MINIATURIZATION CONSIDERATIONS FOR SMART INTERNET OF THINGS (IOT) DEVICES

Gain insights into overcoming design miniaturization challenges associated with antennas, PCB connectors and components.

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A New World of Smart Devices Presents Larger Design Challenges

Electronic devices are increasingly being connected to the world through one or more wireless technologies and are commonly referred to as smart devices. Mobile phones, computers, televisions, video games, watches, vacuum cleaners and coffee machines offer just a few of many examples. By 2025, it is estimated that more than 75 billion devices will be connected as demand accelerates.

The integration of multiple wireless technologies into smart IoT devices presents unique challenges for manufacturers, given environmental requirements such as the need to be waterproof and withstand high temperatures, shock and vibration. Rugged and robust designs, miniaturization, long battery life and high performance are all critical factors that allow these devices to deliver reliable, seamless connectivity.

This white paper investigates challenges related to miniaturization and offers design considerations for overcoming them with a focus on antenna design, PCB connectors and associated components.

IoT Market Trends Indicate a Rapid Move Toward a Hyperconnected World

75B+
Connected devices by 2025

79.4 ZB
Data generated by IoT devices by 2025
(1 ZB = 1 trillion GB)

82%
Of all Internet protocol traffic will be video

The Interplay of Smart IoT Device Components

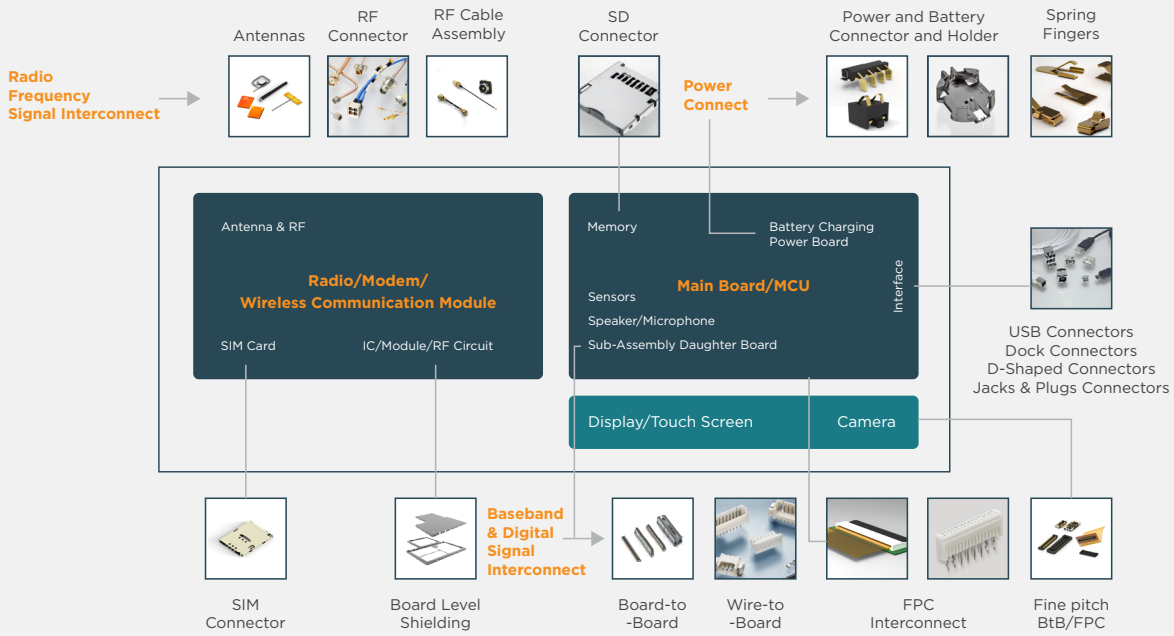


Fig. 1: The many components found in smart devices that must be considered for optimal performance

Antenna Design Miniaturization Considerations

Several factors can affect overall antenna performance, including ground plane dimensions, distance to nearby components, antenna position, PCB layout and component selection. Cutting-edge technologies, such as laser direct structuring (LDS) and metamaterial antenna technology, are also providing innovative solutions to free up space in smart devices.

Ground Plane Size and Antenna Selection

The size of the ground plane is often dictated by the size of the device. For monopole or monopole-based antennas, ground plane size is critical for good antenna performance. It should be at least λ/4 in size, where λ is the wavelength of the lowest frequency band of the monopole antenna. For lower cellular frequency bands (698-960 MHz), the λ/4 would be around 107 mm. A ground plane of this size would not be suitable and possible for most smart IoT devices due to their small form factor. Therefore, a design consideration could be made to avoid monopole-based antennas, which are dependent on the ground plane for good performance. Other antennas, such as dipole, could be used to overcome the ground plane size problem. Sometimes it is possible to extend the ground plane vertically if the height of the device allows. This technique makes it possible to have a large enough ground plane for monopole antennas for higher frequency bands, such as 2.4 GHz or 5 GHz.

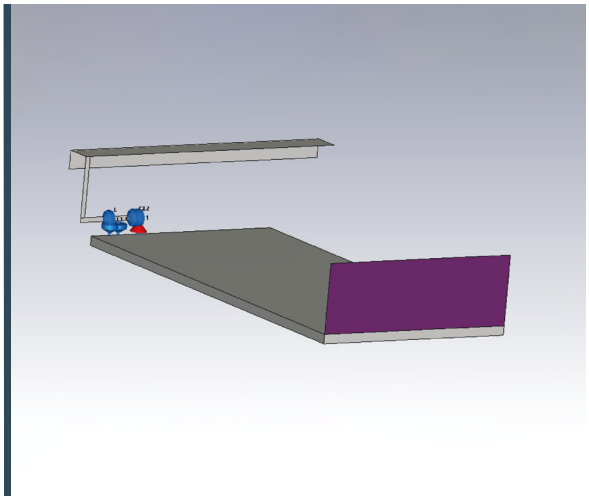


Fig. 2: Extended vertical ground plane

Distance to Nearby Components

Most antenna data sheets recommend a clear-out zone for the antenna to deliver optimum performance, as all components in smart devices can have an impact on antenna performance. Some components, such as the battery, display and charging coil, could detune the antenna. Surface mount device (SMD) components close to the antenna on the printed circuit board (PCB) could detune and decrease the antenna's efficiency. Sometimes, however, it is not possible to adhere to the guidelines provided by the antenna manufacturer. In such cases, a custom antenna design that mitigates the impact of nearby components may be necessary to achieve optimum antenna performance in the given environment.

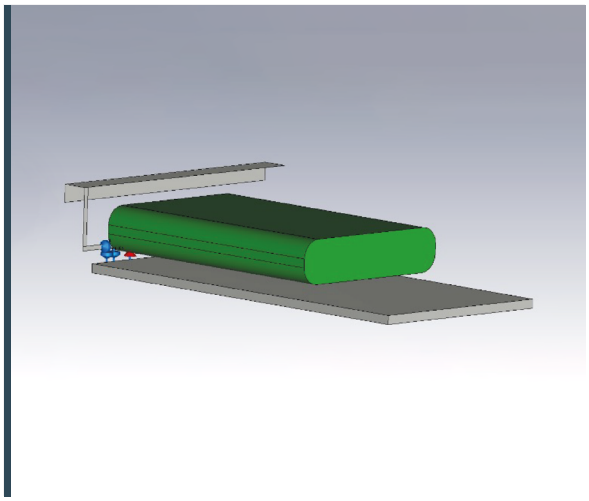


Fig. 3: Having a battery positioned a few millimeters away from the antenna would require a custom designed antenna to mitigate the impact.

Antenna Position

Position is critical for antenna performance in small devices. As discussed above, in small smart IoT devices, it is usually not possible to respect the clear-out zone requirements for the antenna.

One solution could be to choose an antenna with a cable of a certain length to be mounted on the device housing away from the PCB. Another option would be to print the antenna on the inner or outer side of the housing, creating additional free space around the antenna and decreasing the impact from other components. With printed antennas, it is very important to make sure that the housing material does not affect the antenna parameters and is not lossy on the desired frequency bands of operation.

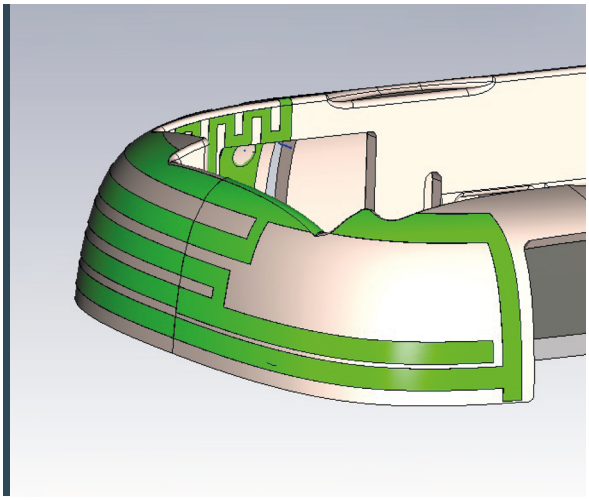


Fig. 4: Antenna modeled on a device plastic housing using LDS

PCB Layout and Component Selection

It is critical to have a 'clean' radio frequency (RF) ground plane without any signal routing on the antenna ground plane. High-speed data lines should be kept away from the RF lines. The choice of components mounted on the PCB is also very important in miniaturization. By selecting smaller components and connectors, it is possible to create more free space for the antenna and greater physical and electrical distance from other components. This helps in providing higher isolation and lower mutual coupling.

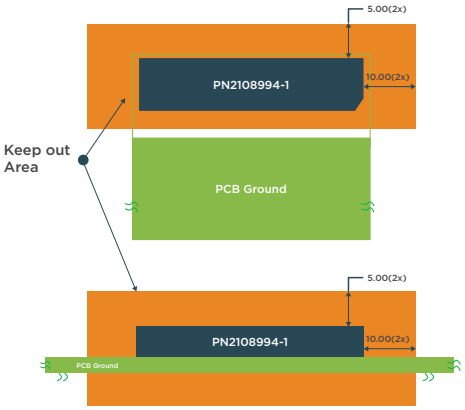


Fig. 5: Antenna clearance zone

Laser Direct Structuring (LDS)

LDS is a state-of-the-art technology used to create molded interconnect devices (MIDs) and can save valuable space in your application by integrating high frequency, mechanical and electrical functionality into one component. Laser structuring enables three-dimensional (3D) design/routing capability, versus the limiting two-dimensional (2D) capability on a PCB or other common substrates. LDS also allows for improved antenna performance because antennas can be placed in the design where they have more room for better bandwidth and efficiency. The use of LDS technology is not limited to antennas, but can also be used for electromechanical, shielding, and other components across an array of applications.

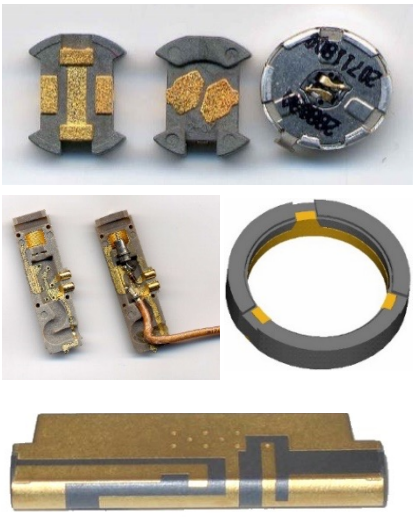


Fig. 6: Examples of laser direct structuring

Metamaterial Antenna Technology

MetaSpan antennas from TE Connectivity (TE) use metamaterial antenna technology making the antenna different from standard designs. TE's MetaSpan antennas are intrinsically designed with capacitive coupling and inductive loading and offer benefits including:

- Enhanced low-band bandwidth and efficiency
- Reduced antenna size
- Intrinsic matching
- Improved stability compared to body loading
- Confined currents on or near the structure to prevent coupling with adjacent RF components or other antennas

Fig. 7: Example of a U-shaped MetaSpan antenna that combines cellular, Bluetooth and GNSS antennas into a single block

Combining the Strengths of LDS and MetaSpan Antenna Technology

- Ability to selectively and repeatably plate three-dimensionally
- Space savings
- Ability to produce thin (0.15 mm) traces
- Improved antenna performance
- Applied cost savings
- Faster time to market
- Flexibility for pattern changes during production
- Simpler/faster/lower cost tooling

Fig. 8: Examples of LTE, GNSS and Bluetooth antennas using MetaSpan antenna and LDS technologies

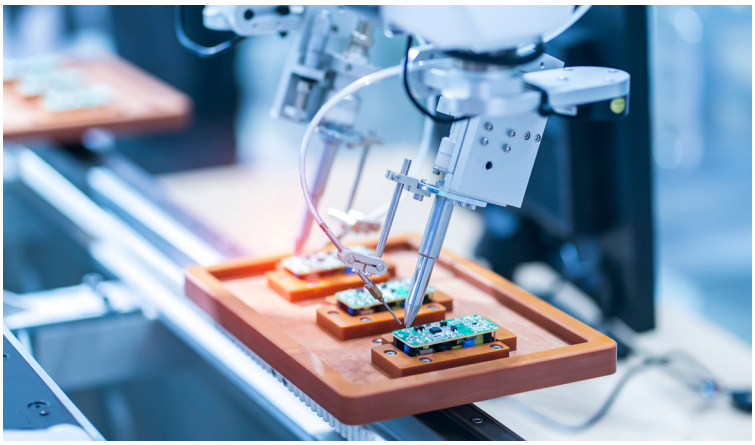
PCB Connectors and Components Miniaturization Considerations

As we move into a world of devices that are handheld, wearable and wireless, the technologies that power these electronics must perform at higher proficiencies in smaller packages. This has created a rapidly expanding trend of miniaturizations in the market.

Miniaturization Drivers and Key Factors

One of the main drivers for miniaturization is the continually decreasing PCB size in IoT applications. Given reduced board real-estate, engineers require products with a compact form factor. The smaller the connectors are, the more that can fit into a reduced space, thus increasing the utility of the board.

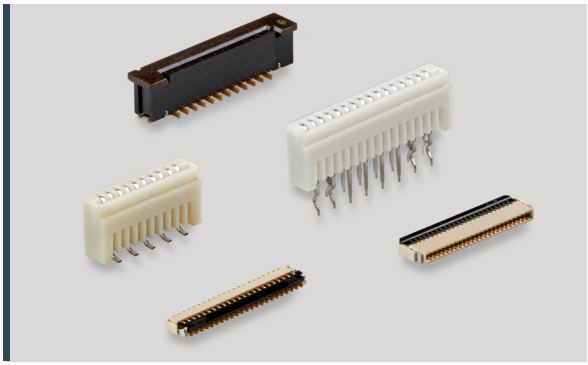
PCB clearance is also a driving factor. Not only are PCBs smaller, but increasingly there are more per application and need to be packed into a cavity that may have a unique or very thin shape. Connector protrusion of a board then becomes an important consideration, making low profile connectors a choice solution.

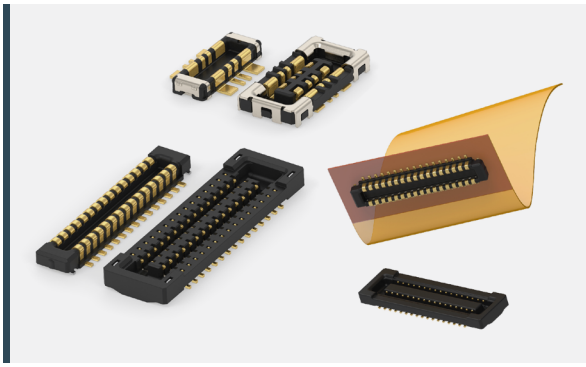


Taking a Holistic Approach to Connector and Component Selection

A wide range of connectors are available for miniaturized applications and support key functions, such as data transfer, input/output (I/O), power and display. Proper connector selection with a holistic approach to device integration early in the design phase is paramount in meeting spatial, weight and performance requirements, as well as helping reduce late-stage changes that hinder speed to market. Below are just some of the many connectors and components that contribute to miniaturization.

Flex Connectors





Flexible Printed Circuit (FPC) Connectors

FPC connectors are highly suited for miniaturized applications and connect to flexible PCB boards with chemically-etched traces that can conduct current. They come in low profiles (1 mm height) and very fine pitches (.25 mm /.3 mm), although .5 mm is the most common in the market and used primarily for LCD displays, which have seen increased incorporation into smart devices. FPC connectors allow for flexible cable orientation, more creative routing options, and custom PCB designs.

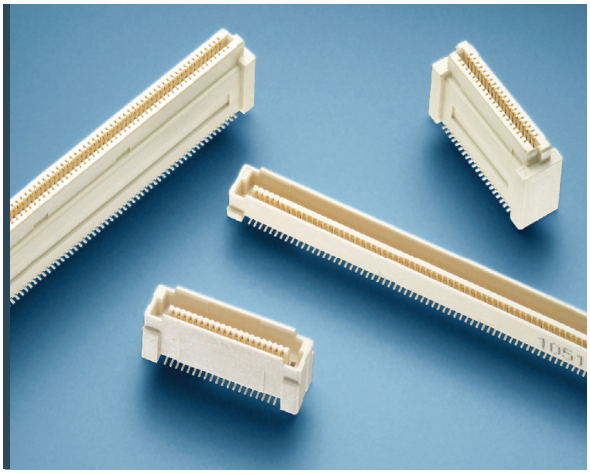
Fine Pitch Board-to-Board and Board-to-FPC Connectors

Fine pitch board-to-board and board-to-FPC connectors are optimized interconnect solutions for smaller and thinner electronic devices. Characteristic of these types of connectors include a smaller centerline, narrower body, and lower mating height.

Board-to-Board Connectors

Free Height Connectors

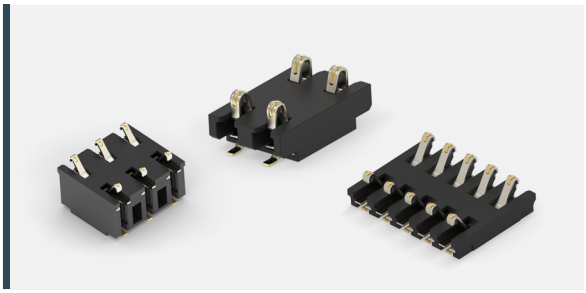
Free height connectors are two-piece, open pin field connectors designed for use in parallel stacking or mezzanine style board-to-board applications. These connectors are offered in various combinations of plug and receptacle height, providing design flexibility with the ability to vary spacing between parallel boards; pitch from .5 mm–1.25 mm; stacking height from 1.5–20 mm and from 20–440 positions.



Board-to-Board Connectors (Continued)

Compressive Board-to-Board (BTB) Connectors

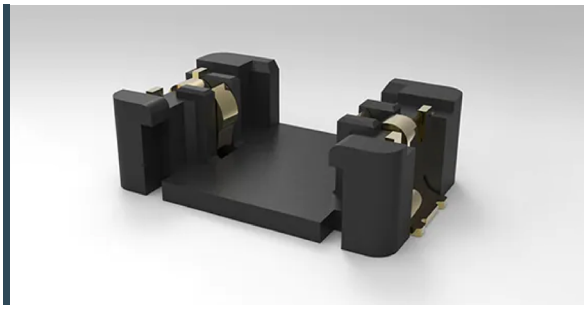
TE's one-piece compressive BTB connectors enable connections to a gold-plated secondary board by compression of the contacts. This connector is designed for transmission of power and signal in miniaturized form factor applications. It provides the designer a low cost, greater reliability and high design flexibility, and is also scalable in a range of positions, height and pitch.



Wire-to-Board Connectors

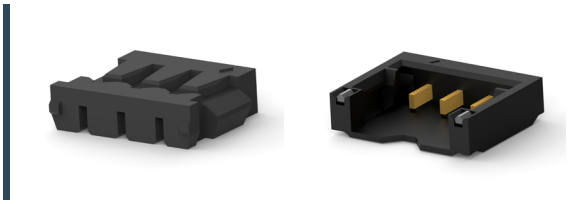
Micro Super Low Profile (SLP) Connectors

Designed with small devices in mind, Micro SLP is a .8 mm centerline top mating wire-to-board connector. This low-profile connector offers a mated height of 1.4 mm and can support currents up to 1 amp. It also features a unique latch to provide a high reliability mating connection and a contact design that provides the assembly operator a tactile click to help prevent mis-mating, making this series' mating connection drop and shock resistant.



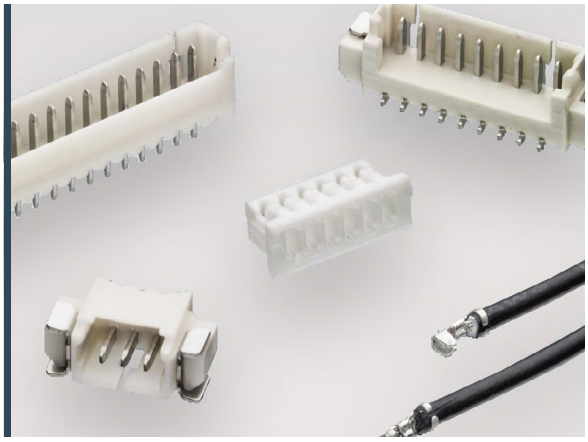
AMP Slim Connectors

The AMP Slim connector is a 1.2 mm centerline top-down contact wire-to-board connector. This connector is another low-profile option available with a mated height of 1.4 mm and position sizes ranging from 2–6. AMP Slim connectors can support currents up to 2 amps.



High Performance Interconnects (HPI)

HPI connectors can be used where signal or low power needs to be routed through a device and are a great solution for connecting ancillary items like a fan, motor, sensor, switch, etc. This product offers centerlines ranging from 1 mm–2.5 mm and vertical and horizontal (right angle) connector mounting options for versatility. Another key feature includes a locking option to ensure secure mating retention, which is critical in applications that require high reliability or have high vibrations. Square-peg technology enables compatibility with industry standard products so they can be used at any point in the customer's design cycle as a close alternative, or in some cases as a drop-in replacement.



AMP CT, AMP Mini CT and AMP Micro CT Connectors

TE common termination (CT) connectors (AMP CT, AMP Mini CT and AMP Micro CT) and cable assemblies provide an economical wire routing solution for power or signal needs. These products also offer a wide range of connectors and accessories available in a variety of sizes and types to satisfy both traditional and emerging applications. AMP CT connectors are available with pitches ranging from 1.2 mm - 2 mm and can support currents up to 4 amps in certain configurations. With a long history of proven performance and some of the lowest applied costs in the industry, AMP CT connectors are a great choice for any wire-to-board needs.

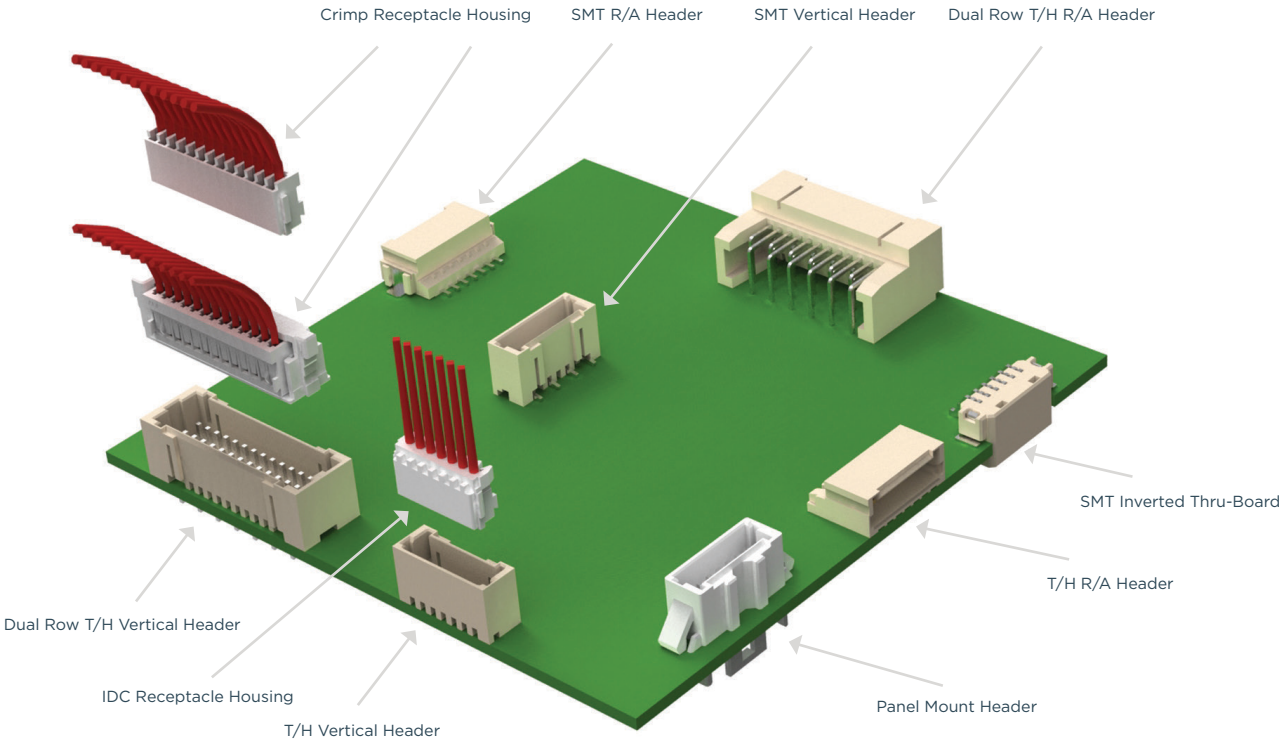


Fig. 9: PCB showing various AMP CT connectors and placements

I/O Connectors

Modular Jacks

Modular jacks are engineered to make secure and reliable I/O connections and include a variety of designations, configurations, sizes and beneficial features to address diverse design requirements. Shielded and unshielded registered jack (RJ) connectors offer a one-piece construction with preloaded contacts, providing a quick-to-install, space-saving solution.

RJ *point five* with a 7 mm centerline occupies half the space of a traditional RJ45 ethernet link, while the MRJ21 series provides space savings with 1.5–3 times the port density of stacked modular jacks (RJ45) and 3 times the port density of RJ21. The low-profile MJ series offers a connector height lower than 10 mm and the offset MJ series reduces the height above board by about 1/3.

Fig. 10: RJ *point five* (right) and MRJ21 (left) modular jacks

I/O Connectors (Continued)

USB Type-C Connectors

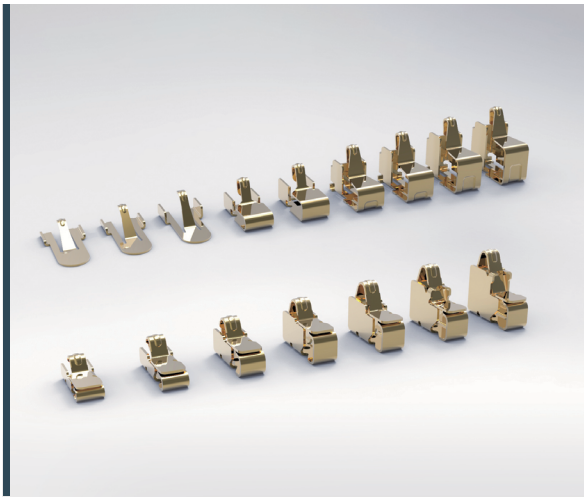
The next-generation solution for current and future USB applications, USB Type-C connectors are engineered to an industry standard that provides a sleek, slim and compact format for handheld devices and small home appliances, yet robust enough for industrial applications. These connectors feature a reversible mating interface and receptacle designed to accept a plug in any direction, which enables easy, reliable mating. They also support a variety of different protocols and, with the use of adapters, are backwards compatible to HDMI, VGA, DisplayPort and other types of connections from a single USB Type-C port. A distinctive EMI design on the back of the receptacle shell helps eliminate unwanted EMI leakage, while offering enhanced board retention features. Waterproof and splashproof options can also deliver improved performance and reliability in rugged environments.

Fig. 11: TE's waterproof IPX8 USB Type-C connector

Grounding

Spring Finger Contacts

Spring fingers (also known as shield fingers, grounding springs or universal ground contacts) are single-contact, surface-mountable internal connectors with multiple functions on a PCB. As applications become more compact and miniaturized, spring finger contacts offer the best choice for grounding, antenna feeding and electromagnetic interference (EMI) shielding, given their small footprint and scalability. Most importantly, this allows for a scalable size spring finger that can utilize the same footprint, thereby minimizing the need for a board redesign.



Summary

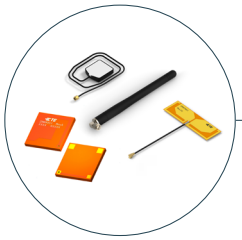
As the demand for smaller smart devices increases, so too will the need for even more miniaturized components that perform reliably and in harmony with other device components. Approaching the design phase with a holistic view of the impact of all components—including antennas and PCB connectors—is a critical step to avoiding unanticipated performance issues that can result in late-stage design changes, higher expense, and delayed time to market. Consulting early and frequently with your antenna and PCB connector manufacturer is essential to identifying the right standard or custom engineered components for your unique application requirements.

Optimize Your Smart IoT Device Design with TE Connectivity (TE)

With extensive experience and global reach, TE delivers products and application tooling for today's and tomorrow's IoT applications, including smart health, smart metering, smart transportation, smart cities, smart buildings and other IoT devices. TE also provides analysis and simulation services to allow OEMs to predict system performance, resulting in faster design cycles and lower costs. Learn more at te.com/IoT.

TE Product Solutions

Antennas

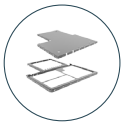


Standard Antennas

Custom Antennas

Grounding Solutions

Spring Fingers



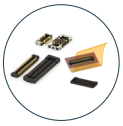
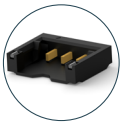
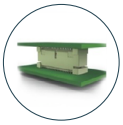
Board Level Shielding

Power Solutions

Battery Pack Interconnect

Standard Battery Interconnect

Other Commonly Associated Interconnect Systems

	FPC Interconnect	Display Applications
	Fine Pitch Board-to-Board and Board to FPC Connectors	Data, Camera & Sensor Applications
	Wire-to-Board Interconnect	Low Power & Signal Routing
	Board-to-Board Interconnect	Parallel Stacking
	I/O Interconnect	Data & Charging

Expertise and Capabilities to Advance Your Designs

Solution Know-How	Test Capability	Time-To-Market	Manufacturing
• Expertise in miniaturization and design modularity • Guidance to requirements, technology, cost and time-to-market tradeoff • Solutions for EMI/ grounding, high data rates, bandwidth and power	• State-of-the-art RF labs around the world • Comprehensive measurement techniques	• Quick front facing engagement • Design and delivery within service level agreement	• Many processes under one roof • Repeatability and scale

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