickel/chrome plating have a longer life cycle and are more wear-resistant than many other materials. Aluminum connectors may be an alternative if weight is a concern.

  Plastics are ideal for single-use applications. If you're thinking about using plastic connector, then test it thoroughly to check if it will hold up to the end-use application. Make sure your connector can resist the sterilizing methods used by the end consumer if it's being utilized in medical applications. Stainless steel may be required in strong corrosive conditions or for particular food sector applications. When choosing a connector material don't put cost ahead of reliability.

- **Define cable and cable assembly:** It is important to check both connector and cable are compatible with each other. Some manufacturers also provide custom cables.

  To reduce the number of vendors you have to deal with, most connector manufacturers provide assembly services. Examine the facilities to determine if the manufacturer can offer termination-only or comprehensive overmolding, sealing, and testing services.

- **Check for compatibility with available AOI equipment:** Any connector selected should be compatible with the company's automated optical inspection (AOI) equipment, thereby reducing cost in the manual inspection stage.

- **Contact pitch:** Choose a connector with a small pitch size as it reduces the size of the connector, hence results in smaller boards and backplanes. For instance, a connector receptacle having a smaller pitch can be mounted in parallel, leading to a smaller connector size.

- **Connector contacts:** Signal losses become higher when the data rate rises exponentially. So, choose connector contacts (two-point rough edge, surface contact, etc.) wisely to have significant improvement in signal strength and insertion losses.

- **Mounting and termination mechanisms:** EMI and ESD shielding are very important when dealing with higher data rates, and special mounting and termination mechanisms in connectors ensure the same.

- **Space:** Always provide more space on the PCB for a connector to handle the required current. Space requirements should also be considered for connector contacts and for cooling purposes. Also, connector manufacturers now offer high-density connectors that accommodate a huge number of pins in a small space.

- **Crosstalk:** As system speed rises, PCB designers face a growing challenge with crosstalk between multiple signals. It is advised to use connectors with anti-crosstalk capability; otherwise, it will ruin the whole system performance, even if adequate board layout techniques are adopted.

- **EMI:** Shields can be designed and manufactured to address this issue, but choosing connectors with in-built shielding is always a wise decision.

- **Prioritizing sequencing for ground power and other signals:** Select a connector with certain pins longer than others. This allows them to mate first and de-mate last for improved electrical performance. This guarantees that the required signal gets mated first.

- **Miniaturization:** Nowadays, it is possible to use only one connector for an application that would have needed two or three connectors earlier. Pay attention to the intricate details of each connector, as they become essential as the voltage and current increase. Compare connector models for pin size, the number of pins, and functionality. Miniature connectors are small and compact, yet only a handful can carry both power and signal. Since terminating these small connectors is challenging, micro plugs and receptacles are sold pre-wired to ensure reliability.

- **Service and delivery:** Check for realistic delivery dates; delivery of a custom connector will always take more time than selecting an off-the-shelf product. If you can use a connector that has already been designed, the delivery time will be reduced. Modifying an existing design may result in shorter wait times. If you decide that a custom connector is the best choice for you, make sure that your supplier is dedicated to the project for the life of your device.

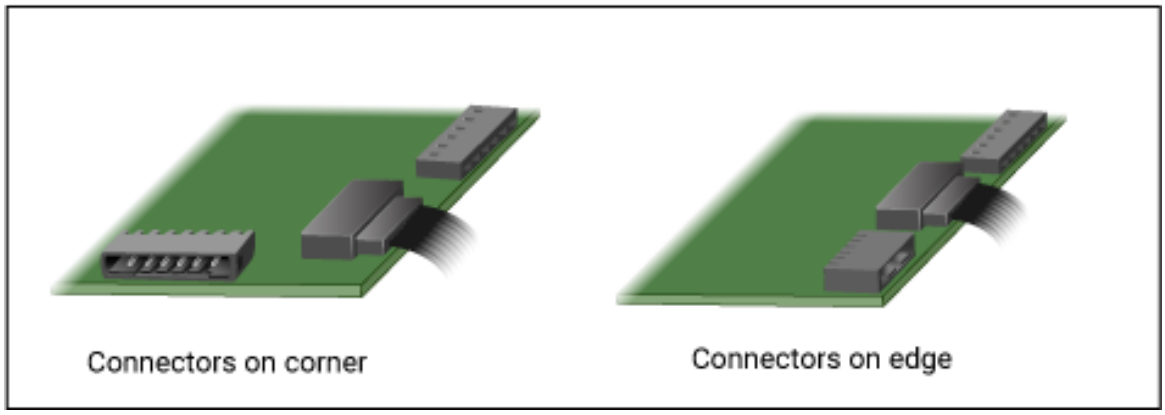
- **Engineering support:** Ask suppliers about the kind of support you can expect from their engineering and product development teams. Check out the design and prototyping services that are offered. Allowing someone else to review your product early in the design process often opens options for cost-cutting and time-saving.

3.2 PCB layout rules when designing with connectors

Spacing is the typical design constraint applicable to connectors that mount on PCBs. The most essential consideration is placement and connectors should be placed on or near the board's edge.

3.2.1 Circuit board layout with respect to connector placement

1. Place all connectors on one edge or on one corner of the PCB.



Place connectors on one corner of the PCB.

Placing connectors on one edge of the board makes it much easier to hold them on the same reference potential. This is important for boards with high-frequency components that will not be shielded.

Some designs require connectors to be placed on different sides of the board. In such situations, it's critical to avoid placing high-frequency circuits between any two connectors. If it is not possible to avoid placing high-frequency circuits in between connectors, a metal enclosure and chassis ground filtering are employed to prevent the board from driving common-mode currents onto the connected wires.

Our BOM Checker tool can help you verify your bill of materials file and also avoid multiple vendor issues and longer lead times.

2. If a device on the board needs to communicate with the device off the board through a connector, then that device should be placed within close proximity (within 2 cms) to the connector.

It can be done by keeping input/output traces short. If traces are long, they will be prone to couple noise to or from other circuits on the PCB.

3. An off-board communication using a single device should be routed through a connector.

This ensures controlling common-mode currents in wires that are part of the same cable assembly.

4. Components that are not part of input/output nets should be placed at least 2 cm away from the nets and connectors.

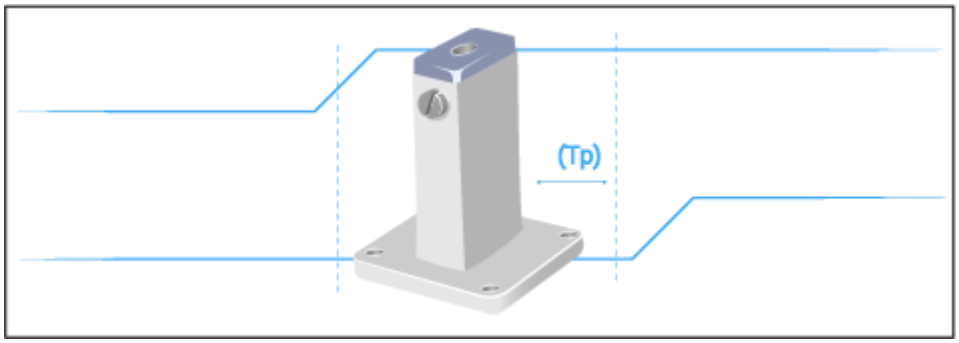
It ensures noise coupling through input/output nets.

5. Place ESD and EMI protection devices as close as possible to the connector.

To avoid EMI exiting or entering the board, the EMI protection devices such as inductors and ferrite beads are placed close to the I/O connectors pins. Similarly, ESD protection diodes are placed close to the I/O connectors pins.

3.2.2 Circuit board layout with respect to trace routing

1. When a trace has a propagation delay of more than half the transition time of the signal it carries, then it requires matched termination.



Place connectors on one corner of the PCB.

Don't use a matched termination unless the rise time has already been slowed as much as possible and the trace length has been shortened as much as possible. Matched terminations are undesirable because they use more power and make it difficult to control rise times. However, they are important for signal integrity and EMC when the trace delay is more than the transition time. You check out our trace width calculator which is capable of calculating trace width, the amount of trace current and the temperature rise.

2. If a trace is not an I/O trace then it should not be laid between an I/O connector and the device(s) transmitting and receiving signals using that I/O connector.

I/O traces provide very simple routes for noise to enter and exit the board. Unintentional coupling to or from these traces should be avoided at all costs.

3. Alignment tolerances: Tolerances become an issue when numerous connections like pin headers and sockets, are utilized to link two boards. The connector alignment must always be within tolerance owing to the positioning on the circuit board and the manufacturing process tolerances so that PCBs mate correctly without placing undue strain on the solder joints.This is why many connector manufacturers propose certain land patterns for PCB pads so that solder surface tension helps with better positioning during reflow.

4. Remove solder mask web from the fine-pitch connector pads: The spacing between the solder pads must be carefully addressed when putting fine-pitch connectors on a PCB. If two component pads are close together, providing space on both sides may not be adequate to present enough surface area to the solder mask to adhere to the board between these pads, correctly. When placing fine-pitch connectors to a PCB, the distances between the solder pads need to be considered carefully. Therefore, it's critical to consult the board fabricator when designing solder pads for fine-pitch connections. The DFM team choose to eliminate the solder mask web between pads in most cases.

5. Stick to the connector dimensions given by the manufacturer: Backplane and panel mount applications require connectors meant to be fixed to the edge of a PCB, and their location is essential to the precise spacing of the boards themselves. When installing them, pay strict attention to the manufacturer's specifications.

6. Engineers must take care not to inhibit any airflow paths that could cause thermal issues to arise.

3.3 Panelization guidelines when using PCB connectors

Today, there are two main approaches for depanelization: scoring and routing. Scoring (also known as V-scoring) is a less expensive but less flexible way of cutting a V-shaped groove. When connectors are close to eachother, or on the PCB, or overhanging from the board edge, scoring is challenging to execute. Routing, which may use perforations or solid tabs, supports edge connectors but generates more waste material and is more expensive.

Your contract manufacturer (CM) must create a panelization plan to easily fabricate your boards. This design must conform to the CM's equipment, therefore it may not be optimal for your connection needs or even cost reduction. You can optimize panelization and save money if your board is flexible enough. If not, you may reduce the likelihood of a longer redesign turnaround time and save needless expenses by following the suggestions mentioned below.

1. **Components with extensive connection areas should be placed away from the board's edge.**

   If solder connections are positioned too close to the V-groove line, they may fracture or detach.

2. **Connectors should be placed distant from the board's edge.**

   If this is possible, you may be able to save money by solely using V-scoring.

3. **Low-profile connections should be used.**

   Connectors with a higher height must be placed further away from the board edge to employ V-scoring.

4. **Place all edge or overhanging connectors on one side of the board.**

   Doing so may minimize the amount of tab scoring required and reduce material waste and manufacturing costs.

If you follow these panelization design principles, you should be able to use any of the standard PCB connectors without having to worry about manufacturing difficulties. Always consult with your CM to check that your design requirements can be manufactured.

4. Connector testing

PCB connectors should not only be reliable but should also follow the miniaturization trend. They should be smaller and robust at the same time. Additionally, they must be easy to handle and incorporate new options to meet the design needs.

Connectors are tested and inspected to ensure quality and whether they are suitable to the PCB design requirement.

4.1 Material tests

Material tests ensure the long-term behavior and reliability of the connector system since it also affects the device performance. Glow wire test, thermographic imaging, scanning electron microscopy, and computer tomography are some preferable tests for connector materials.

4.2 Mechanical tests

Test name	Standard	Purpose
Flexion and bending test	IEC-60999-1	To ensure mechanical safety of the contact points
Conductor pull out test	IEC-60998-2-1	To check the tensile load capacity
Protection against contact	IEC-60529	To ensure protection against electrical shock
Cold impact test	UL-746C, 57/UL-1703, 30	To check the impact on cable-connected cables and housings

4.3 Electrical tests

Test name	Standard	Purpose
Insulation resistance test	UL 1703, 27	To check weather and wind withstanding capability of connectors
Current carrying capacity	IEC-60512-5-2	To quantify current carrying capacity of a connector which is generally limited by thermal properties of the material used in contacts and connections
Impulse withstand voltage test	IEC-60664-1	It ensures sufficient air clearances and creepage distances between two neighboring potentials
Volume resistance measurement	IEC-60998-2-1	It assesses the connection quality which in turn ensures reliable electrical contact

4.4 Environmental tests

Test name	Standard	Purpose
Degree of protection test	DIN 40050-9/60529	It describes the protection of a housing from contact with dangerous parts foreign bodies or water
Corrosion test	IEC-6988	Check for the influence of the corrosive environment onthe contact point
Temperature shock test	IEC-60512-11-4, test 11d	Checks for the impact of temperature changes
Vibration test	IEC-60068-2-6	It demonstrates the vibration resistance of an electrical connection

4.5 Special tests

Test name	Standard	Purpose
Heat cycling test	UL-1059	It verifies the service life of an electrical connectionunder extreme electrical loads
Explosion protection test	IEC-60079	It verifies air clearances and creepage distances, the clamping pressure. It says that terminal points for connecting stranded conductors must be provided with an elastic intermediate element
Whisker test	IEC-60512-11-4, test 11d	Checks for tin whiskers; a needle-like structure that grows out of a tin-plated surface
Solderability test	IEC 68-2-54	To assess the soldering properties of surfaces and systems and ensures high quality of the soldering metals

4.6 CableScan system for connector testing

The CableScan system is an apt choice for evaluating PCBs with many connectors, such as backplanes or other complicated interface boards. CableScan connects to the board to be examined through connectors and checks every pin against every other pin for assembly issues such as solder shorts or openings. It also checks the jumper arrangement and diode functioning, as well as measuring resistance and capacitance.

There are certain limitations to how large of a connector the CableScan system can examine in a single pass, and there are some minor costs associated with the development of a hardware interface. Mating connectors must be ordered and connected into the system, which might take time depending on the lead time, complexity, or cost. CableScan setup and testing durations might be lengthy depending on the number and complexity of connectors involved.

4.7 Maxwell 3D software to check connector signal quality

Maxwell 3D software may be used to simulate signal quality for connectors. The connectors can be incorporated in a SpecctraQuest DML application to determine their functionality in the board once the connector model is produced. The design rules are given by the program and the simulation results serve as additional design guidelines. The simulation accuracy is determined by the correctness of the data supplied throughout the simulation.

4.8 PCB connector cleaning

Cleaning is an important element in keeping PCB connectors and electrical equipment in excellent working order. Connectors, especially if not used every day, are prone to accumulating dirt and eventually corroding, rendering them useless. Cleaning the connectors on a regular basis allows you to minimize power loss and maintain excellent connector contacts, but you must know what equipment to use in order to avoid damage.

- Cleaning scrub block (also known as PCB edge eraser) is a simple eraser with a fine abrasive roughness. Since it is more efficient and abrasive than a regular pencil eraser, it must be handled with care to avoid damaging any sections of the connector when removing dirt and rust.
- When the terminals are extremely tiny and more accuracy is required, a brush (such as a PCB cleaning brush) might be useful.
- Isopropyl alcohol works best to remove corrosion, but its use on connectors requires due care as it is a flammable compound.

5. Application-specific PCB connectors

A variety of application-specific connector options are available to fit design needs.

5.1 Signal connectors

Signal connectors are general-purpose connectors. These connectors have an open pin field and are generally used for low voltage-low current applications. An open pin field means each pin has its own connection and patterns of signals and ground can be decided by the end-user. This makes signal connectors suitable for most applications, but not for high-performance applications.

5.2 Power connectors

Power connectors are designed to reliably connect power, providing efficient supply and distribution in communications equipment.

5.3 RF connectors

RF (radio frequency) connectors are designed to work at radio frequencies for signal transmission in radio, antenna, coaxial cables, etc. RF connectors provide a fastening mechanism such as thread, bayonet, braces, blind-mate, and springs for a low ohmic electric contact which allows for extremely high mating cycles while reducing the insertion force.

Connector types	Power connectors	Signal connectors	RF connectors
B2B	Heavy-duty connectors (5 to 25 amps)	Mezzanine connectors	----
	Solid-state lighting connectors	Rectangular connectors	
	Photo-voltaic connectors	Headers	
	Heavy-duty mezzanine connectors (Samtech, Harting, Amphenol)	Backplane connectors (Euro connectors, Edge	
		Memory connectors	
		LGH connectors	
W2B	Phoenix connectors	Banana and tip connectors	Coaxial connectors
	Terminal connectors	Pluggable connectors	
	Barrel audio connectors	USB, DVI, HDMI connectors	
	Blade type connectors	FFC and FPC connectors	
		Ethernet connectors	
		Fiber optic connectors	
W2W	Molex connectors	MLX power connectors from Molex	----
	Phoenix connectors	Phoenix connectors	

There are different types of connectors based on the board application. To select any connector, there are various parameters to be considered, such as current rating, signal type, environment, etc. When a connector is designed, the main goal is to minimize any variations from the ideal line with regard to costs, loss, reflection, and dispersion. You can find many different types of connectors on various electronic component websites with various filters according to your specification. There are several manufacturers (Amphenol, Molex, 3M, etc.) who design and manufacture connectors.

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