We get technical

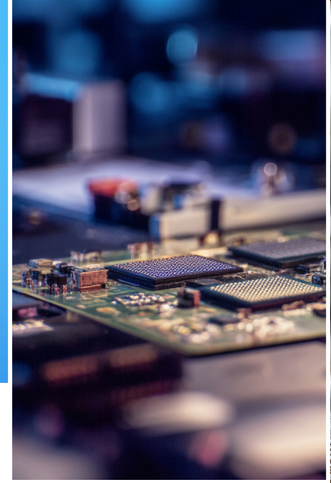
Best practices for the selection of rugged connectors

Why choose lever-based terminal blocks in PCB circuits

Select the right connector to ensure high-current power integrity in extreme environments

The basics of HDMI connectors

DigiKey



contents

DigiKey

Editor's note

Welcome to the DigiKey eMagazine Volume 27 – Interconnect.

This edition is packed with fresh insights, helpful tips, and expert perspectives from some of the biggest names in connectivity. It kicks off with feature articles from Amphenol FCI, Molex, Samtec, and 3M that provide a look into the latest trends and technologies shaping how we design and build reliable, high-performance connectivity solutions across diverse applications.

We then take a closer look at the unsung heroes of reliable electronic design — connectors and terminal blocks. From withstanding harsh environmental conditions to simplifying everyday assembly tasks, these components play a crucial role in keeping systems running smoothly.

We begin with "Best Practices for the Selection of Rugged Connectors," a guide to ensure your designs maintain top performance even under the toughest conditions. Next, "Why Choose Lever-Based Terminal Blocks in PCB Circuits," highlights how these intuitive components can streamline wiring and improve assembly efficiency.

For engineers tackling high-power applications, "Select the Right Connector to Ensure High-Current Power Integrity in Extreme Environments," provides valuable insights into maintaining stable performance where it matters most. Finally, we round out the issue with "The Basics of HDMI Connectors," a concise refresher on a familiar interface that continues to evolve in our connected world.

Whether you're an engineer, a designer, or just curious about the world of electronics, there's something here for you.

Amphenol samtec molex 3M
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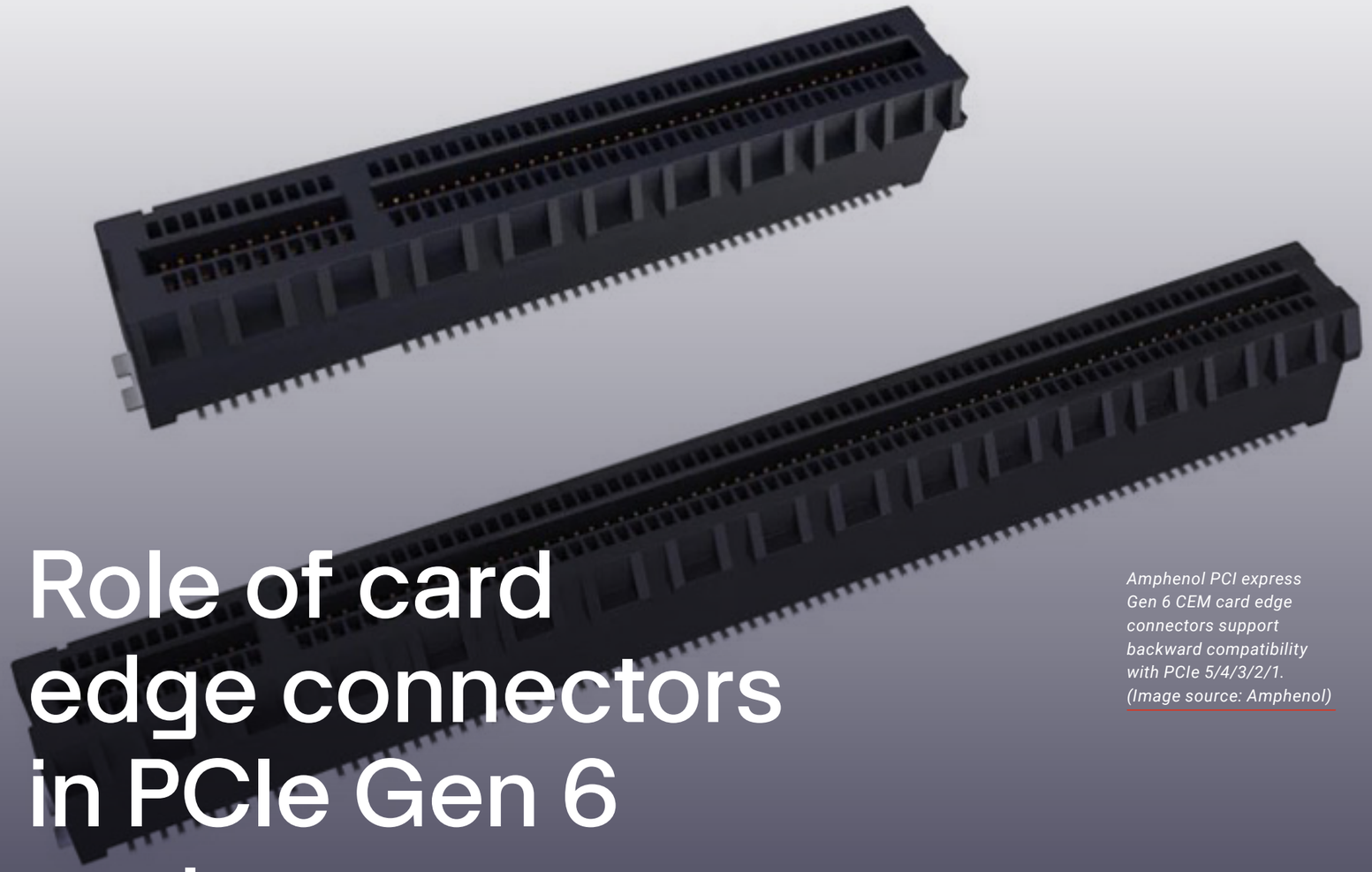


Amphenol PCI express Gen 6 CEM card edge connectors support backward compatibility with PCIe 5/4/3/2/1. (Image source: Amphenol)

Role of card edge connectors in PCIe Gen 6 systems

By Abhishek Jadhav

Amphenol

Amphenol

For two decades, the Peripheral Component Interconnect Express (PCIe) standard has supported modern computing infrastructure with scalable bandwidth to connect CPUs to high-speed peripherals, storage controllers, and network interface cards. The exponential growth in AI and HPC workloads has led the industry to transition from the 32 Gigatransfers per second (GT/s) of Gen 5 to the 64 GT/s of Gen 6.

The Gen 5 interconnects are losing usable signal margin faster than anticipated due to the demand for higher lane speeds and wider channels. In response, the PCIe 6.0 specifications have continued the trend of doubling interface bandwidth with each new generation to improve data throughput.

Historically, the PCI Special Interest Group (PCI-SIG) maintained the cadence of bandwidth doubling primarily through frequency scaling and improvements in coding efficiency. From Gen 1 through Gen 5, the interface used Non-Return-to-Zero (NRZ) signaling, a binary modulation scheme in which high and low voltage levels represented 1s and 0s, respectively. This method was simple to implement and offered substantial noise margins.

However, the physics of copper interconnects imposes a frequency wall at which insertion loss and skin-effect degradation become unmanageable. Therefore, to achieve the 64 GT/s target of PCIe Gen 6 without exceeding doubling the baud rate to 64 GBaud, the standard has adopted Pulse Amplitude Modulation with 4 levels (PAM4). The shift has allowed the bus to transmit 64 GT/s while maintaining the same 16 GHz Nyquist frequency as Gen 5.

The move from PCIe Gen 5 to Gen 6 has become more than just an upgrade. It is a discontinuity in the design complexity. The PAM4 reduces the signal eye height to one-third of NRZ signals, degrading the Signal-to-Noise (SNR) ratio by approximately 9.5 dB. The fragility necessitates the implementation of Forward Error Correction (FEC) and a transition to Flow Control Unit (FLIT) encoding.

For system designers, the margin that was previously relied upon in Gen 3 and Gen 4 designs has effectively disappeared. The industry generally targets a channel loss budget of around 32 dB at 16 GHz. This has forced engineers to re-evaluate components in the signal chain. Designers can no longer treat connectors as passive mechanical commodities.

In addition, the risk of delaying this transition to PCIe Gen 6 is significant. As AI accelerators and GPUs continue to scale in power and performance, legacy Gen 5 infrastructure is rapidly becoming the bottleneck. Designing Gen 6 provides the necessary signal integrity and architectural longevity to support the next wave of computing density.

Card edge connectors at Gen 6 speeds

Among all the pieces in the PCIe channel, the card edge connectors that mate an add-in card to a host motherboard are the most important for system performance. The connector serves as a high-speed gateway between a PCIe expansion card and the system board. At Gen 6 speeds, the card edge connectors must maintain controlled impedance across many high-speed signal pairs, introduce minimal insertion loss, and isolate each lane from interference.

Equally important is compliance with the PCIe Gen 6 Card Electromechanical (CEM) standard. The specification describes the mechanical form factor, pinout, and electrical performance requirements for the card edge connector and slot interface.

Amphenol PCIe Gen 6 CEM card edge connectors, for example, were designed to comply with the PCIe 6.0 specifications, including all mechanical and electrical interface standards. The company is among the first to offer a qualified Gen 6 CEM card edge connector solution that meets the demand for 64 GT/s operation.

To facilitate the adoption of the Gen 6 card edge solution, the connector is backward-compatible and footprint-interchangeable with legacy PCIe connectors down to Gen 1. This means they physically drop into the same connector slot on a motherboard and align with the same PCB footprint as Gen 5 or earlier generation connectors.

Measurable performance metrics of Gen 6 card edge

One of the primary challenges at 64 GT/s is maintaining an open eye diagram in the presence of noise. Amphenol achieves this through several design features. The connector housing uses low-halogen, high-temperature thermoplastics with optimized dissipation factor and dielectric constant properties.

To ensure crosstalk isolation, Amphenol has designed the connector to reduce capacitive and inductive coupling between adjacent pairs. This is essential for PAM4, where the reduced noise margin makes the system more sensitive to crosstalk.

The datasheet indicates that the PCIe Gen 6 CEM card edge connector meets the insertion loss and return loss requirements. As a result, the connector consumes only a limited portion of the roughly 32 dB channel loss budget. This is crucial because every decibel saved at the connector is a decibel that can be used for longer PCB traces. The manufacturing tolerance of the contacts also ensures that the impedance remains close to the 85 Ohm target.

Signal integrity also depends on mechanical parameters. The Amphenol PCIe Gen 6 CEM card edge connector is rated for a minimum of 50 mating cycles, with some variants, like the Mini Cool Edge IO, rated for up to 250 cycles. This durability ensures that the contact plating remains intact, preventing oxidation and increased resistance that could lead to link failures.

Mini Cool Edge IO
(Image source: Amphenol)

The connectors have specific insertion and removal forces to ensure a secure connection that does not disconnect. The integration of side latches or locking mechanisms further secures the add-in card in high-vibration environments.

The Amphenol PCIe Gen 6 CEM card edge connector family provides an early and comprehensive solution for designers targeting the new standard. It offers the necessary high-speed electrical performance while preserving the mechanical interchangeability with existing PCIe slots. The connectors have bridged the gap between theoretical requirements and practical, deployable hardware, a crucial step in the transition to the Gen 6 era.

Conclusion

By adopting these Gen 6 connectors, system designers can ensure that their platforms are not left behind as the PCIe ecosystem evolves.

The move to PCIe Gen 6 is both a challenge and an opportunity. It challenges tightening every aspect of design and revisiting legacy assumptions, but it offers a doubling of performance. With Amphenol PCIe Gen 6 CEM card edge connectors now on the market, designers have the tools they need to build systems ready for the next generation of PCIe.

To learn more, visit the Amphenol PCIe Gen 6 card edge connectors.

Putting interconnects to the test in the harshest environments

By Abhishek Jadhav

A satellite in low-Earth orbit might cycle between intense sunlight and deep shadow several times a day. As this happens, its internal electronics can be exposed to significant temperature changes. These systems also experience ongoing vibration throughout operation, as well as mechanical shock during major events like launch or deployment.

Ground-based systems introduce their own kinds of stress. Industrial equipment runs continuously in settings that expose components to mechanical load. Medical devices experience repeated sterilization cycles that can take a toll on materials and construction. In automotive systems, interconnects may sit close to parts that generate heat.

Within these harsh environments, interconnects must hold up even when conditions push them far from typical operating limits. Samtec, a global manufacturer of electronic interconnects, has developed a Severe Environment Testing (SET) program to determine how components will behave under heat, vibration, voltage stress and other conditions that exceed standard commercial test requirements.

What is SET?

SET builds on a multi-tiered testing structure that evaluates interconnect durability at increasing levels of stress.

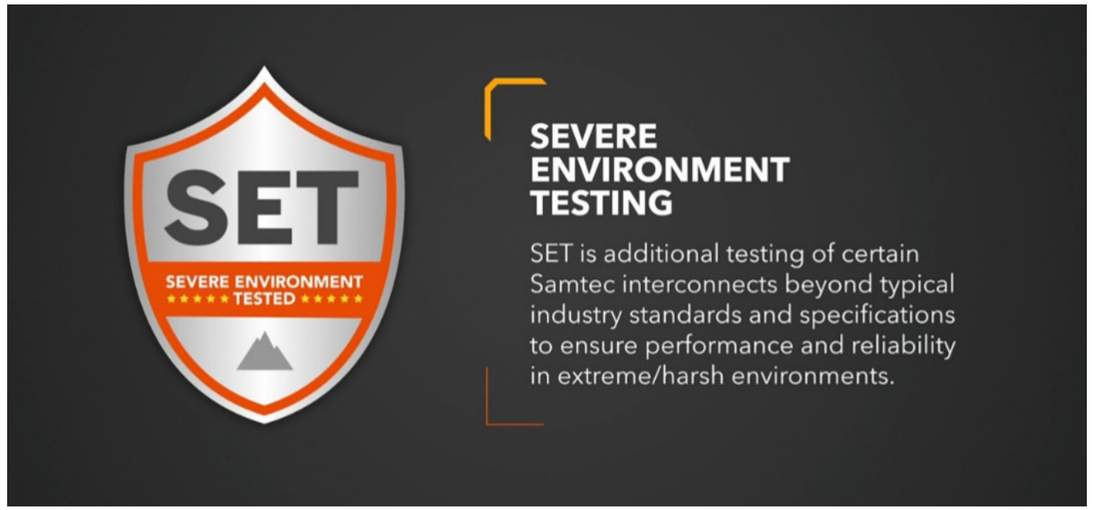
At the foundation is Design Qualification Testing (DQT), which applies to all Samtec product series. DQT covers a range of baseline evaluations. Normal force measures how firmly contacts press together. Thermal aging examines how materials behave after long-term exposure to heat. Mating and unmating durability looks at how well a connector holds up to repeated use. Current-carrying capacity determines how much electrical current a contact can safely handle. Insulation resistance measures how well insulating materials prevent unintended current flow between contacts. Event detection monitors for brief interruptions in electrical continuity when the connector is subjected to mechanical stress. DQT also includes checks such as dielectric withstanding voltage (DWV), and mechanical shock and random vibration, which are explored further in the next section.

For products that require added assurance, Samtec offers the Extended Life Product program (ELP). ELP certifications involve more rigorous testing to evaluate contact resistance under simulated storage and field conditions. One example is ten-year mixed flowing gas testing, where gases such as sulfur dioxide, chlorine, hydrogen sulfide and nitrogen dioxide flow around components for two weeks to simulate harsh atmospheric conditions. ELP also includes high mating-cycle testing, ranging from 250 to 2,500 cycles, to assess how contacts perform after repeated use.

SET sits above both programs to focus on high-risk environments. It targets interconnects used in applications ranging from military/aerospace, industrial, medical, and automotive, to test connectivity, AI/machine learning, instrumentation, 5G networking, and broadcast equipment. Products qualified under SET are also approved for NASA Class D missions that include low-Earth orbit (LEO) satellites, SmallSats and CubeSats.

Outgassing considerations for space applications:

Outgassing is a key concern for systems that operate in vacuum environments. It occurs when non-metallic materials such as polymers or adhesives release small amounts of gas when exposed to heat or low pressure. In a vacuum, these vapors can settle onto nearby surfaces and



Severe Environment Testing (Image source: Samtec)

may interfere with optics, sensors, or other components that are sensitive to contamination.

NASA's ASTM E595 standard is commonly used to assess whether materials are suitable for these conditions. The test measures total mass loss (TML) and collected volatile condensable materials (CVCM), with acceptable thresholds of less than 1.0% TML and less than 0.10% CVCM. Samtec references NASA outgassing data to determine whether specific materials meet these criteria when space applications are involved. Although outgassing is not part of the SET test sequence, it is still relevant for SET-qualified products used in NASA Class D missions.

Key stress categories in SET

Samtec's SET program subjects interconnects to a combination of thermal, mechanical, electrical, and environmental stresses that exceed what is typically required for commercial components.

Altitude testing:

Changes in altitude can affect the ability of insulating materials to withstand voltage. Dielectric withstanding voltage assesses how well a connector's insulation can "hold its ground" when exposed to higher-than-normal voltage—similar to increasing pressure on a barrier to see if it leaks.

SET includes altitude testing that exceeds VITA 47.1 requirements. In this evaluation, a controlled over-voltage is applied at approximately 70,000 feet to confirm that the insulation continues to keep conductors isolated under electrical stress.

Temperature cycling and non-operating temperature testing:

Temperature changes can place significant stress on connector materials. Thermal expansion and contraction can shift materials over time, affecting contact resistance, plating, and overall mechanical stability. SET includes temperature cycling that moves parts between –65°C and 125°C, with time spent at each extreme before shifting to the next. Some evaluations involve as many as 500 cycles. These tests help show how an interconnect responds when it is exposed to sharp swings between hot and cold conditions.

SET also includes non-operating temperature testing to assess durability outside recommended ranges. Parts are cycled between –55°C and 105°C for 100 cycles, and between –65°C and 125°C for another 100 cycles. This type of testing helps confirm whether materials and connector structures remain stable when exposed to severe temperature excursions.

Mechanical shock and vibration:

Mechanical forces are another source of stress that can influence how well a connector performs over time. In many applications, electronics encounter sudden impacts, steady vibration, or a mix of both. These forces can come from equipment that rotates, from motors running nearby, or from machines operating across uneven surfaces. Over time, this kind of motion can affect how securely contacts meet and whether electrical connections remain stable.

SET includes both mechanical shock and random vibration testing to evaluate how interconnects respond to these conditions. Mechanical shock testing subjects components to a peak of 40 G using an 11 millisecond half-sine pulse, which represents a sharp, momentary impact. Random vibration testing exposes parts to motion ranging from 5 to 2,000 Hz at 12 gRMS, simulating the continuous shaking that can occur in environments such as industrial equipment, aerospace systems, or automotive applications.

Humidity exposure:

Moisture in the environment can also affect the materials inside a connector. High humidity and repeated humidity cycling can contribute to corrosion on metal surfaces or changes in insulation resistance.

SET includes humidity testing based on VITA 47.3 to evaluate how interconnects respond under these conditions. In this test, components are exposed to humidity levels far higher than they would normally encounter, for an extended period.

Electrostatic discharge (ESD):

When two surfaces come into contact and then separate, they can build up static electricity. If that charge suddenly transfers to a connector or nearby circuitry, it can disturb sensitive electronics or affect the surfaces where contacts meet. In everyday handling, even a small spark created by static buildup can reach surprisingly high voltages.

SET evaluates how interconnects respond to these events by exposing components to repeated electrostatic discharges at 5 kV, 10 kV, and 15 kV, with ten discharges applied at each level. The evaluation also incorporates VITA 47.1 ESD resistance criteria as part of the testing process.

Samtec's SET-Qualified products

The SET program spans several types of interconnect families from Samtec. These examples highlight some of the products that fall under SET test conditions.

Edge Rate:

Edge Rate connectors are qualified for altitude testing that measures DWV at 70,000 feet. The family uses a rugged contact geometry with a smooth, milled surface to reduce wear in high-mating-cycle applications. Edge Rate is built on a 0.80 mm pitch board-to-board format and is designed for high-speed systems, supporting data rates up to 56 Gbps PAM4. Shielded versions are also available for designs that require additional protection.

Tiger Eye:

Tiger Eye connectors are built to withstand the intense shock and vibration testing performed under SET. The system uses a 1.27 mm pitch and a multi-finger, heat-treated beryllium copper contact that helps maintain engagement under mechanical stress. Tiger Eye is available in board-to-board and wire-to-board formats, with options for surface-mount or through-hole assembly. The durability of the contact design makes it suitable for applications involving frequent mating cycles or vibration exposure.

SEARAY:

SEARAY connectors are included in the temperature-related evaluations in SET. The family features an open pin-field architecture available in 1.27 mm or 0.80 mm pitches, supporting high-density layouts with configurations reaching up to 500 I/O. The Edge Rate contact system is also part of the SEARAY design, enabling data rates up to 56 Gbps. Multiple board-to-board configurations are available, including mezzanine, coplanar, and right-angle layouts.

Tiger Claw:

Tiger Claw connectors appear in the SET-qualified list for the electrostatic discharge portion of testing, which includes exposure to discharge levels up to 15 kV. Built on a 0.100 inch (2.54 mm) square-post header and socket format, the system is listed as a general-purpose option for harsh environments that use larger pitch spacing or traditional header-and-socket layouts.

Samtec also offers digital models for 97 percent of its stocking parts on DigiKey to assist engineers during early stages of development.

To learn more, visit Samtec Severe Environment Testing.

Designing high-speed interconnects for automotive systems

By Abhishek Jadhav

molex

Figure 1. Molex HSAutoLink Interconnect high-speed automotive-grade connector family for point-to-point connections. (Image source: Molex)

High-speed data connectivity has become a critical constraint in modern automotive electronics as they generate enormous data streams that must be transmitted with minimal latency. Next-generation advanced driver-assistance systems (ADAS) alone demand in-vehicle networks exceeding 1 Gbps to handle high-resolution cameras and radar feeds in real time.

Similarly, infotainment and connected services are expected to deliver a smartphone-like experience, raising the bar for bandwidth and reliability in vehicle data links. These trends have created a need for reliable, high-speed interconnects that can handle harsh automotive conditions while carrying multi-gigabit data between modules.

To address this need, Molex offers the HSAutoLink Interconnect System (Figure 1) for robust in-vehicle data connectivity. The HSAutoLink system is a proven, automotive-grade connector family that enables high-speed point-to-point connections for cameras, displays, sensors, and other vehicle electronics.

The genesis of the system

In the mid-2000s, as MP3 players and early smartphones began to interface with vehicles, original equipment manufacturers (OEMs) initially relied on standard consumer-grade USB connectors. However, it quickly became apparent that these connectors were prone to failure. The friction fit of a standard USB plug could not withstand the random vibration profile of a moving vehicle.

Molex addressed this by re-engineering the interface. They retained the core electrical interface of the USB but discarded the consumer-grade housing. Instead, they encased the electrical contacts in a rugged, automotive-grade shell featuring positive latching mechanisms, polarization keys, and robust shielding.

The HSAutoLink consists of mating cable assemblies and PCB headers. The cable assemblies use mini-USB style plugs and receptacles with full shielding and latching features. Corresponding board-mount headers are available in right-angle or vertical orientations, which are well-suited to tight packaging in automotive electronic control units (ECUs).

The system was first deployed in vehicle infotainment and telematics modules to bring consumer USB connectivity into the car with automotive-grade reliability. Today, HSAutoLink is used as a general-purpose data connector standard in many vehicles, supporting not just USB data but also other serial data protocols over a common interface.

A defining characteristic of the HSAutoLink system is its adherence to USCAR30. The United States Council for Automotive Research (USCAR) establishes a performance standard for automotive electrical connector systems. Compliance with USCAR30 requires passing a series of environmental tests.

Technical benefits of HSAutoLink

The engineering value of the HSAutoLink system lies in its ability to maintain signal integrity in an environment actively seeking to degrade it. The interconnect system also enhances design flexibility by supporting multiple protocols in the same connectors, and being able to withstand high temperatures.

Signal integrity and connection stability

In the hierarchy of automotive failure modes, intermittent connection is among the most common. HSAutoLink connectors are designed to maintain stable electrical connections even under vibration, shock, and repeated use. Unlike standard USB, the system implements positive latching mechanisms and robust keying to prevent accidental unplugging or mis-matching.

The headers and plugs include mechanical latches and guide rails that ensure a strong connection, proven to withstand vibration and repeated service events. Molex also offers multiple polarization key options and color-coded connector housings to avoid assembly errors when multiple HSAutoLink cables are used.

The result is an interconnect system that maintains signal continuity and integrity even in high-vibration automotive environments. This far exceeds the reliability of a conventional consumer USB connector.

Operation in harsh conditions

The HSAutoLink system is built to withstand the extreme conditions encountered in vehicles, including temperature swings, moisture, and electromagnetic noise. The connectors are designed to protect connections from water, dust, and fluids in exposed locations such as under the hood or off-highway equipment. All HSAutoLink components are made from high-temperature thermoplastics and materials rated for -40°C to +105°C operation.

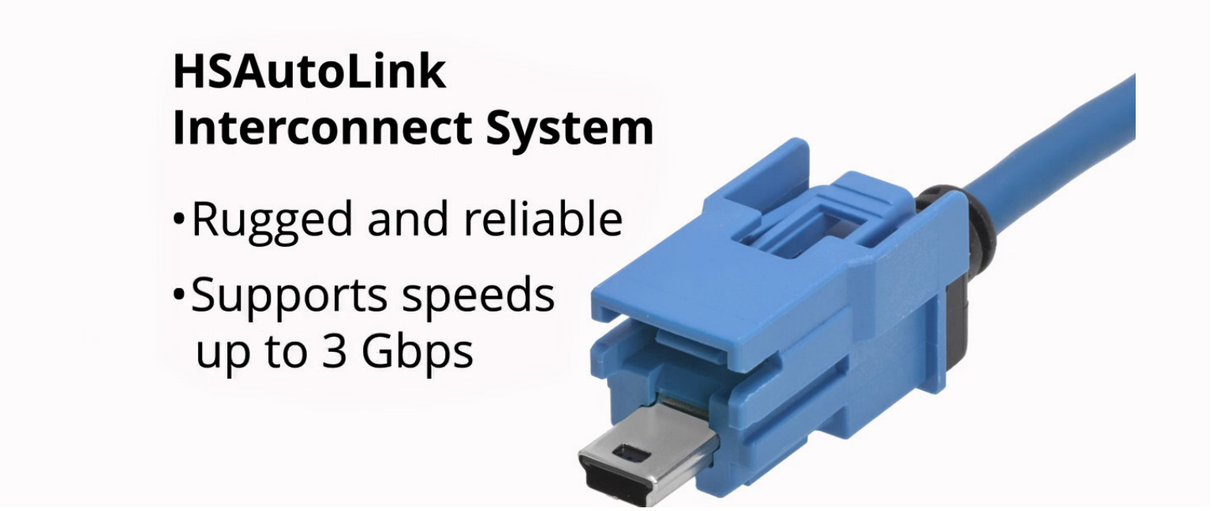


Figure 2. Molex HSAutoLink cable with data rates of up to 3.0 Gbps. (Image source: Molex)

The cables use full-length shielding, and a fully enclosed metal case to reduce electromagnetic interference (EMI) and crosstalk in noisy electrical environments. This shielding preserves signal integrity for high-speed data even when routed alongside other wiring in the car.

More importantly, the connection between the cable shield and the connector shield is continuous. This creates a Faraday cage around the signal path, preventing external EMI from coupling onto the data lines and conversely, preventing the high-speed data signals from radiating out and interfering with the vehicle's radio antenna.

Multiple protocol support

One of the core advantages of HSAutoLink is the support for a variety of high-speed data protocols. It is developed with enough bandwidth to support data rates up to 3.0 Gbps for proprietary or automotive protocols (Figure 2). This makes it suitable for carrying USB 2.0, automotive Ethernet (100Base-T1), LVDS video links, an A2B audio bus, and other serial interfaces over a common 4-pin or 5-pin connector.

For instance, the same 5-circuit HSAutoLink cable assembly could be used to transmit a rear camera's LVDS video feed, an infotainment system's USB data, or an Ethernet diagnostic link by matching the transceivers at each end. This multi-protocol flexibility helps reduce wiring complexity in modern cars by consolidating multiple data harnesses into one.

Low-profile, space-efficient design

In automotive electronics, space comes at a premium. HSAutoLink solves this with a very compact and low-profile connector design that reduces PCB footprint and cable bulk. The header receptacles have a 0.80 mm pitch and a profile that fits densely populated control modules. By reducing the size, HSAutoLink helps save device-side space and allows modules to shrink.

The interconnect system offers various mounting orientations and cable exit angles for tight packaging. These options include right-angle and vertical headers, as well as cable plug exits at 30°, 45°, 60°, 90°, and 120 °. The net benefit of these options is the design flexibility they offer. The compact footprint and low mating height of HSAutoLink make it easier to fit high-speed data ports into dashboards, pillars, headliner electronics, or camera modules where space is limited.

Applications beyond automotive

HSAutoLink is not limited to passenger cars or off-highway and industrial vehicles. In the agriculture sector, the interconnect cables are used in precision farming equipment and heavy machinery, where on-board computers connect to cameras and GPS receivers. The secure latching and optional sealed housing enable reliable data collection in tractors and combines operating in the field.

Even beyond vehicles, the system has been adopted in some telecommunications and robotics applications where a robust, multi-protocol mini connector is required for data transfer. Molex highlights how HSAutoLink can enable high-speed links in marine and factory automation.

In summary, any industry that requires secure, high-bandwidth connections with automotive-grade toughness can leverage the HSAutoLink Interconnect System.

To learn more, visit the Molex HSAutoLink Interconnect System.

Rethinking industrial wiring for sensor-rich systems

By Abhishek Jadhav

3M
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Open up the wiring panel on a piece of industrial equipment and the first thing you may notice is how much is happening in a very small space. Dense clusters of sensors feed into a busy control board, with some systems relying on hundreds of terminations. As these tightly routed cables accumulate across long production lines and increasingly advanced machines, the amount of wiring involved becomes a significant part of the build and maintenance effort.

Although traditional crimping methods remain widely used, they involve several steps and specialized tools. Each conductor must be stripped, placed into a contact, crimped with a dedicated tool, and then inserted into a housing or tightened into a terminal block. These steps generate scrap and introduce several opportunities for improperly installed connections. In some cases, different wire gauges require different crimp pins, adding another layer of handling and inventory to manage. For technicians working in inconvenient locations, this multi-step process makes things slower and more error-prone. These inefficiencies can add up in systems with large sensor counts. The impact is even more meaningful when equipment needs to be brought back online quickly, such as semiconductor manufacturing where downtime is costly, or automated warehousing where delays ripple through an entire facility.

As a result, there has been growing interest in connection methods that make wiring less cumbersome. One approach that continues to gain traction is insulation displacement contact (IDC) termination. First introduced by 3M in 1961, IDC has been refined over decades and expanded into a range of durable, field-installable connectors that help streamline wiring across various applications.

How IDC simplifies wiring

While many of the pain points in conventional wiring come from the number of steps involved, IDC's underlying mechanism is simple. The insulated wire is pressed into a U-shaped slot that pushes aside the insulation and makes copper-to-copper contact. This eliminates stripping, tinning, and other pre-treatment steps. Many IDC designs also terminate several wires at once, rather than one at a time. They often employ semi-transparent covers or guide features to ensure that conductors are positioned correctly before the connector is closed. Some families incorporate an audible or tactile latch to indicate when the connection is fully seated.

These features support repeatable results—while requiring no more than a standard pair of pliers for most field installations.

Because it removes several handling steps, IDC can reduce labor costs in equipment build and field work. In many applications, wiring time is shortened by as much as 60 to 80 percent, which becomes significant when spread out over dozens of connections. The simpler workflow also leaves fewer chances for incorrect strip lengths, missed strands, or crimps that do not fully seat. In 3M's case, the copper used in the contact is chosen for its elasticity, to help create a high-quality connection between the wire and the channel. Because the insulation is displaced rather than cut away, there is no loose debris to manage, which is useful in clean manufacturing environments where stray fragments can be problematic. The compact pitches and controlled contact geometry found in many IDC families allow engineers to manage dense wiring more efficiently within tight layouts.

Top applications for IDC connectors

The following use cases illustrate where IDC connectors are a strong match for wiring requirements.

High-density sensor networks

Semiconductor manufacturing tools and other precision machines implement huge numbers of sensors feeding into centralized control electronics. At times, there can be as many as thousands of terminations in one system. EV battery production equipment is similar, as automation expands and more sensing points are added within limited enclosures. In these environments, a connector that eliminates wire stripping and can terminate several wires at once helps shorten the time required for assembly and maintenance. The faster workflow is especially relevant for such systems where an hour of downtime can translate into hundreds of thousands of dollars in lost output.

Long-run distributed systems

Material-handling equipment, conveyor systems, and automated warehouses stretch across long distances; in some facilities, these paths can run for miles. Sensors are placed at intervals along the line, with each sensing point connecting back to the control system. Traditionally, adding a new device meant pulling another cable all the way to a terminal block, regardless of where it was installed along the line.

IDC-based branching connectors offer a different approach. Instead of routing a separate home-run cable, a technician can splice into the main trunk line at the point where a new sensor is installed. IDC termination makes it possible to add a new node with only a few straightforward steps. By branching off the existing line, the amount of cable required drops, installation becomes simpler, and changes to the system layout are easier to accommodate.

Field-maintained and vibration-prone equipment

Some equipment is wired in places that are simply difficult to reach. Recreational vehicles are a good example: HVAC units, sensors, lighting systems, and entertainment electronics are all routed through narrow compartments, and constantly exposed to vibration once on the road. Industrial electronics, automation equipment and outdoor control panels also have much of their wiring tucked into awkward spaces. Technicians may be working in cramped settings, sometimes outdoors in the elements, and they often need to get a system back up and running without much delay.

IDC connectors lend themselves well to this kind of work. Because the wire does not need to be stripped and the termination is made with a single press, the process is easier to carry out during field service. Latching and polarization features available on some IDC families help keep the connection secure once the equipment is in operation, even under nonstop movement.

Debris-sensitive environments

Cleanroom processes used in semiconductor, LCD, and medical manufacturing place strict limits on anything that could introduce debris. Traditional stripping can leave behind insulation fragments or fine strands. Because IDC displaces the insulation rather than cutting it away, the termination does not generate loose scraps. Therefore, IDC connectors align well with applications that prioritize contamination control, without adding extra steps to the process.

3M's IDC connector portfolio

To support this variety of applications, 3M offers several IDC connector families, each tailored to meet specific wiring needs.

Mini-Clamp Connector Series

Mini-Clamp connectors are designed for compact sensor and signal wiring, with a 2 mm pitch that helps conserve space. They are well-suited for equipment that relies on many small-gauge conductors, using IDC to terminate three to eight wires at once. A transparent cover lets installers confirm wire placement, and the audible click when the connector seats fully is an effective quality check during assembly. Mini-Clamp supports 30–20 AWG wires and comes in wire-to-wire, panel-mount, and board-mount versions. Recent updates include improved wire-holding mechanics and a latch guard that keeps the connector from catching on other cables.

Mini Stack Connector Series

Mini Stack connectors address applications where PCB space is limited, offering a footprint that can free up roughly 30 percent more board area compared to Mini-Clamp. They use a double-IDC termination method and can terminate two to four wires simultaneously. The series supports 30–22 AWG wires. Terminals are integrated into the housing to simplify handling, and up to four sockets can be stacked into compact blocks for easy mating or unmating. Fixed tabs on the board-mount headers help keep the connector aligned during soldering.

Link Connector Series

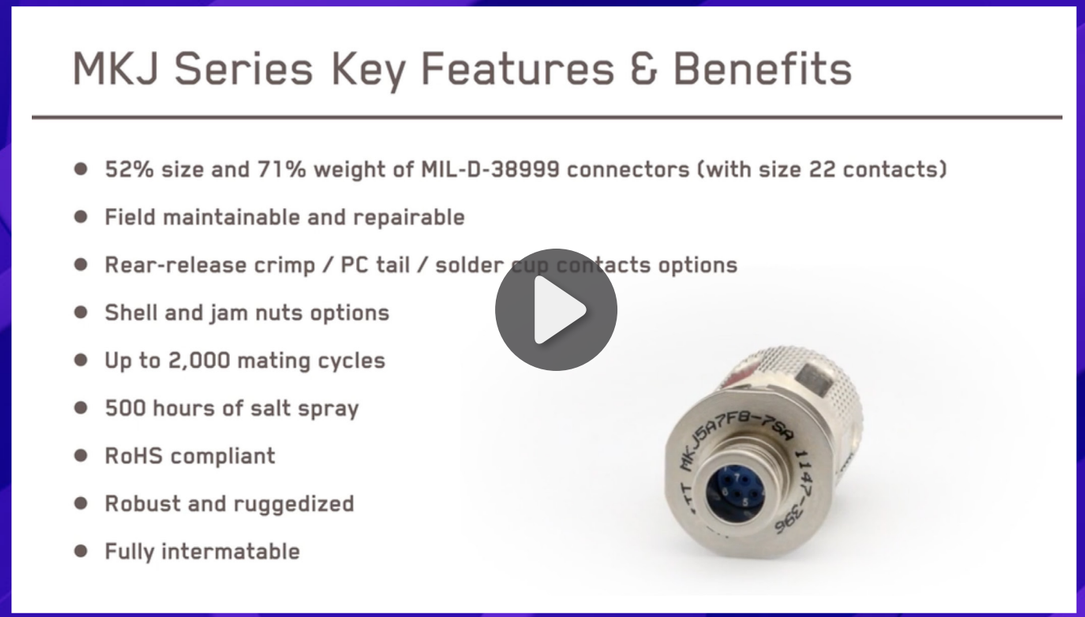
Link connectors apply IDC technology to branching and splicing along existing wiring runs, making them particularly useful in distributed systems. Rather than pulling a new cable all the way back to a terminal block, a technician can create a T-branch directly on the trunk line, even mid-cable. The family supports 22–16 AWG wires and includes detachable hermaphroditic versions that mate with themselves. Compact one-piece options and an IP54 splash-resistant variant for environments that require added protection are available.

Power Clamp Connector Series

Power Clamp connectors are intended for more rugged applications where wiring must stay secure under mechanical stress. They support 20–18 AWG wires and are rated up to 250 volts and 10 A on a single contact, or 7 A across multiple contacts. Semi-transparent, color-coded covers assist with wire placement, while polarization and latching keep the connection locked in place during operation.

To learn more, visit 3M IDC Connectors.

Video spotlight



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FX31 Series Floating High-Current Connector

Meet the FX31 Series: a rugged, floating board-to-board connector for internal power applications. With a 9.5 mm pitch, and a 20 mm stacking height, the FX31 supports up to 25 A per pin at 800 V while absorbing vibration and compensating for misalignment. Its vibration-absorbing structure reduces PCB stress by 0.05 mm in the Z direction, and heat resistance up to +125°C ensures long-term reliability in harsh environments.

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ITT Cannon MKJ Series

Deliver highly reliable connectivity for space-constrained, mission-critical applications. Engineered for defense, aerospace, industrial, smart weapons, UAVs, and oil and gas sectors, these compact, microminiature connectors support vertical exit for seamless integration with PCBs, flex circuits, flat cables, and multi-layer boards

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Video spotlight

molex

Stac64 and stAK50h Connectors

These connectors use the smallest terminals qualified to global automotive standards. Stackable headers function like building blocks, allowing manufacturers to customize wire-to-board connections without costly tooling changes or wasting valuable board space.

Learn More

TE connectivity
AUTHORIZED DISTRIBUTOR

Dynamic Ultra Series Connector System

TE Connectivity's Dynamic Ultra Series is a compact wire-to-board connector system designed for EV powertrains, battery packs, and automotive lighting. It features multiple contact points, a secondary lock for secure retention, LV 214 compliance, visual lock verification, and color options. Ideal for BESS, EVI, HVAC, e-drives, and onboard charging.

Learn More

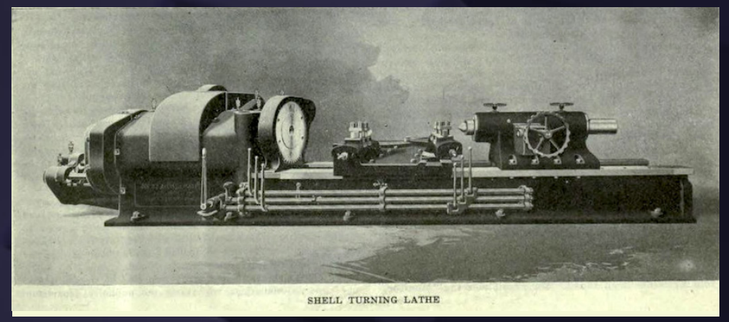
The Spark Salesman: from Scintilla to Amphenol Aerospace

By David Ray, Cyber City Circuits

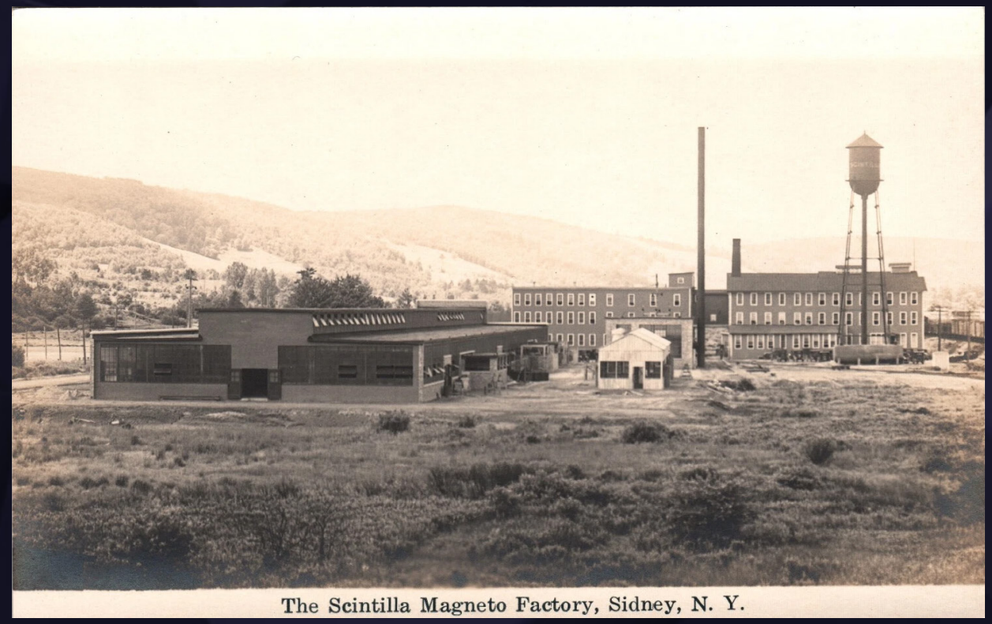
The In the time between the First World War and World War II, the United States experienced a boom of industry and innovation. Especially in places like Chicago, where companies like Motorola, Amphenol, Molex, Zenith, Littelfuse, and Ideal can all trace their origins to this time and place. This story starts with one of those Chicago businessmen named Laurence Wilder.

The Chicago machinery man who would not let the lights go out

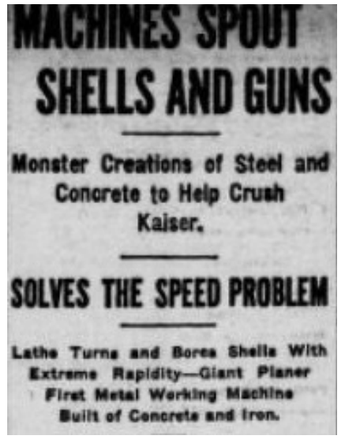
As a young man, Wilder managed his family's leather business, turning it into a million-dollar enterprise with a contract from the Dodge brothers to outfit all of their automobiles with Wilder's leather. He stayed there until the United States entered into the First World War in 1917. Unable to enlist due to an underlying medical issue, he joined the Amalgamated Machinery Corporation as the president and general manager of the Chicago offices. This company specialized in automotive production tooling, while also making the tools needed to produce mortar shells and other ordnance for the war effort.



This is one of the lathes that Amalgamated Machinery Corporation produced for ordnance production.



The Scintilla Magneto Factory, Sidney, N. Y.



MACHINES SPOUT SHELLS AND GUNS

Monster Creations of Steel and Concrete to Help Crush Kaiser.

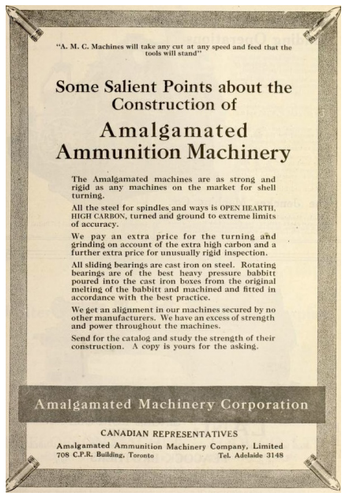
SOLVES THE SPEED PROBLEM

Lathe Turns and Bores Shells With Extreme Rapidity—Giant Planer First Metal Working Machine Built of Concrete and Iron.

Machines Spout Shells and Guns – Monster Creations of Steel and Concrete to Help Crush Kaiser – Solves Speed Problem

The Amalgamated Machinery Corp stands out historically for collaborating with Lucian Yeomans, who invented a unique purpose-built shell-turning lathe. A cast concrete assembly with large cavities to hold the metal parts. This approach enabled the assembly of a 10-ton lathe in just 7.5 hours, a task that would typically take up to six months with traditional methods, enabling the United States military to quickly overtake other nations in the manufacture of mortars and other ordnance. Yeomans' machines produced millions of highly precise shells over time, earning him the nation's highest engineering prize, the Franklin Institute Medal.

After the war ended and all the money from their ordnance tooling dried up, the automotive part of the business couldn't keep itself afloat and declared bankruptcy in 1921. During his time at Amalgamated Machinery, he had become the American licensee for the Swiss company Brown, Boveri & Cie., which specialized in a wide range of electrical components, including electric motors, dynamos, and ignition magnetos. This relationship proved invaluable for him as soon after closing the doors at Amalgamated Machinery, he became president of the American Brown Boveri Electric Corp. (ABBE)



"A. M. C. Machines will take any cut at any speed and feed that the tools will stand"

Some Salient Points about the Construction of

Amalgamated Ammunition Machinery

The Amalgamated machines are as strong and rigid as any machines on the market for shell turning.

All the steel for spindles and ways is OPEN HEARTH, HIGH CARBON, turned and ground to extreme limits of accuracy.

We pay an extra price for the turning and grinding on account of the extra high carbon and a further extra price for unusually rigid inspection.

All sliding bearings are cast iron on steel. Rotating bearings are of the best heavy pressure babbitt poured into the cast iron boxes from the original melting of the babbitt and machined and fitted in accordance with the best practice.

We get an alignment in our machines secured by no other manufacturers. We have an excess of strength and power throughout the machines.

Send for the catalog and study the strength of their construction. A copy is yours for the asking.

Amalgamated Machinery Corporation

CANADIAN REPRESENTATIVES

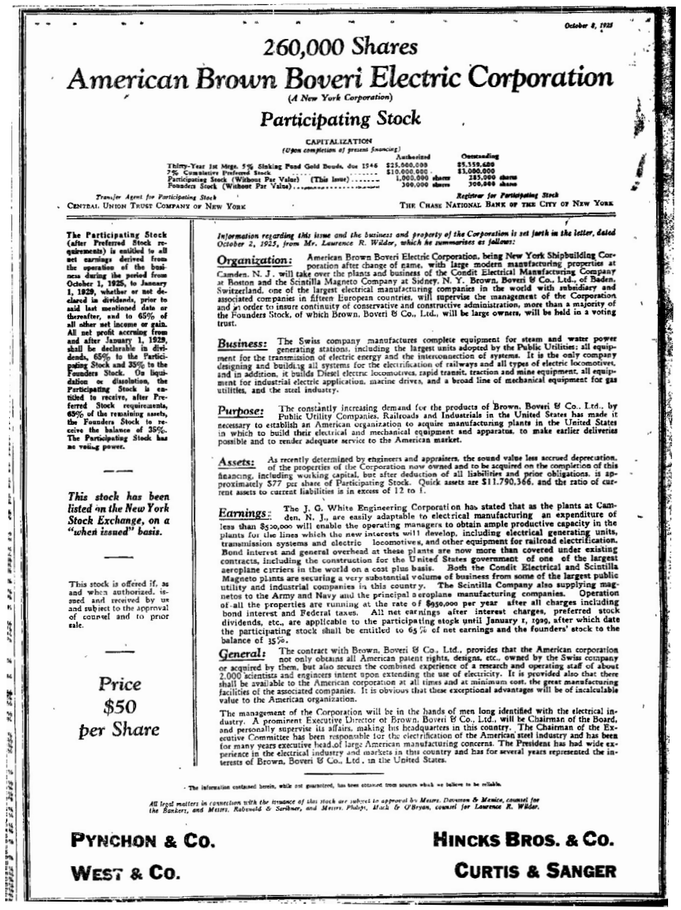
Amalgamated Ammunition Machinery Company, Limited
708 C.P.R. Building, Toronto — Tel. Adelaide 3148

1916 advertisement for Amalgamated Machinery Corporation's ammunition tooling.

American Brown Boveri Electric Corp.

Brown, Boveri & Cie. was a large Swiss corporation with interests across Europe and the US during the war. One of their subsidiaries was the Scintilla Magneto Company, which made high-quality ignition systems for engines. Wilder and Amalgamated Machinery were the exclusive rights holders in the US until the company's bankruptcy. After the war, many companies that had prospered were going out of business daily. To maintain a foot in the US market, Wilder and a team from the Swiss company founded the American Brown Boveri Electric Corp in New York City . Wilder was named president of this new corporation as they bought up the assets of several other failed companies, including Amalgamated Machinery.

The Scintilla Magneto Company, a Swiss subsidiary of Brown Boveri, produced aircraft-grade ignition systems and magnetos regarded as the finest of their time. A magneto is a self-contained electrical generator that produces the high-voltage current needed to fire the spark plugs of an internal-combustion engine, without requiring an external battery. It works by rotating a magnet past



October 2, 1925

260,000 Shares

American Brown Boveri Electric Corporation

(A New York Corporation)

Participating Stock

CAPITALIZATION
(Upon completion of present financing)

	Authorized	Outstanding
Thirty-Year 1st Mtge. 5½% Sinking Fund Gold Bonds, due 1946	$25,000,000	$5,359,600
7% Cumulative Preferred Stock	$10,000,000	$3,000,000
Participating Stock (Without Par Value) (This issue)	1,000,000 shares	260,000 shares
Founders Stock (Without Par Value)	300,000 shares	300,000 shares

Transfer Agent for Participating Stock
CENTRAL UNION TRUST COMPANY OF NEW YORK

Registrar for Participating Stock
THE CHASE NATIONAL BANK OF THE CITY OF NEW YORK

The Participating Stock (after Preferred Stock requirements) is entitled to all net earnings derived from the operation of the business during the period from October 1, 1925, to January 1, 1929, whether or not declared in dividends, prior to said last mentioned date or thereafter, and to 65% of all other net income or gain. All net profit accruing from and after January 1, 1929, shall be declarable in dividends, 65% to the Participating Stock and 35% to the Founders Stock. On liquidation or dissolution, the Participating Stock is entitled to receive, after Preferred Stock requirements, 65% of the remaining assets, the Founders Stock to receive the balance of 35%. The Participating Stock has no voting power.

This stock has been listed on the New York Stock Exchange, on a "when issued" basis.

This stock is offered if, as and when authorized, issued and received by us and subject to the approval of counsel and to prior sale.

Price $50 per Share

Information regarding this issue and the business and property of the Corporation is set forth in the letter, dated October 2, 1925, from Mr. Laurence R. Wilder, which he summarizes as follows:

Organization: American Brown Boveri Electric Corporation, being New York Shipbuilding Corporation after change of name, with large modern manufacturing properties at Camden, N. J., will take over the plants and business of the Condit Electrical Manufacturing Company at Boston and the Scintilla Magneto Company at Sidney, N. Y. Brown, Boveri & Co., Ltd., of Baden, Switzerland, one of the largest electrical manufacturing companies in the world with subsidiary and associated companies in fifteen European countries, will supervise the management of the Corporation and as order to insure continuity of conservative and constructive administration, more than a majority of the Founders Stock, of which Brown, Boveri & Co., Ltd., will be large owners, will be held in a voting trust.

Business: The Swiss company manufactures complete equipment for steam and water power plants for the transmission of electric energy and the interconnection of systems. It is the only company designing and building all systems for the electrification of railways and all types of electric locomotives, and in addition, it builds Diesel electric locomotives, rapid transit, traction and mine equipment, all equipment for industrial electric application, marine drives, and a broad line of mechanical equipment for gas utilities, and the steel industry.

Purpose: The constantly increasing demand for the products of Brown, Boveri & Co., Ltd., by Public Utility Companies, Railroads and Industrials in the United States has made it necessary to establish an American organization to acquire manufacturing plants in the United States in which to build their electrical and mechanical equipment and apparatus, to make earlier deliveries possible and to render adequate service to the American market.

Assets: As recently determined by engineers and appraisers, the sound value less accrued depreciation, of the properties of the Corporation now owned and to be acquired on the completion of this financing, including working capital, but after deduction of all liabilities and prior obligations, is approximately $77 per share of Participating Stock. Quick assets are $11,790,366, and the ratio of current assets to current liabilities is in excess of 12 to 1.

Earnings: The J. G. White Engineering Corporation has stated that as the plants at Camden, N. J., are easily adaptable to electrical manufacturing an expenditure of less than $630,000 will enable the operating managers to obtain ample productive capacity in the plants for the lines which the new interests will develop, including electrical generating units, transmission systems and electric locomotives, and other equipment for railroad electrification. Bond interest and general overhead at these plants are now more than covered under existing contracts, including the construction for the United States government of one of the largest aeroplane carriers in the world on a cost plus basis. Both the Condit Electrical and Scintilla Magneto plants are securing a very substantial volume of business from some of the largest public utility and industrial companies in this country. The Scintilla Company also supplying magnetos to the Army and Navy and the principal aeroplane manufacturing companies. Operation of all the properties are running at the rate of $950,000 per year after all charges including bond interest and Federal taxes. All net earnings after interest charges, preferred stock dividends, etc., are applicable to the participating stock until January 1, 1929, after which date the participating stock shall be entitled to 65% of net earnings and the founders' stock to the balance of 35%.

General: The contract with Brown, Boveri & Co., Ltd., provides that the American corporation not only obtains all American patent rights, designs, etc., owned by the Swiss company or acquired by them, but also secures the combined experience of a research and operating staff of about 2,000 scientists and engineers intent upon extending the use of electricity. It is provided also that there shall be available to the American corporation at all times and at minimum cost, the great manufacturing facilities of the associated companies. It is obvious that these exceptional advantages will be of incalculable value to the American organization.

The management of the Corporation will be in the hands of men long identified with the electrical industry. A prominent Executive Director of Brown, Boveri & Co., Ltd., will be Chairman of the Board, and personally supervise its affairs, making his headquarters in this country. The Chairman of the Executive Committee has been responsible for the electrification of the American steel industry and has been for many years executive head of large American manufacturing concerns. The President has had wide experience in the electrical industry and markets in this country and has for several years represented the interests of Brown, Boveri & Co., Ltd., in the United States.

The information contained herein, while not guaranteed, has been obtained from sources which we believe to be reliable.

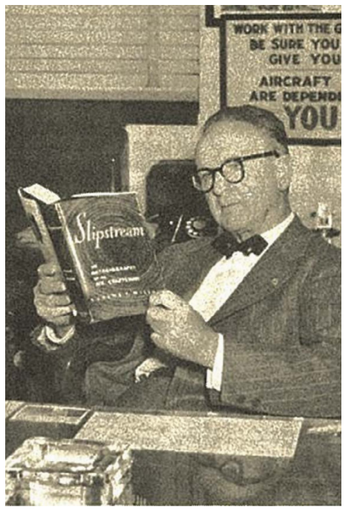
All legal matters in connection with the issuance of this stock are subject to approval by Messrs. Dawson & Menzie, counsel for the Bankers, and Messrs. Rabenold & Gardner, and Messrs. Phelps, Mack & O'Bryan, counsel for Laurence R. Wilder.

PYNCHON & CO. — HINCKS BROS. & CO.

WEST & CO. — CURTIS & SANGER

A newspaper advertisement for stock in the American Brown Boveri Electric Corporation (1925)

a coil of wire to induce current, then interrupting that current with a cam-driven breaker to deliver timed sparks to each cylinder. The technology emerged in the late nineteenth century through the work of engineers like Hippolyte Pixii and Robert Bosch, becoming indispensable for early automobiles, aircraft, and farm engines, where reliability and self-sufficiency mattered more than convenience. By the time of the First World War, magnetos powered nearly every airplane and tractor engine. Their rugged, self-exciting design made them the ignition of choice until battery-coil systems and electronic ignition gradually displaced them after World War II.



Thomas Fagan in his Bendix Electrical Components office in 1950.

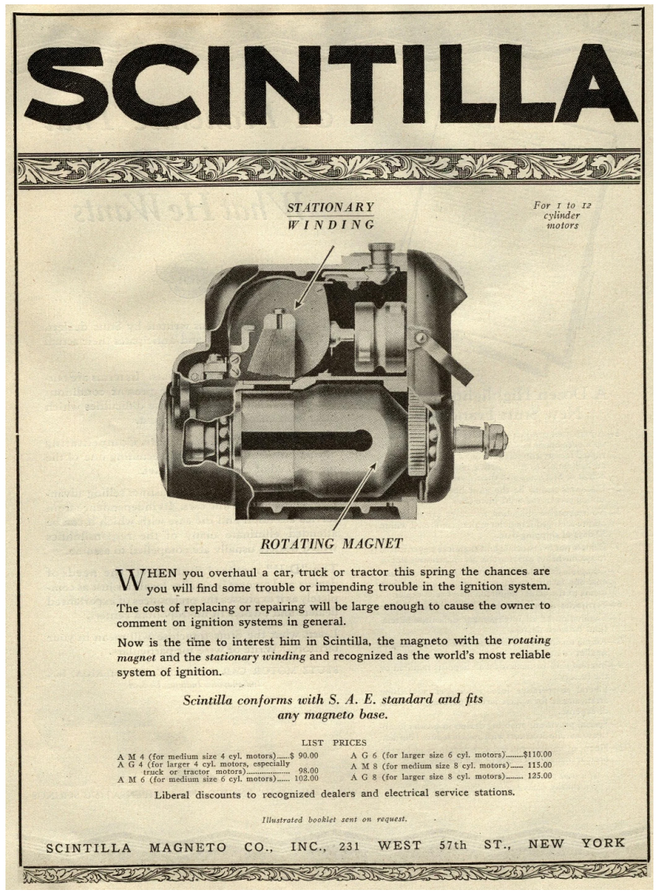
Thomas Fagan

One of the people that Wilder brought with him from Chicago was Thomas Z Fagan. Fagan was born in 1890 in Boston. His father worked in the Boston Navy Yard, teaching his son about engines and ignition systems. He joined the Navy Aviation Corps in 1917,

where he was quickly promoted to chief machinist. Following the war, he worked at Fansteel Products Company in Chicago, making specialty metals for the aircraft industry. Here is where he met Wilder. Later, Wilder hired Fagan as a sales representative for the then-Swiss-based Scintilla Magneto Co.

Fagan, trying desperately to enter the Naval Aviation market, made a trip to the testing facilities at Wright Aeronautical Corporation's test shop in Paterson, NJ. He tried to get the engineers to test his equipment, but they didn't seem interested. The magnetos they were using were inferior and Fagan knew this and confidently told them so.

"You claim you've got enough magnetos. I say they can't stand up to mine. There's a test engine in your shop on an endurance run. When the magnetos fizzle, give me a shout. I'll be sitting right here."


SCINTILLA

STATIONARY WINDING

For 1 to 12 cylinder motors

ROTATING MAGNET

WHEN you overhaul a car, truck or tractor this spring the chances are you will find some trouble or impending trouble in the ignition system.

The cost of replacing or repairing will be large enough to cause the owner to comment on ignition systems in general.

Now is the time to interest him in Scintilla, the magneto with the *rotating magnet* and the *stationary winding* and recognized as the world's most reliable system of ignition.

Scintilla conforms with S. A. E. standard and fits any magneto base.

LIST PRICES

A M 4 (for medium size 4 cyl. motors)	$ 90.00	A G 6 (for larger size 6 cyl. motors)	$110.00
A G 4 (for larger 4 cyl. motors, especially truck or tractor motors)	98.00	A M 8 (for medium size 8 cyl. motors)	115.00
A M 6 (for medium size 6 cyl. motors)	102.00	A G 8 (for larger size 8 cyl. motors)	125.00

Liberal discounts to recognized dealers and electrical service stations.

Illustrated booklet sent on request.

SCINTILLA MAGNETO CO., INC., 231 WEST 57th ST., NEW YORK

1922 advertisement for Scintilla Magneto Company's NYC offices.

After three days of waiting, just as Fagan predicted, the magnetos failed. He jumped into action, assembling the Scintilla magnetos onto the test engine, and to the surprise of everyone, but Fagan, they outlasted the engine. This was the test that he needed, convincing Wright Aeronautical Corp. that Scintilla magnetos were indeed far superior to anything else. He then took samples to the Army Air Corps in Ohio, where the testing again proved the high quality of his product.

Retro Electro fun fact: During the First World War, the US Navy commandeered control of the American Marconi Company and awarded it to General Electric in order to make it American-owned. This later formed the Radio Corporation of America (RCA). Read more of that story in the Retro Electro article "The Origin of Discrete Semiconductor Part Designators."

Soon, the news spread quickly across the industry. These magnetos enabled airplanes to fly at higher altitudes with reduced fuel consumption, enabling air travel to cover greater distances than ever before. The problem was that the Navy did not want to buy the magnetos from a foreign-owned company. On their initial order of five-hundred units they agreed that half of the order could come from Switzerland, but the other half and all of the following orders must be made in America.

In 1925, Wilder incorporated the new business Scintilla Magneto Company of America in Sidney, New York. They moved all of their operations from New York City into a 30,000-square-foot former Cortland Cart & Carriage factory. In the beginning, they lacked many of the specialty machines they needed, but they made do with what they had, producing very small quantities. By the end of the year, they brought in a handful of Swiss engineers to train the new employees, and they were able to bring in the needed machinery.


NORWICH, N. Y., MONDAY EVENING, OCTOBER 5, 1925.

Church

SIDNEY MAGNETO PLANT PURCHASED

SWISS COMPANY ACQUIRES ELECTRICAL CONCERN IN DELAWARE COUNTY VILLAGE

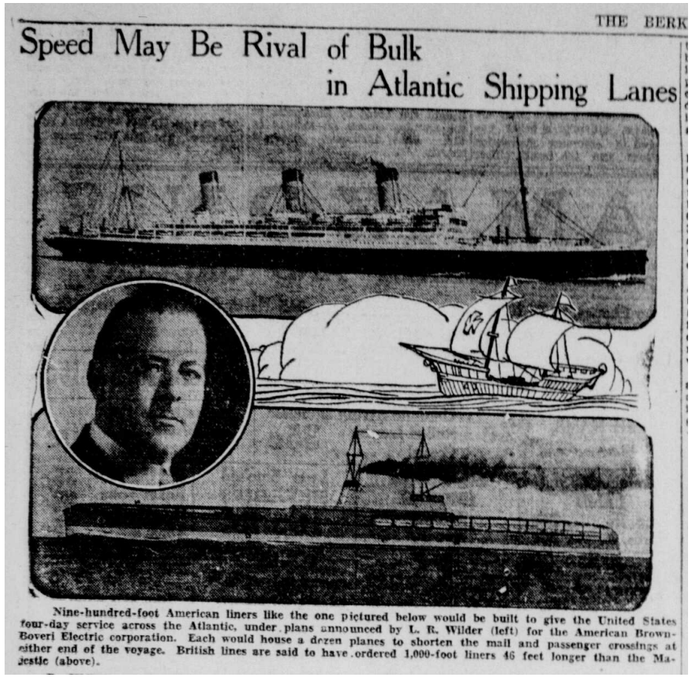
Press dispatches Monday confirmed the sale of the Scintilla Magneto Company of Sidney, owners and operators of a specialty plant, its business being the manufacture of magnetos and other electrical equipment, to the newly organized American Brown-Boveri corporation of New York. The same company has also purchased the Condit Electrical Manufacturing company of Boston. It is also understood that negotiations are under way for the purchase of other electrical companies.

Stockholders of the New York Shipbuilding Corporation will vote October 14 upon recapitalization of that company under the name of the American Brown-Boveri Corporation.

But this is a mere formality, as the majority stockholders already have given their approval. Minority stockholders will be offered the same basis as majority stockholders.

Woman T

Newspaper article from 1925 announcing Scintilla Magneto moving to Sidney.



THE BERK

Speed May Be Rival of Bulk in Atlantic Shipping Lanes

Nine-hundred-foot American liners like the one pictured below would be built to give the United States four-day service across the Atlantic, under plans announced by L. R. Wilder (left) for the American Brown-Boveri Electric corporation. Each would house a dozen planes to shorten the mail and passenger crossings at either end of the voyage. British lines are said to have ordered 1,000-foot liners 46 feet longer than the Majestic (above).

In 1928, American Brown Boveri spun off a shipbuilding subsidiary to Wilder for $8,000,000. Wilder spent the remainder of his professional career building ships, trying to solve the problems with trans-Atlantic travel.

A new era in aviation

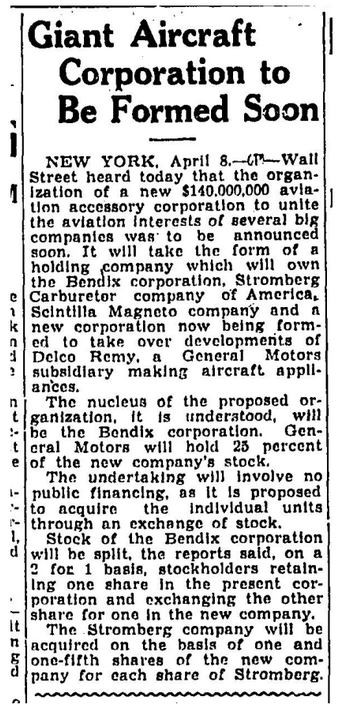
In 1925, Congress passed the Air Mail Act, which allowed the Postmaster General to contract with private companies to carry mail. Soon after, the US government placed an order for two Scintilla magnetos for every aircraft engine in the government's inventory. Every Army plane and every Navy plane, but more importantly, every mail-carrying plane. This forced private industry to adopt the Scintilla magneto if they wanted to contract with the US Postal Service, eventually coming standard from the factory on all Pratt & Whitney, Wright Aeronautical, and Packard airplane engines.

In 1927, Charles Lindbergh dared to transit the Atlantic Ocean with the plane 'Spirit of St. Louis,' flying over thirty-three hours from Long Island to Paris. The day after landing Wright Aeronautical Corp. sent a telegram to the Sidney offices praising their magnetos.

"Captain Lindbergh's Ryan monoplane could never have reached Paris without the unfailing spark delivered by Scintilla aircraft magnetos to his Wright Whirlwind Engine. Your splendid magneto is playing a prominent part in making history."

– Telegram from Wright Aeronautical Corp. to Scintilla on Lindbergh's historic flight

Most simply put, Scintilla's magnetos revolutionized air travel. Planes suddenly could fly higher than ever before. Pilots were setting new distance and flight time records. A team flew from New York to Germany in forty-three hours. Another team completed the first nonstop flight to Hawaii from Oakland. Suddenly, municipalities across the country were scrambling to build airports in their towns.



Giant Aircraft Corporation to Be Formed Soon

NEW YORK, April 8.—(AP)—Wall Street heard today that the organization of a new $140,000,000 aviation accessory corporation to unite the aviation interests of several big companies was to be announced soon. It will take the form of a holding company which will own the Bendix corporation, Stromberg Carburetor company of America, Scintilla Magneto company and a new corporation now being formed to take over developments of Delco Remy, a General Motors subsidiary making aircraft appliances.

The nucleus of the proposed organization, it is understood, will be the Bendix corporation. General Motors will hold 25 percent of the new company's stock.

The undertaking will involve no public financing, as it is proposed to acquire the individual units through an exchange of stock.

Stock of the Bendix corporation will be split, the reports said, on a 2 for 1 basis, stockholders retaining one share in the present corporation and exchanging the other share for one in the new company.

The Stromberg company will be acquired on the basis of one and one-fifth shares of the new company for each share of Stromberg.

Article announcing the formation of Bendix Aviation. Corsicana Daily Sun April 8, 1929

In 1929, right before the stock-market crash, the Bendix Aviation Corporation, founded earlier that year by financier Vincent Bendix, purchased and consolidated Scintilla with Stromberg Carburetor Company and other component makers under a $140 million holding company, rebranding it to the Scintilla Magneto Division. By the mid-1930s, Bendix Aviation was a primary provider for the Army Air Corps, the Navy, and most major aircraft manufacturers.

The finest electrical connector money can buy

Under Bendix management, Scintilla magnetos dominated the market through to the end of World War II. However, once the war was over, the military suddenly had a surplus of equipment. More than 90% of open government orders were quickly canceled. Sidney, once full of Scintilla employees, soon felt like a ghost town.

The standard military connector of the day used a brittle phenolic resin, popularized by the Chicago-based Amphenol. During the tail end of World War II, Scintilla engineers started developing a new type of dielectric for connectors called 'Scinflex.' These connectors directly competed with Amphenol's offerings. These circular aluminum connectors followed the Army–Navy standard pattern (later MIL-C-5015), and from an untrained eye, they would have looked identical.

In step with JACOBS

The new Jacobs Model L-3 equipped with 2 Scintilla Magnetos.

SCINTILLA
AIRCRAFT MAGNETOS

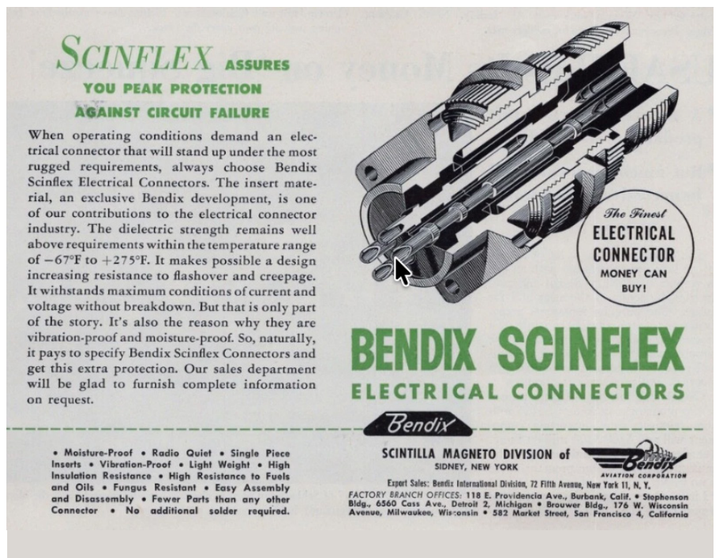
The Jacobs L-3 Aircraft engine—a new model entering the low horse-power field—is equipped, like all its predecessors, with Scintilla Aircraft Magnetos.

Most leading builders of aircraft engines find dependability and satisfaction in Scintillas.

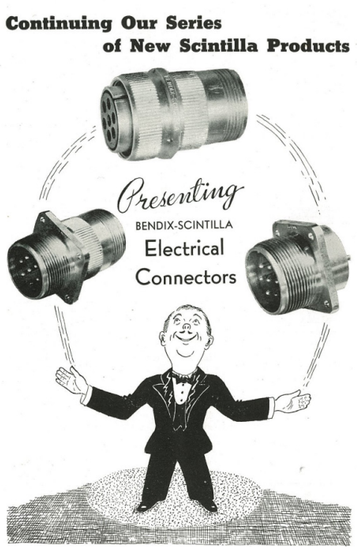
SCINTILLA MAGNETO CO., INC.
SIDNEY, N. Y.
Contractors to the U. S. Army and Navy
(Subsidiary of Bendix Aviation Corporation)

DEPENDABILITY
SIMPLICITY
ACCESSIBILITY

1931 Scintilla magazine advertisement.



Advertisement for the Scinflex series of connectors.



Retro Electro fun fact: Amphenol is a portmanteau of the company's original name, 'The American Phenolic Corporation.'

By 1950, four years after their introduction, up to 10% of Scintilla's revenue came from its connectors, and soon connectors eclipsed magneto sales altogether. In 1966, Bendix formally rebranded the Scintilla Magneto Division to Bendix Electronic Components Division.

This Bendix cable is part of the Apollo 11 collection at the Smithsonian. It was used to power the camera equipment.

Bendix was instrumental in the US space program. For the Apollo space program, Bendix Electronic Components Division produced Teflon-braided cables and gold-plated electrical connectors, which formed the electronic nerve system of the life support system that manages the space capsule's environment, along with much of the rest of the cabling needed for a safe journey.

In 1982, Allied Corporation acquired Bendix. Allied had already purchased the company Amphenol, and the following year it merged Bendix Electrical Components in Sidney, NY with Amphenol, forming Amphenol Aerospace.

In 1987, Allied divested Amphenol, making it a privately owned company, and in 1999, it went public with a successful IPO on the New York Stock Exchange. Since then, Amphenol Aerospace has become the largest division within the Amphenol corporate structure.

The writer acknowledges the invaluable help of Chris Cappello, the director of marketing communications at Amphenol. Chris's book, Connecting History, gives a complete and comprehensive history of Amphenol Aerospace in Sidney, NY.

Digi-Key is a strong distribution partner with Amphenol Aerospace, offering everything from connectors to network solutions. (Link: https://www.digikey.com/en/supplier-centers/amphenol-aerospace-operations)

Suggested Reading

Connecting History: From Scintilla to Amphenol by Chris Capello

Amphenol 75 Years Documentary by Amphenol Industrial Operations

"Amphenol Aerospace Celebrates a Century of Connectivity" by Amy Goetzman

"The Aircraft Magneto – Part One" by Scintilla Magneto Division

"Scintilla Aircraft Magnetos Gain Wide Favor" by Aviation Magazine (March 28, 1927)

The Scintillator (1942-1965) – An Internal Monthly Magazine

"A Swiss Magneto" by The Motor Cycle Magazine (Oct 27, 1921)

"Aeronautical Firms Buy One-Third Interest in Scintilla Magneto" by American Machinist (1928-10-04)

Amalgamated Machinery Corp (1917-1919): The Defunct Automotive Equipment Maker

"Will Make Doble Cars in Chicago" by Automotive Industries (1919-07-31)

"New Method of Building Lathes" by Machinery Magazine (1916 June)

"Cable, Power, Apollo 11" at the Smithsonian Air and Space Museum

"Scintilla – A Famous Name in Sidney" by I. J. Palmer

"Closely Linked For More Than a Hundred Years. Robert Bosch AG in Switzerland" by Bosch Corporate

"ALSEP: Apollo Lunar Surface Experiments Package" by Hamish Lindsay

"The Story of Amphenol: 1981-1987" by Douglas Ott

"Sale of Shipyards to Wilder Approved" by the New York Times

The current headquarters of Amphenol Aerospace in Sidney, NY.

Best practices for the selection of rugged connectors

By Poornima Apte
Contributed By DigiKey's North American Editors

Ensuring that data, signals, or power flows between different components in a system requires connectors that link essential equipment with each other. For example, connectors route a microphone's output to an amplifier. Similarly, linking power supplies to radar and other communication systems, and sensors to data processors to relay analog or digital signals, are just two of the many ways connectors find uses in everyday operations.

Connector technology continues to evolve along with the use cases for these essential parts. Although the military is expected to continue to be one of the biggest markets for connectors in the future, demand is not restricted to this sector alone. Globally, the rugged connector market is forecast to grow at a steady clip of 3.5% compounded annual growth until 2030, according to market research from Lucintel.

Advances in connector technology

Connector technology has a storied history, starting with a circular connector commissioned for the Douglas DC-1 aircraft in the 1930s. James Cannon of ITT Cannon developed the product. Since then, connector technology—and the wide ranges in which these products are available—has evolved to meet industry demand. Tracking these new advances in connector technology gives a peek into the many industrial use cases for connectors.

Made for high temperatures

Military operations in extreme climate conditions or space missions require connectors that can not only take severe cold and heat, but also withstand rapid cycling between two dramatically different temperature states. Advances in connector technology have enabled material composition that tolerates such conditions without compromising performance.

Lightweight materials

Weight has always mattered in aerospace applications, where every ounce affects aerodynamics and fuel requirements. Now, the topic is under renewed research as connectors find use in autonomous driving systems, electronic vehicles (EVs), robotics, and industrial automation. Large loads and battery life are incompatible, which means connectors are being made with lightweight composites to meet engineering and design constraints.

Modular designs

Infrastructure needs change frequently, and today's solutions can become obsolete by tomorrow. In such cases, an entire rip-and-replace approach to components is wasteful and expensive. Modular connectors address this problem by delivering the ability to swap parts out selectively. Users can also mix and match configurations for greater flexibility to meet custom needs.

Miniaturization of components

The adoption of sensors in a variety of use cases, including automotive systems, is driving the need for connectors in a wider range of sizes. Miniaturization will help design engineers develop compact circuitry that can fit into tighter spaces, which is becoming necessary in a variety of applications from the military to aerospace and beyond.

The rise of rugged connectors

The growth in the demand for rugged connector technology likely coincides with the rise of connected machines in the industry. Industrial IoT necessitates data collection from sensors that might have to withstand a variety of severe conditions.

While it is easy to imagine that data centers are the hubs for computing and real-time information, data-driven decisions underpin most modern-day operations. The military, railways, aerospace, oil and gas, agriculture, factory automation, and robotics all depend on real-time data—field operational and environmental conditions are far from ideal. Equipment might have to tolerate extreme temperatures, dirt, and windstorms without losing signal integrity and speed. All hardware equipment—down to the connectors used for communications, networking, data, and power transmission in the field—needs to be ruggedized.

Exacting specifications for rugged connectors

Not all rugged connectors are the same; a variety of operating conditions dictates connector characteristics. A few best practices before choosing a connector include:

- *The end-use application:* It is important to consider whether the connector will be used in medical settings—in which case it might have to withstand sterilization—in a military war zone, or underwater. ITT Cannon's CA/5015 connectors, for example, are rugged interconnects designed for the most demanding applications. Originally developed for commercial aviation, these connectors are now widely used in the military, transportation, industrial, and heavy equipment sectors.
- *Weight of final system:* Weight can affect the performance of a connector simply by increasing pressure on the ends and causing wear and tear. Weight also matters for battery-powered systems like robots or semi-autonomous machines, as the power needed to lug extra weight can shorten battery life. Weight also determines the material of the shell casing for the connectors. Housings made of lightweight aluminum decreases the final weight.
- *Cybersecurity and the need for stealth:* Military operations especially call for systems that can avoid detection by the enemy. This requires specialty shielding techniques in rugged connectors. Full-metal backshells preserve electronic signals and prevent electromagnetic interference. ITT Cannon's CA/5015 series offers an extensive range of backshells with connections using individual wires or jacket cables in shielded or unshielded versions.
- *Connector shape:* Connectors come in a variety of shapes, including circular, rectangular, blade, or modular, to name just a few. The circular connectors are the most common variation to transmit power, signal, or data. It is easier to align pins during mating, and the circular design provides compact sealing. Circular connectors have many pins or contacts arranged in a specific grid pattern to accommodate the various kinds of connections needed, such as power or data.

Kinds of locking systems

Once the connector links two systems, it needs to be locked into place so the connection does not come loose and affect the transmission of power, data, or signal quality. The most common locking systems include a screw-like threaded coupling mechanism to hold connections firmly in place, and push-pull where connections lock together when pushed and release when pulled. Connectors like the TBF10SL-4PS-B from ITT Cannon (Figure 1) have a bayonet mechanism, which has pins and grooves that lock into place with a twist.

Figure 1: ITT Cannon's TBF10SL-4PS-B rugged circular connector uses a bayonet locking mechanism. (Image Source: ITT Cannon, LLC)

Of these, the threaded coupling mechanism offers superior vibration resistance, which is especially useful in aerospace and military applications.

Mating cycles

A mating cycle is the process by which the plug and receptacle connect and disconnect. Repeated plugging and unplugging of equipment can cause wear and tear on leads in the connector. As a result, connectors are rated by the number of mating cycles they can withstand. A reliable unit can handle hundreds of such couplings without significant damage.

Ingress protection

The International Electrotechnical Commission (IEC) instituted a series of ratings to gauge the effectiveness with which electrical equipment can ward off hazards like dirt and water. These ratings are especially important in military operations where equipment must function in severe conditions like dust and hailstorms, and where performance is tested routinely. Repeated exposure to abrading sand or water can corrode electronic leads, lead to poor signal transmission, and create barriers that prevent strong connections. Extreme environments typically demand connectors have a rating of IP68 or higher.

These stipulations and a host of others are ones that military specification (MIL-SPEC) connectors pass. Circular connectors typically embrace MIL-SPEC standards like MIL-DT-5015, which the ITT Cannon's CA/5015 connectors meet (Figure 2). These circular connectors function well across a wide range of temperature conditions from -55°C to +200°C.

ITT Cannon's CA/5015 connectors are ideal for defense, rail, aerospace, and industrial applications, as well as factory automation and robotics. The series offers five different polarizations through which users can ensure that the components are mated in the right orientation to prevent damaging circuits. The connectors come in a variety of plating options: cadmium, TinZinc (J plating), ZincNickelBlueGen, ZincCobaltBlack, and nickel compositions. The connectors also comply with RoHS (Restriction of Hazardous Substances), a European Union regulation that oversees the use of certain hazardous materials in electrical and electronic equipment.

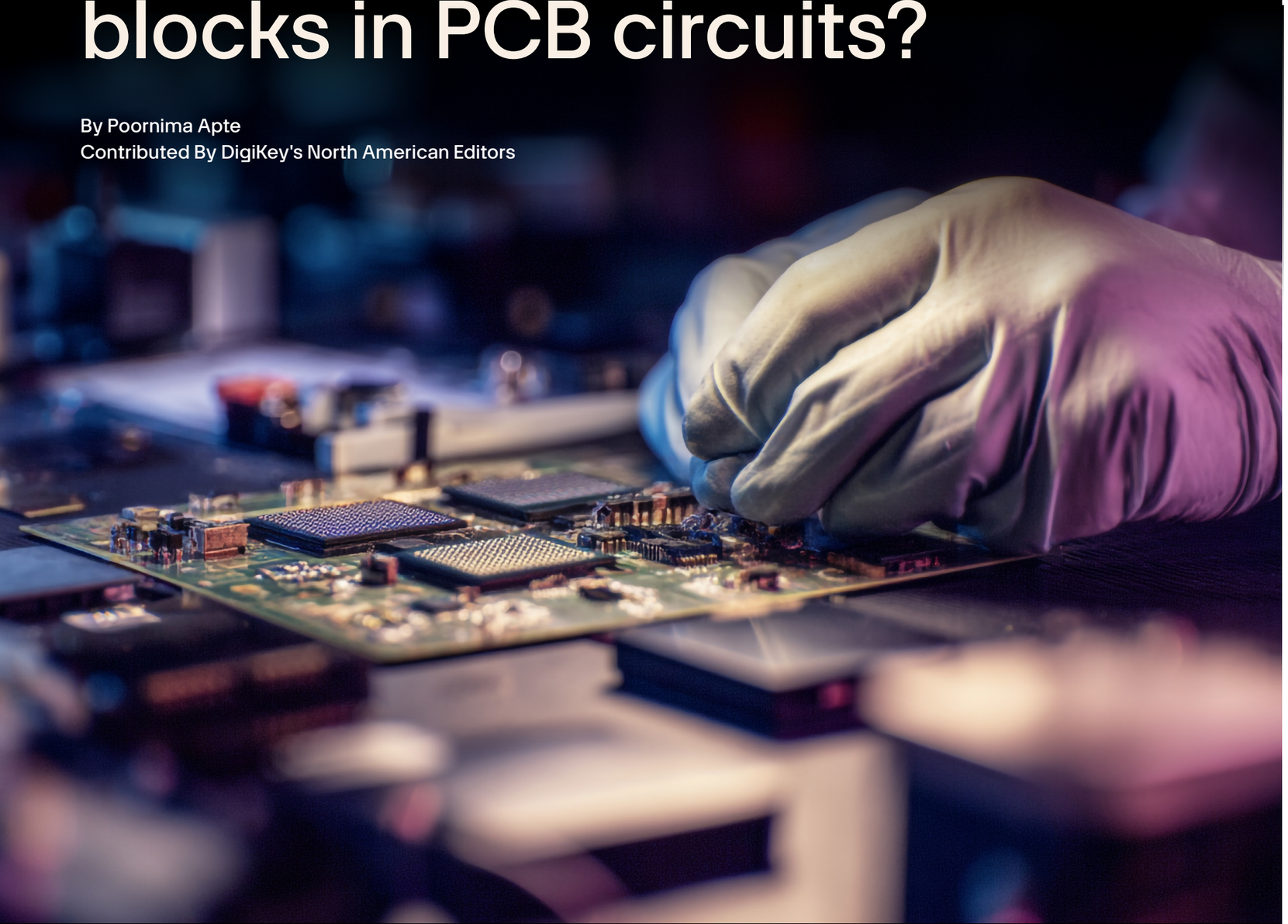
Conclusion

The vital functioning of electronic and electrical equipment in severe environments is becoming increasingly necessary across various sectors, including discrete manufacturing, oil and gas plants, solar and wind technologies, and industrial operations such as mining. Given that many of today's industrial and military operations run on real-time data, computing hardware and sensors need frontline-tested equipment to support a robust field infrastructure. Rugged connectors such as the CA/5015 Connector Series from ITT Cannon play a key role in carrying out this mission of data-driven operations in all sectors.

Figure 2: ITT Cannon's CA/5015 connectors are rugged and versatile solutions for demanding environments (Image Source: ITT Cannon, LLC)

Why choose lever-based terminal blocks in PCB circuits?

By Poornima Apte
Contributed By DigiKey's North American Editors



Printed circuit boards, the building units of electronic circuits, comprise a number of components. A terminal block is one such part that connects two wires or a wire and a board together in electrical or electronic circuits. Various electrical, mechanical, and other factors dictate the selection criteria for terminal blocks.

The computing ecosystem driving the use of terminal blocks

As more businesses, even those that used to operate traditional manufacturing lines, become data-driven, Industrial IoT (IIoT) is growing to accommodate this change. The number of IoT devices globally is expected to reach 40 billion by 2030.

In addition to the rise of IoT, the following trends are spurring an increased demand in the use of a variety of electrical and electronic components:

- Industry 4.0 and 5.0: IIoT and robots are cornerstones of advanced manufacturing. Both require plentiful sensors and electronic equipment to read machine data and relay information for processing. The growth of industrial automation is fueling demand for electronic circuitry and, correspondingly, terminal blocks.
- AI and edge computing: IIoT operations have routed data to the cloud for processing, but that has been changing with the need for real-time, split-second decision-making. The use of AI at the edge has increased the demand for high-performance computing, which, in turn, calls for sophisticated and complex circuitry.
- Decarbonization and electrification of the economy: As the push toward decarbonization intensifies, more electrical circuits will be pressed into service through a variety of applications—including electric and hybrid vehicles and electric power grids.

Against this broader context of the growth of electrical and electronic circuits, terminal blocks will also register growing demand. The global market for terminal blocks is projected to reach $5.2 billion by 2027, growing at a CAGR of 5.7%.

Connection mechanisms for terminal blocks

Terminal blocks can be classified into different categories, and one of their distinguishing features is the mechanism employed to make connections. A screw-type terminal block uses a screw to hold a wire in place. A push-button mechanism involves pushing a button down, inserting a wire, and releasing the

button so the wire clamps into place.

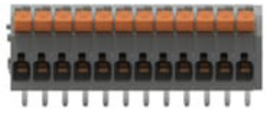
In a push-in style of terminal block, the user simply pushes the wire in, and a spring clamp locks it in place. This is how WAGO's 2601 Series PCB terminal blocks with levers work using WAGO's patented Push-In CAGE CLAMP® connection technology. To make the connection, the user pushes the wire into place. To free the wire, the user flips the lever up, easing pressure on the clamp (Figure 1). The simple flip up and flip down operation makes the lever terminal block easy and fast to use.

Figure 1: Levers on terminal blocks help ensure quick and easy connections through a simple mechanism that clamps wires and holds them in place. (Image Source: WAGO)

Advantages of lever-based connections

The lever-operated terminal block offers a significant set of advantages over other locking mechanisms:

- Tool-free operation: Not having to use a screwdriver to tighten wires makes assembly faster and more efficient. Applications that call for frequent wiring changes, such as those in field installations or lab prototyping, particularly benefit from the lever-based terminal block.
- Less strain on wires: Equipment is likely to last longer because wires are not screwed in and, thereby, less subject to wear and tear. Connecting and reconnecting wires is easier and less strenuous on circuits, improving lifespan.



- The right amount of force: Screw-in mechanisms for terminal block connections run the risk of over-tightening. Increased pressure from over-tightening can damage wires faster, decreasing the life of electrical and electronic components. Push-in terminal blocks with a lever release eliminate the need to guess the amount of force required to keep wires in place.
- Stronger and more consistent connections: Screw-in mechanisms also run the risk of loose connections, leading to faulty signals and data loss. Using a terminal block with push-in clamping technology ensures consistent connections that do not change with the technician's expertise. Consistency and full-contact connections make these terminal blocks particularly useful in high-vibration environments like industrial manufacturing and aerospace.
- Flexibility and compatibility: When integrated with larger electrical circuits, IoT sensors will likely yield a non-uniform mix of wires, all of which need connections to relay data and signals. Using push-in terminal blocks with a lever release is compatible with different kinds of wire—solid, stranded, or fine-stranded.
- User-friendly: Having a lever release for terminal block wires makes it easier to gauge the locked or unlocked state of the connection. Visual and tactile clues make for easier use and decrease the chance for errors when setting up elaborate circuits.

Inspection and maintenance are also easier because of the modular structure of each block unit. Modular designs also allow for faster switching out of wires. Technicians do not have to rip up and replace entire boards when making changes; instead, they can focus on the specific sections that need work and replace modules selectively.

Selecting the right terminal block

As circuitry becomes more complex and in demand, finding the right terminal block for connecting wires will likely focus on units that can perform under extreme environmental conditions and be packed into smaller form factors.

The criteria to consider before choosing a terminal block include the current and voltage the circuits must endure. Designers typically allow some leeway in the numbers (150% of the needed rating) before selecting a product. Pole count determines the number of circuits the terminal block can accommodate. The terminal block's voltage/current allowance, creepage, etc., determine the block's pitch, which is the distance between the center of one pole and the next (Figure 2). Finally, designers have to ensure that the housing for the terminal block will accommodate the wires, a size usually specified in American Wire Gauge (AWG).

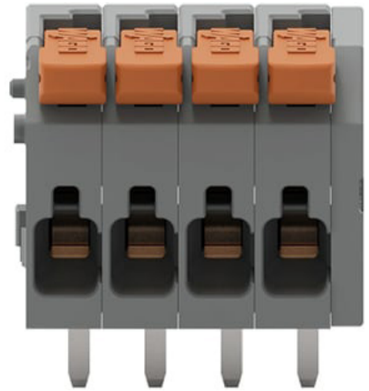


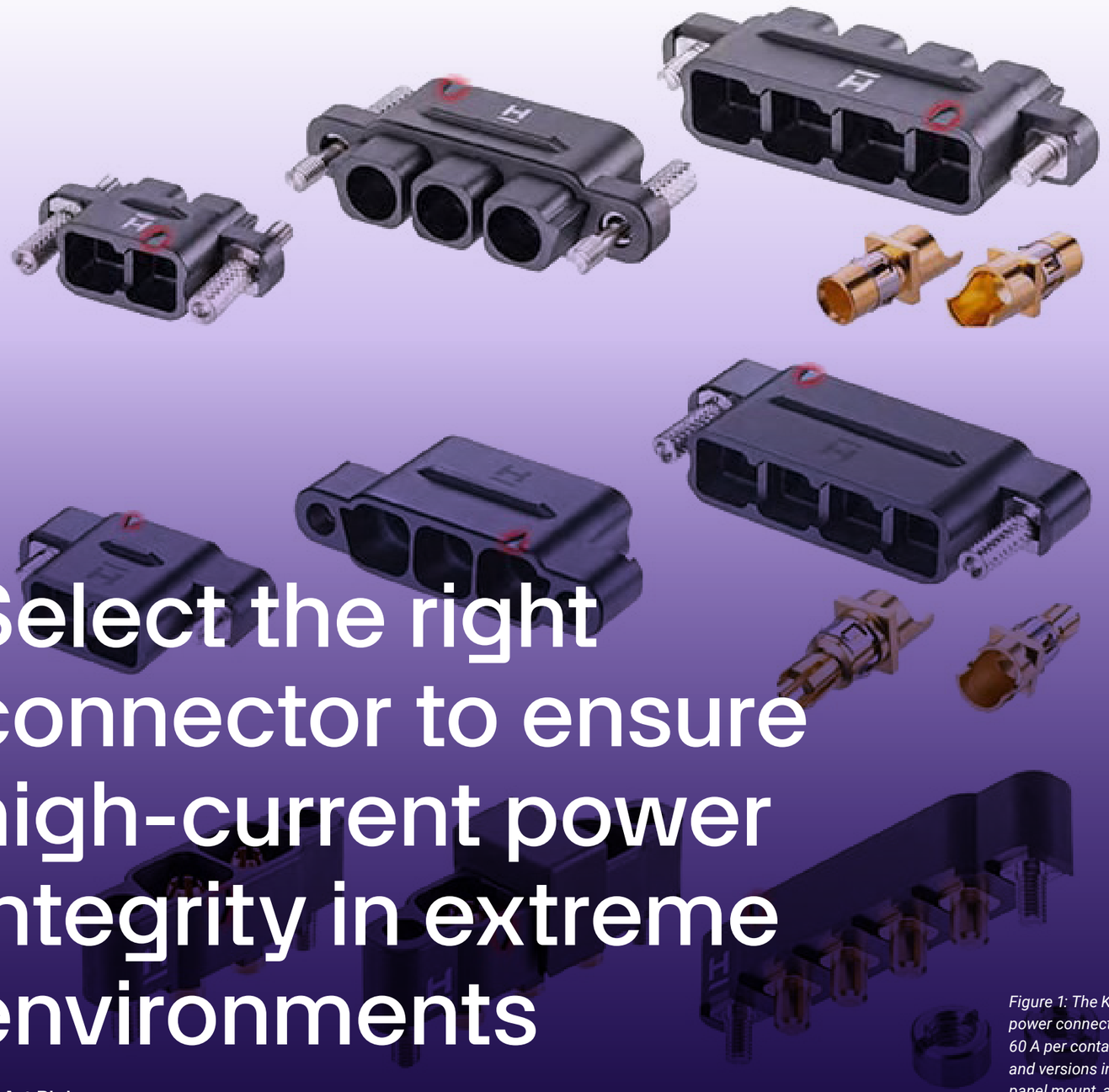
Figure 2: The terminal block's pitch, one of the selection criteria for circuit designers, is the distance between the center of one pole and the next. (Image Source: WAGO)

Electrical performance must be factored in with mechanical parameters and other metrics before picking a terminal block. For example, WAGO's 2601 Series PCB terminal blocks with levers are compact and tool-free, allowing quick and easy termination for 26 AWG to 14 AWG wire. Relying on WAGO's patented Push-In CAGE CLAMP® connection technology, solid and fine-stranded conductors with ferrules are connected by pushing them into the block.

With the ability to be connected vertically or horizontally to the PCB and with a pin spacing of just 3.5 mm, the 2601 series takes up minimal board space. The 2601 series makes WAGO's selection of lever-equipped PCB terminal blocks ideal for device connections in the field, no matter the performance class. The tool-free wiring is intuitive for worldwide use, and the lever technology ensures that the contact point is always secure. The series finds applications in power supplies, control boards, device manufacturing/device connections, interface modules, sensors, smart homes, and control boards.

Conclusion

Terminal blocks are crucial for establishing the integrity and performance of complex electrical and electronic circuits. When selecting one, design engineers must consider various factors, including the application, voltage and current tolerances, and mechanical connection mechanisms. Push-in terminal blocks with a lever release are especially easy to work with as they deliver quick, consistent and reliable connections.



Select the right connector to ensure high-current power integrity in extreme environments

Figure 1: The Kona series power connectors handle up to 60 A per contact at 1500 VAC, and versions include header, panel mount, and cable mount. (Image source: Harwin Inc.)

By Art Pini
Contributed By DigiKey's North American Editors

With supply voltages decreasing and load currents increasing proportionally, resistive power loss and voltage drops must be minimized for efficiency and thermal management. Power applications such as electric vehicles (EVs), aerospace, and industrial electronics also expose circuits to shock, vibration, and temperature extremes.

Designers must be aware of these requirements to ensure they select and correctly apply power connectors that are mechanically rugged, maintain electrical integrity, and operate over extended temperature ranges.

This article discusses the selection and use of power connectors for the most demanding environments and applications. It then introduces example power connectors from Harwin and shows how they can be used to achieve excellent power integrity with low losses while guaranteeing mechanical reliability.

Considerations for high-power interconnections

Connecting high current and high voltage to a printed circuit board (pc board) requires great care. Poor connections can result in power losses and unexpected electrical breakdowns. If the interconnection is also subject to extreme temperature, shock, or vibration, the problems can be multiplied. Power connectors with inadequate current ratings may force designers to use multiple contacts to obtain the required current levels, resulting in larger connectors with more contacts and additional pc board real estate. Multiple current paths also increase the chances of improper insertion, resulting in overcurrent on a single contact. The solution to these issues is to use power connectors with the correct single-contact current rating.

Consider the Harwin Kona series connectors (Figure 1). These connectors are rated to handle 60 amperes (A) per contact and up to 3000 volts AC (VAC) maximum (for 1 minute) and 1500 VAC or volts DC (VDC) peak working, even in extreme temperature, shock, and vibration environments.

The Kona connectors are available in two, three, or four-contact single-row housings. Configurations include a pc board header, a panel mount, and a male and female cable mount with various locking arrangements. They can be used in cable-to-board and cable-to-cable mating.

These connectors use contacts spaced at 8.5 millimeters (mm) (0.335 inches (in.)). This spacing, along with individually recessed contacts that are each shrouded with polarizing keyed structures,

ensures the connector's high voltage and current ratings. The design also helps to protect against incidental damage due to poor mating and random physical strikes.

The secret to this connector series' high current rating and reliability is the six-fingered male contact (Figure 2).

The Kona series contacts are made of beryllium copper, allowing a maximum operating temperature range of -65°C to 150°C, and they are plated with a durable hard-acid gold finish for protection against long-term exposure in harsh environments. The contacts are rated for 250 mating operations, and the contact resistance of a mated pair is 2 milliohms (mΩ) or less. The voltage drop across the contact pair at the maximum rated current of 60 A is only 0.12 volts.

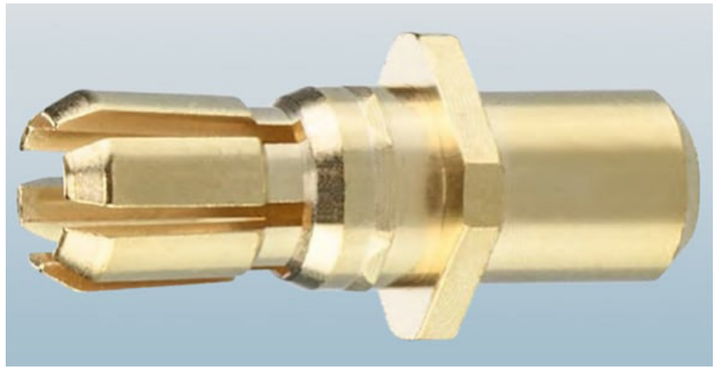


Figure 2: The six-fingered male contact provides positive normal spring force against the interior walls of the female contact to ensure a good connection even in the presence of shock and vibration. (Image source: Harwin Inc., modified)

Headers for board mounting

The Harwin Kona KA1-MV10405M1 is an example of a four-contact vertical header intended for pc board mounting (Figure 3).

The header's body is made of a glass-filled, high-temperature thermoplastic, and it comprises four recessed, six-fingered male contacts with a 4.5 mm (0.185 in.) pc board solder tail. A clearly visible embossed marker provides header orientation and contact 1 identification. Internal thread screw locks and board-mount studs provide a mating lock for the jack connector, as well as mechanical mounting to the pc board using a KA1-4240000 slotted board mounting nut. Headers with right-angle, horizontal mounting contacts and alternative locking arrangements are available. Make-before-lock is used to prevent the possibility of damage during the locking process.

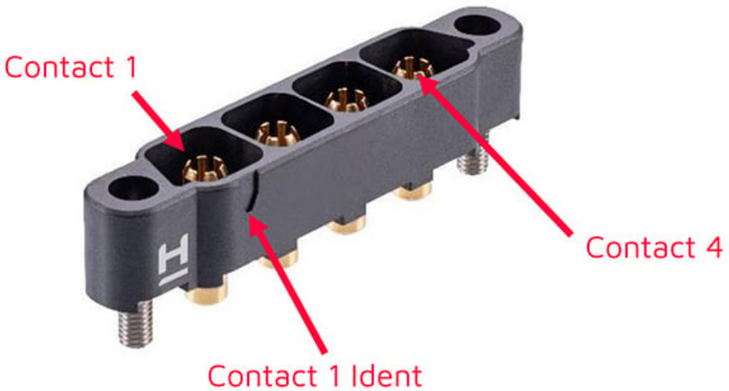


Figure 3: The Kona KA1-MV10405M1 header has four contacts. The clearly visible identifying marker for contact 1 and the mounting studs are shown. (Image source: Harwin Inc.)

Receptacles for cable and panel mounting

The Kona KA1-2010498F1 (Figure 4, left) is a four-contact, cable-mounted receptacle housing that uses separate contacts, such as the Harwin Kona KA1-0400005 (Figure 4, right). This housing can mate with the KA1-MV10405M1 four-contact header above.

The female cable-mounted housing includes shroud extensions with polarizing keys that prevent accidental connection with the female receptacle contacts and provide electrical isolation to the mated contacts. The Kona KA1-0400005 connector socket contact uses a solder connection to the cable. The contacts are designed for #8 AWG equipment wire. Silicone rubber insulation with a maximum diameter of 7.5 mm (0.295 in.) is recommended.

The standard gender connectors are fitted with floating thumbscrews with hex socket cavities for torque screwdrivers. Reverse fix hardware, with the locking direction flipped, has 5.2 mm long panel mount studs for front-panel mounting on an enclosure. The locking hardware is corrosion-resistant stainless steel.

Plugs for cable and panel mounting

The Kona KA1-3010498M5 (Figure 5, left) is the male cable-mounted version of the KA1-2010498F1 housing, and it uses the KA1-1410005 pin contact (Figure 5, right).

Figure 4: Shown are the KA1-2010498F1 four-contact receptacle housing (left) with its shroud extension and the female solder contact used with the housing (right). (Image source: Harwin Inc.)

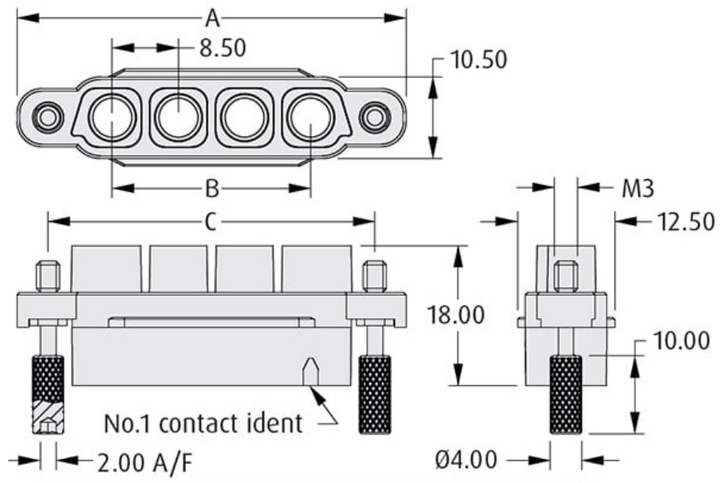
Figure 5: Shown are the four-contact KA1-3010498M5 male housing (left) and the solder version of the six-fingered male contact used with the housing (right). (Image source: Harwin Inc.)

The male or plug housing uses the solder version of the six-fingered male contact, which is designed to use the same #8 AWG wire as the female version. This model connector uses reverse fix locking thumb screws, which mate with a female connector with reverse fix hardware for panel mounting. Standard locking hardware is also available.

Small size, lightweight

The physical size of the connectors is small, given their 60 A and 3000 volt ratings (Figure 6).

The four contact connectors have a length (A) of 50 mm (1.97 in.), a width of 12.5 mm (0.49 in.), and a height of 18 mm (0.71 in.). A receptacle cable housing mated with a plug header has a height of 21.7 mm (0.85 in.) from the pc board. The mated pair weighs about 25 grams (g) (0.88 ounces (oz)).



CALCULATION	
A	B + 24.5
B	8.5 x (No. of contacts - 1)
C	B + 16.5

Figure 6: A dimensional drawing of Kona receptacle housings shows their small size. (Image source: Harwin Inc.)

Testing standards

All the Kona connector designs have been tested under the appropriate sections of EIA-364. The electrical tests include contact resistance, power, withstand voltage, and insulation resistance. The mechanical tests include shock and vibration, insertion and withdrawal forces, thermal shock, humidity, and salt spray. The vibration specification is 20 g peak for 12 hours (hr) without a contact failure. Similarly, the shock specification is 100 g for 6 milliseconds (ms) without a contact failure.

In addition to their shock and vibration tolerance, which makes the connectors suitable for EV power connections, Kona connectors meet the NASA and ESA outgassing requirements, making them ideal for space, avionic, and unmanned aerial vehicle (UAV) applications.

Shielding for interference

In applications that have limits on electromagnetic interference (EMI) and radio frequency interference (RFI), the Kona connectors offer a range of lightweight aluminum back shells for both cable and header connectors (Figure 7).

Figure 7: For EMI/RFI protection, an aluminum back shell with flexible braiding attached to a tie band is available. (Image source: Harwin Inc.)

The back shells are designed to accommodate an abrasion-resistant, flexible metal braid and are supplied with tie-bands to secure the braiding to the shell. The combination of the back shell and braiding provides shielding for effective EMI/RFI protection. Additionally, the back shells provide additional strain relief for the cables.

Assembly tooling

The Kona connectors require a minimum of tooling. As the cable contacts are soldered, they can be inserted by pushing them in without using tools. A removal tool is available if the need arises to remove or replace a contact. A screwdriver can also be used to tighten or loosen slotted nuts on mounting studs.

Conclusion

The Kona 8.5 mm pitch, high-reliability connector family ensures power integrity in the most demanding environments. These connectors provide a quick and easy mating process that does not require additional tooling. They are ideal for avionics, UAVs, satellites, EVs, and other applications with high-power systems operating in extreme environments.

The basics of HDMI connectors

By Ryan Smoot
Technical Support Engineer, Same Sky

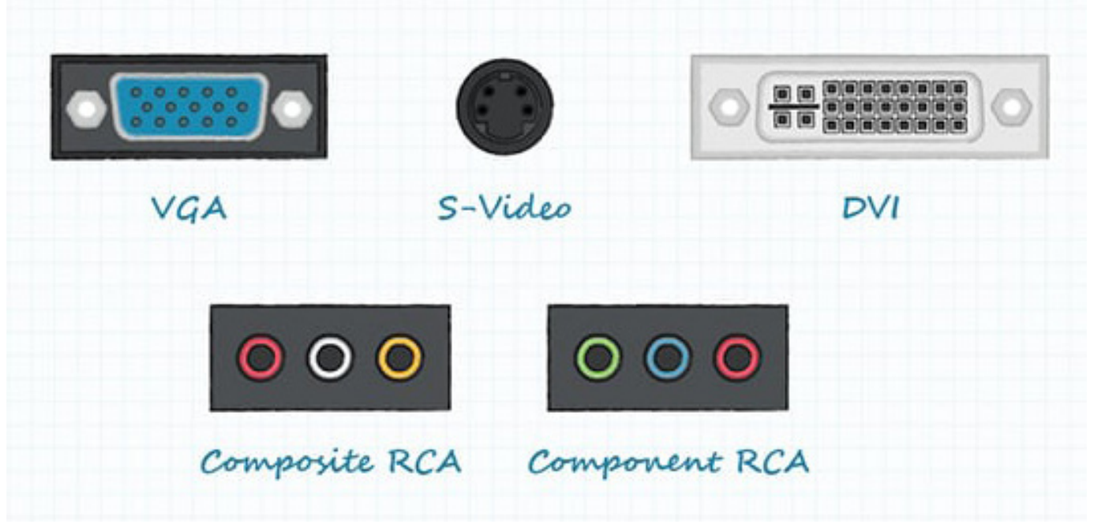


Figure 1: The progression of audio and video connectors throughout history (Image source: Same Sky)

Devices that generate both video and audio output have the option to either display it on an onboard screen or transmit the signal to an external monitor or display. To achieve the latter, a cable system with integrated connectors is required.

This article section outlines the evolution of interconnect technology over several years (Figure 1). It begins with the introduction of the Composite RCA standard for televisions in 1956, progresses through the adoption of S-Video for VCRs and home computers in 1979, and embraces VGA for IBM PCs in 1987. Subsequently, it advances to Component RCA and DVI during the 1990s. Apart from DVI, these standards primarily used analog cable connections, enabling the transmission of either audio or video signals individually. In essence, multiple cables were required to ensure operational compatibility.

DVI progressed the field by introducing support for digital video. However, users seeking to transfer both audio and video simultaneously still had to resort to utilizing up to five separate cables. The breakthrough came with the advent of the High-Definition Multimedia Interface (HDMI 1.0) standard in 2002, which consolidated these multiple cables into one.

This evolution propelled HDMI to become one of the most prevalent formats for audio-video signal transfer in both home and workplace settings today. This article will take a closer look at the continued progression of HDMI standards, connector types, capabilities, and more.

HDMI standards overview

Since its inception in 2002, the original HDMI standard has undergone a dozen updates, each offering enhancements such as faster speed, increased bandwidth, improved resolution, support for new broadcast formats, and multiple connector sizes.

GENERATION	HDMI 1.0	HDMI 1.3	HDMI 1.4	HDMI 2.0	HDMI 2.1
Speed	4.5 Gbps	9 Gbps	9 Gbps	18 Gbps	48 Gbps
New Features	1080p	Deep Color	4K at 30 FPS and 3D	4K at 60 FPS	Up to 10K, Dynamic HDR, Ethernet, Variable Refresh Rate
Initial Release	December 2002	June 2006	May 2009	September 2013	November 2017

Table 1: HDMI standards progression and specifications (Image source: Same Sky)

Initially developed by the HDMI Forum, HDMI 1.0 aimed to streamline the clutter of cables required for audio and video transmission while enhancing functionality. This specification outlined the fundamental capabilities of a single cable, digital audio, and video connector interface system. Over time, HDMI technology has evolved into the primary digital interface, seamlessly connecting ultra-high-definition displays with a myriad of consumer electronics, PCs, mobile devices, automobiles, commercial AV equipment, and beyond.

The most recent iteration of the standard, HDMI 2.1, was introduced in November 2017 and supports an array of higher video resolutions and refresh rates, reaching up to 10K. Additionally, it incorporates support for High Dynamic Range (HDR) formats and boasts bandwidth capabilities of up to 48 Gbps. Notably, despite these advancements, the physical connector itself remains unchanged.

Common connector types

An HDMI cable comprises multiple shielded twisted pairs of wire responsible for transmitting the video signal, alongside individual conductors for power, ground, and additional lower-speed device communication channels. HDMI connectors serve to terminate the cable and establish connections with the devices in use. These connectors exhibit a trapezoidal shape, featuring indents on two corners to facilitate precise alignment during insertion and bear some resemblance to USB connectors. The HDMI standard encompasses five distinct connector types (Figure 2):

- **Type A (Standard):** Equipped with 19 pins and three differential pairs, this connector measures 13.9 mm x 4.45 mm, with the female version slightly larger. It boasts electrical backward compatibility with DVI-D.
- **Type B (Dual Link):** Incorporating 29 pins and six differential pairs, this connector measures 21.2 mm x 4.45 mm. It is intended for use with very high-resolution displays but has never been employed in products due to its size. It also maintains electrical backward compatibility with DVI-D.
- **Type C (Mini):** Smaller in size compared to the Type A (Standard), measuring 10.42 mm x 2.42 mm, yet featuring the same functionality and 19-pin configuration. It is designed for portable devices.
- **Type D (Micro):** Compact in size, measuring 5.83 mm x 2.20 mm, and carrying 19 pins. It shares similarities with micro-USB connectors and is tailored for small portable devices.
- **Type E (Automotive):** Engineered with a locking tab to prevent vibration-induced disconnection and a shell to resist moisture and dirt. Intended for automotive applications, a relay version is available to facilitate interface with consumer A/V products.

All these connector types are available in both male and female versions, offering flexibility for various connection needs. They may be straight or right-angled, with orientations either horizontal or vertical. Female connectors are typically integrated into both the source and receiving devices. Additionally, adapters and couplers are readily accessible to accommodate different connection configurations. For applications in demanding environments, rugged connector versions are also available, ensuring durability and reliability under harsh conditions.

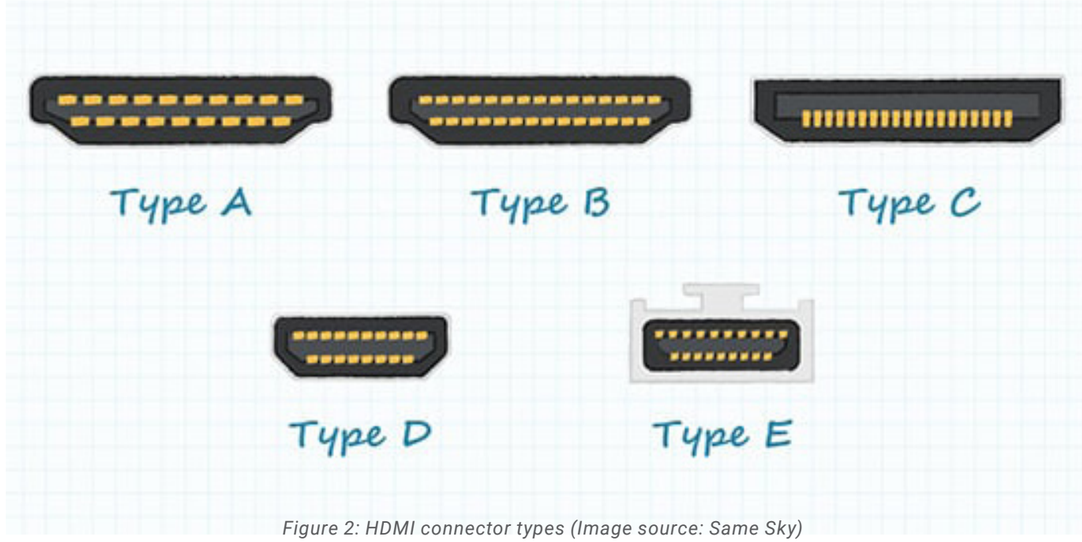


Figure 2: HDMI connector types (Image source: Same Sky)

HDMI pin configurations

Except for Type B, the various HDMI connector types all contain 19 pins. However, the pin configuration for the signals they convey varies from type to type. Consequently, within a specific type, there exists backward compatibility. However, it's imperative to exercise caution during cable design or assembly to ensure the correct pin numbers are utilized for different signals.

Since connectors of different types cannot intermate, cross-connecting issues do not arise.

Figure 3 below illustrates a typical Type A pin configuration. Individual pins have the capacity to carry data signals, clock signals, low voltage power, control signals, CEC, or HEC.

Common cable types

HDMI cables are offered in various types, including:

- HDMI Category 1 – Standard Speed Cables:
  - Standard (Category 1): Basic HDMI cable
  - Standard with Ethernet (Category 1): Identical to the standard cable but incorporates an Ethernet channel
  - Standard Automotive (Category 1): Meets the basic cable requirements but tailored for automotive applications
- HDMI Category 2 – High-Speed Cables:
  - High-Speed (Category 2): Employed for transmitting higher resolution video signals
  - High-Speed with Ethernet (Category 2): Similar to high-speed cables but equipped with Ethernet capability

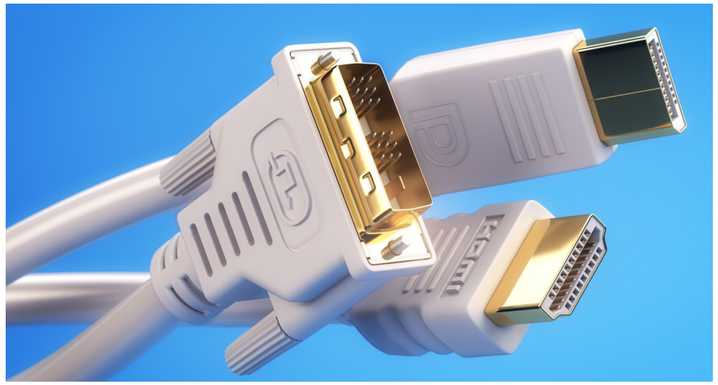
Final design considerations

In a PCB layout involving HDMI devices, careful consideration is essential to mitigate crosstalk and maintain signal integrity. Attention should also be paid to designs employing twisted wire pairs. Cables utilizing twisted pairs may experience signal loss, particularly over distances nearing 50 feet due to attenuation. To extend this range, HDMI extenders can be employed, enabling distances of up to 300 feet.

Furthermore, HDMI technology is not ideally suited for simultaneously driving multiple devices. It lacks the capability to transmit multiple signals to separate devices and cannot concurrently transmit surround and stereo audio signals.

Conclusion

HDMI connection technology serves as an excellent solution for streamlining cable clutter and simplifying systems while accommodating high-quality, high-bandwidth audio and video signals simultaneously. Evolution within the standard has facilitated enhancements in data transfer speed, bandwidth, and the integration of significant features such as Ethernet. The connectors and cables constituting this system are prevalent across various domains including home entertainment, workplace communications, and commercial and industrial sectors. Same Sky has a range of HDMI receptacle connectors to assist engineers in their AV signal design needs.



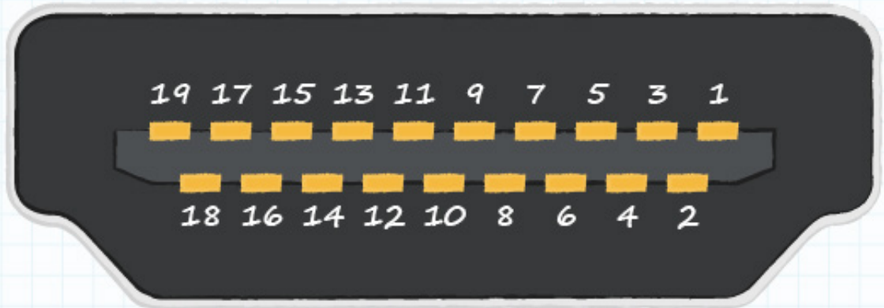


Figure 3: HDMI pin configuration (Image source: Same Sky)

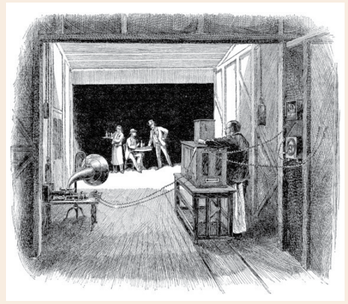
This month in history

1893

February 1

Edison completed first motion picture studio

Built on Edison's property at a total cost of $637.67, the Black Maria Studio was designed to produce film strips for the kinetoscope. It was constructed to let in natural sunlight during the day. After completing the patent for the kinetoscope, Edison held his first public demonstration of his film, called "The Blacksmith Scene."



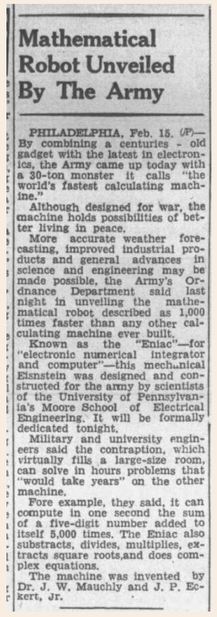
Sketch of the inside of the Black Maria.

1946

February 15

ENIAC, first electronic computer, unveiled

ENIAC, the world's first general-purpose computer, known as the "Electronic Numerical Integrator and Computer." This machine was capable of performing calculations at a rate 1,000 times faster than any previous calculating machine.



Mathematical Robot Unveiled By The Army

PHILADELPHIA, Feb. 15. (AP)—By combining a centuries - old gadget with the latest in electronics, the Army came up today with a 30-ton monster it calls "the world's fastest calculating machine."

Although designed for war, the machine holds possibilities of better living in peace.

More accurate weather forecasting, improved industrial products and general advances in science and engineering may be made possible, the Army's Ordnance Department said last night in unveiling the mathematical robot described as 1,000 times faster than any other calculating machine ever built.

Known as the "Eniac"—for "electronic numerical integrator and computer"—this mechanical Einstein was designed and constructed for the army by scientists of the University of Pennsylvania's Moore School of Electrical Engineering. It will be formally dedicated tonight.

Military and university engineers said the contraption, which virtually fills a large-size room, can solve in hours problems that "would take years" on the other machine.

Fore example, they said, it can compute in one second the sum of a five-digit number added to itself 5,000 times. The Eniac also substracts, divides, multiplies, extracts square roots,and does complex equations.

The machine was invented by Dr. J. W. Mauchly and J. P. Eckert, Jr.

Newspaper announcement of the new mathematical robot.

1947

February 23

The founding of the International Standards Organization (ISO)

After a year of planning, 65 dedicated delegates from 25 different countries worked together to form the International Standards Organization, supported by 67 technical committees.

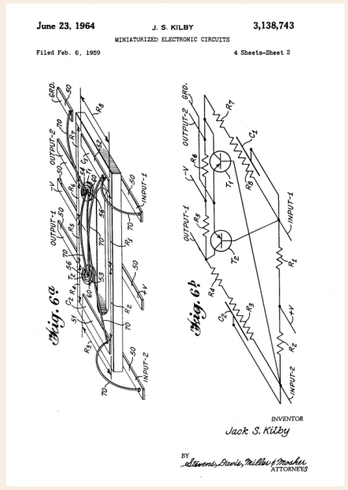
Group photo of the founders of ISO.

1959

February 6

Jack Kilby files for a patent for the first integrated circuit

Jack Kilby, a Texas Instruments engineer, is credited with the first monolithic integrated circuit. In 2000, he was awarded the Nobel Prize in physics for this world-changing invention.



June 23, 1964 J. S. KILBY 3,138,743

MINIATURIZED ELECTRONIC CIRCUITS

Filed Feb. 6, 1959 4 Sheets-Sheet 2

Fig. 6a

Fig. 6b

INVENTOR
Jack S. Kilby

BY Attorneys, Davis, Miller & Marcus
ATTORNEYS

Patent 3,138,743 – Miniaturized Electronic Circuits.

1978

February 16

First computer bulletin board system (BBS) goes live

Using a homemade 300 baud modem, Ward Christensen and Randy Suess launched the first BBS (then called CBBS) in Chicago. Users could dial in, leave messages, and share files long before the World Wide Web existed.

This is the hardware from the first computer BBS.

1978

February 22

Launch of Navstar 1, the first GPS satellite

Satellite OPS 5111, also named Navstar 1, was the first part of the United States Global Positioning System (GPS) and was in service until 1985.

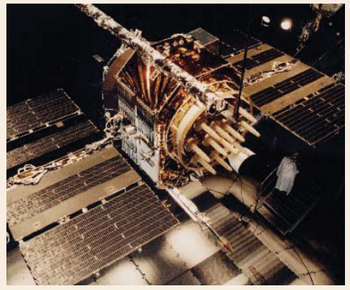


Image of the Satellite OPS 51111, also named Navstar 1.