Siemon's Z-MAX™ Structured Cabling Solution:

Reinventing the RJ-45 for Tomorrow's Network

Think of an Ethernet port and the mated modular RJ-style plug and jack connector is sure to come to mind. The interface has dominated the telecommunications market since the idea of structured telecommunications cabling was conceptualized. And, before that, a 2-pair version of the connector appeared on every telephone headset sold since the late 1960's. Yes, there is no doubt that the RJ-style plug and jack interface is ubiquitous, but with data transmission speeds approaching 10 Gb/s, these components are starting to show their age. Furthermore, instead of recognizing an opportunity for innovation, most manufacturers endeavor to overcome the inherent high frequency electrical and mechanical shortcomings of the manually terminated RJ-style modular plug connector by continuing to make tweaks and adjustments to existing modular jacks with archaic compensation circuits reliant on outdated housing and contact designs.

In a revolutionary move, Siemon has completely overhauled the internal functionality of the RJ-style modular plug and outlet. Newly patented and patent pending techniques virtually eliminate plug and outlet termination variability, optimize mated performance, and prescribe the use of complete and focused corrective compensation circuitry that result in a connections system that exhibits unprecedented transmission headroom and mechanical reliability. These revolutionary enhancements are incorporated into Siemon's new Z-MAX family of category 6A connecting hardware and patching solutions.

BUILDING A BETTER CONNECTOR

Today's RJ-style modular connectors are tasked to deliver performance headroom and operate in conditions that were unforeseen just 5 years ago. In particular, the interface is expected to exhibit extraordinarily low levels of internal (pair-to-pair) and external (alien) crosstalk up to 500 MHz, support up to 600 mA of current applied per pair for Power over Ethernet Plus, maintain reliable and robust connections throughout a wide range of environmental conditions, as well as be constructed from ecologically-friendly materials. When faced with the challenge of designing a next generation category 6A connector that exceeds these deliverables, Siemon Engineers agreed that it was time to perform a ground-up overhaul of the RJ-style modular plug and jack.

Siemon identified the following critical areas as opportunities for design improvement:

Electrical:

1. Eliminate the high variability normally associated with both field and factory termination processes
2. Ensure that modular plug performance consistently falls within the "sweet spot" of the modular outlet to provide optimum mated performance
3. Position cable terminations to eliminate pair splitting and crossovers
4. Apply sophisticated finite element transmission modeling techniques to optimize magnitude and phase at each point between the input and output cable connections
5. Electrically isolate adjacent connectors in patch panels and faceplates to minimize alien crosstalk and eliminate incidental channel-to-channel shield connections

Mechanical:

1. Optimize contact geometry and configuration to minimize transmission length and discontinuities in all components and maximize distance between contacts in adjacent outlets to improve AXT performance
2. Eliminate non-ecologically-friendly manufacturing materials, such as beryllium and lead
3. Reduce contact insertion force and minimize normal force variation within the plug/jack interface
4. Ensure "make first"/"break last" contact geometry provides arc zones that are distinct and isolated from mated interface areas on plug and outlet contacts for optimum reliability when transmitting power and data
5. Feature a modular outlet core or "kernel" subassembly that is suitable for the full range of requirements for copper cabling connectivity (e.g. hybrid flat/angled, or keystone and patching in the full color range)

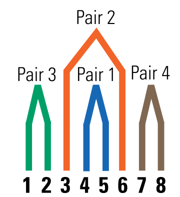
ELECTRICAL ENHANCEMENTS

Eliminating RJ-45 Modular Plug Variability

Twisted-pair cables rely on precise pair geometry to ensure proper transmission performance. By its nature, the cable-to-modular plug termination process disturbs this pair geometry and introduces substantial variability into the finished plug assembly. Furthermore, the 4-pair T568A and T568B wiring schemes used in data transmission specify that the pair terminated on pins 3 and 6 be untwisted and split around the pair terminated on pins 4 and 5 (see figure 1). This common wiring practice creates a significant source of crosstalk coupling within the modular plug. The pair terminated on pins 3 and 6 is commonly referred to as the "split pair."

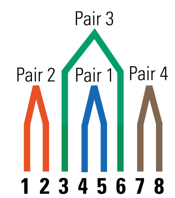
In addition, the fact that the cable pair orientation has a right-hand lay or a left hand lay depending upon which end of the cable is being worked (see figure 2) is often overlooked. To accommodate the "mirror image" pair orientation, a different pair is crossed over to achieve parity of pin/pair connections on each end of the cable. As a result, it is virtually impossible to achieve performance consistency between terminations on each end of the cord using the same plug design.

Some have called the modular plug termination process an art. Likely, this is because the process depends upon the skills of an operator who is keenly able to minimize pair disturbance and untwist when preparing pairs for termination. It can take a substantial amount of time to train an operator to properly terminate a modular cord. Even then, finished patch cords must be 100% transmission tested to ensure proper construction. Recognizing the dependence of transmission performance on the quality and consistency of plug terminations, cabling manufacturers stopped providing warranty coverage for category 5e and higher field manufactured patch cords. Without strict process controls in manufacturing and testing, there is no way to guarantee performance.



Pair ID	PIN #
T1	5
R1	4
T2	3
R2	6
T3	1
R3	2
T4	7
R4	8

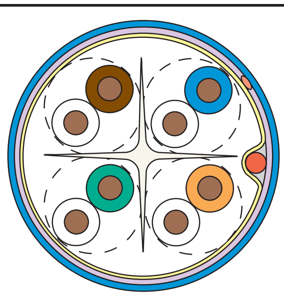
T568A: Pair 2 is Split Around Pair 1



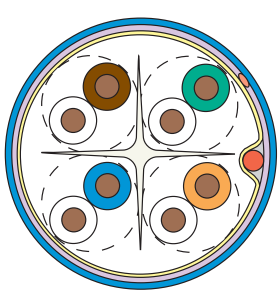
Pair ID	PIN #
T1	5
R1	4
T2	1
R2	2
T3	3
R3	6
T4	7
R4	8

T568B: Pair 3 is Split Around Pair 1

Figure 1



Pair Lay —End A (bl-or-gn-br)



Pair Lay —End B (bl-br-gn-or)

Figure 2

Since the modular plug and its termination to the cable is so critical to mated performance, it was a central point of focus in the Z-MAX design. Siemon Engineers overhauled the existing modular plug technology to create a Z-MAX plug that:

1. Is backwards compatible and interoperable with existing TIA and IEC compliant outlets, regardless of manufacturer
2. Eliminates variability associated with untwisting pairs and positioning the "split pair"
3. Eliminates variability introduced by different color sequence at each end of the cable
4. Is fully compliant with industry standards and consistently performs within the TIA- and ISO/IEC-specified performance range that delivers maximum mated performance while also maintaining full compatibility with other outlets and categories

To achieve these objectives, Siemon employs patented and patent-pending printed circuit board technology strategically located within the Z-MAX modular plug body (see figure 3). To eliminate the variability associated with the typical plug termination process, different printed circuit board (PCB) designs are used to align with the cable lay and pair color sequence at each end of the cable. This design optimizes performance and preserves the integrity of the pairs as four coherent units up to the point of termination without untwisting pairs or crossing one pair over another. Each cord is terminated with two unique plugs, which have a distinct circuit design and connection scheme designed to deliver consistent performance and ensure full compatibility and interoperability with all TIA and IEC compliant modular outlets.

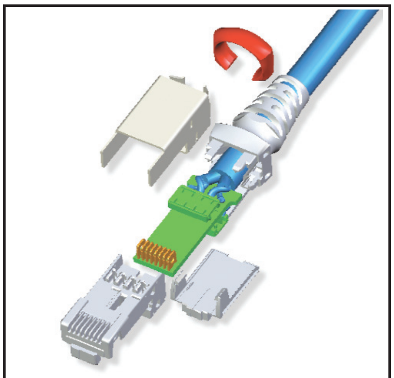


***Figure 3:** Z-MAX Modular Plug PCB-Based Design*

Finding the "Sweet Spot":

For the purpose of connecting hardware performance qualification, both TIA and IEC specify ranges of acceptable plug near-end crosstalk (NEXT loss), far-end crosstalk (FEXT loss), and return loss. The ranges are specified such that successively higher categories of test plugs fall within a subset of the lower categories. This approach supports backward compatibility (e.g. a category 5e plug mated to a category 6 connector will deliver no less than category 5e mated performance) and interoperability between manufacturers.

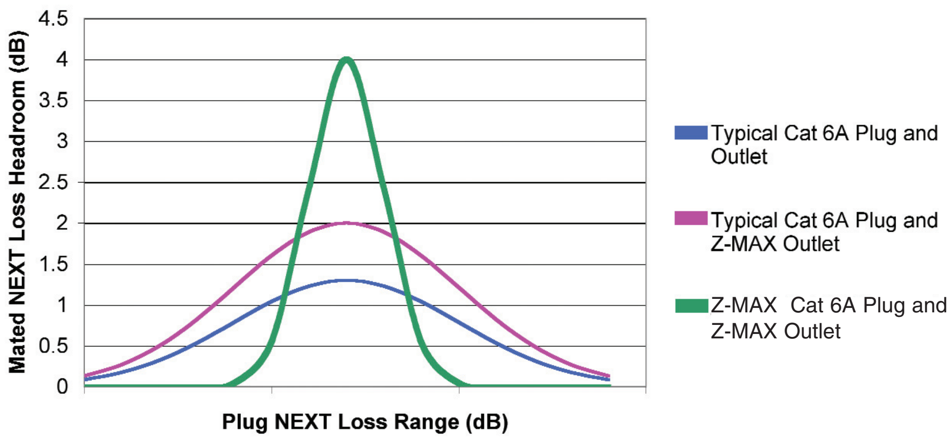


***Figure 4:** Standard Distribution of Plug NEXT Loss*

Compensation circuitry is a critical element in the design of all category 5e and higher-rated modular outlets. Its function is to apply reactive (i.e. capacitive and inductive) elements to counteract crosstalk that is inherent to the plug and outlet interface in order to comply with specified performance limits. Historically, RJ-45 outlet compensation circuitry has been designed to accommodate as large a range of terminated plug performance as possible. This approach results in a relatively flat mated response since low crosstalk plugs tend to be over-compensated by the outlet circuitry and high crosstalk plugs tend to be under-compensated. These typical outlet designs deliver minimally compliant mated performance with very little performance headroom as represented by the blue curve of the standard distribution of plug NEXT loss profile shown in figure 4.

The patent-pending Z-MAX "circuit-in-plug" design delivers precisely and consistently controlled performance. Siemon Engineers optimized the Z-MAX plug to perform in the "sweet spot" of the test plug range, where mated outlet performance yields substantial headroom to the Standards-specified limits as represented by the green curve of the standard distribution of plug NEXT loss profile shown in figure 4. The headroom provided by the Z-MAX modular plug and outlet solution is highly desirable because it helps to ensure that the entire cabling system will perform reliably and robustly over its lifecycle. Headroom is especially beneficial when the cabling plant is subjected to frequent changes and allows the cabling to be more tolerant of variables associated with real-life cabling installations. In networks having hundreds or thousands of installed drops, even a low percentage of links having marginal test results can consume hundreds of hours and thousands of dollars to resolve.

As additional evidence of the precision performance of the ground breaking "circuit-in-plug" cord design, it is interesting to note that field testers employ this technology in their permanent link adapter cords. Furthermore, both TIA and IEC connecting hardware test methods also specify the use of printed circuitry in the test plug construction to ensure measurement repeatability and reproducibility in the laboratory.

Reducing Outlet Termination Variability:

Modular outlets connect to twisted-pair cables using insulation displacement contacts (IDCs). IDCs are robust, gas-tight connections that can withstand multiple re-terminations. These cable termination points can also be a source of variability since their layout often requires the installer to split and/or cross pairs, which introduces unwanted and uncontrolled crosstalk. This variability can adversely affect outlet performance in much the same way as cable terminations to the modular plug.

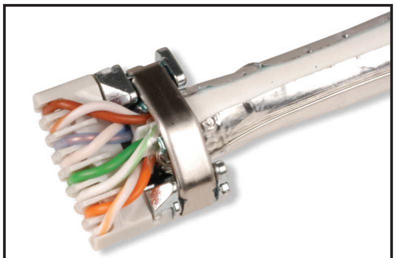


Figure 5: *Z-MAX Zero-Cross™ Termination Module*

Siemon Engineers designed the Z-MAX IDC termination field to ensure the integrity of the twisted-pairs up to the point of termination while also eliminating the need to have pairs cross one another at either end of the cable. The Z-MAX Zero-Cross™ termination module minimizes disturbances to the cable pair geometry by supporting a linear lacing configuration (see figure 5). Inside the outlet, the IDC contacts are precisely arranged in an orientation that maximizes the spacing of the pairs between adjacent outlets and reduces crosstalk (see figure 6). These features ensure the electrical characteristics of the IDC terminations remain consistent from outlet to outlet, thus maximizing the effectiveness of the Z-MAX compensation circuitry.

Figure 6: *Z-MAX IDC Orientation*

Corrective Compensation Circuitry:

The role of the compensation circuitry is to offset the crosstalk that is inherent to the mated plug-jack interface and the connections to the cable. Engineers have developed models demonstrating that undesired crosstalk is introduced into a connector due to the addition of capacitance and inductance resulting from transmission discontinuities. In theory, crosstalk can be cancelled by adding capacitance and inductance of equal magnitude and opposite phase into the circuit. This technique is called "reactive balancing". In practice, however, implementation of reactive balancing is extremely difficult because:

1. Undesired crosstalk levels can fluctuate significantly due to plug and IDC termination variability

2. Compensation elements exhibit non-linear frequency response – extreme care is required to ensure that compensation circuitry intended to reduce crosstalk at 100 MHz does not increase crosstalk at 500 MHz

3. The multi-dimensional aspect of a four-pair connector makes it extremely difficult and complex to improve one aspect of performance without degrading another

Siemon's new Z-MAX modular plug and outlet IDC construction effectively eliminates the impact of termination variability from the corrective compensation design. With stable and repeatable plug and IDC performance, Siemon Engineers were able to develop a sophisticated finite element transmission model as the basis for developing a highly precise compensation circuit. The magnitude and type of reactive elements account for connector characteristics on each side of the circuit, as well as the time shift associated with its position in the connector. Computational models were used to optimize the shape and position of these elements to account for the bi-directional interactions of all 8 circuits (four pairs) and the shield. Siemon then applied patented and patent-pending circuit technology to incorporate these elements into the Z-MAX outlet.

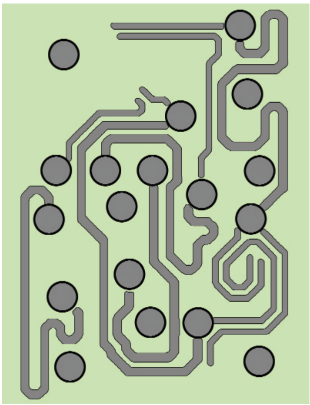
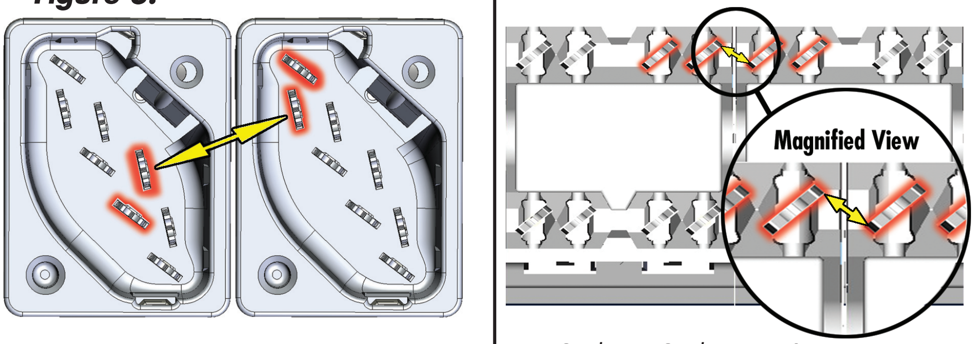


Figure 7: *Example Z-MAX Outlet PCB Showing Reactive Balancing Compensation and Phase Delay Reduction Elements*

Close examination of the sophisticated circuitry in the Z-MAX outlet reveals a variety of new and innovative techniques for incorporating reactive elements and phase delay (see figure 7). Patented strategies for manipulating magnitude and phase in the compensation circuitry include precise control of PCB trace parameters such as length, width, and thickness. These parameters are optimized to guarantee that the entire Z-MAX outlet has minimal reflections and increased balance overall. These strategies provide a highly accurate and repeatable compensation circuit, which is essential to the remarkable performance delivered by Siemon's Z-MAX outlet. In fact, the design not only supports substantial Z-MAX system headroom, but it even supports increased performance margin when the Z-MAX outlet is mated to a typical category 6A plug as represented by the pink curve of the standard distribution of plug NEXT loss profile shown in figure 4!

Figure 8:



Maximized Outlet-to-Outlet Pair Separation Via Z-MAX Diagonal IDC Orientation

Outlet-to-Outlet Pair Separation With Traditional IDC Orientation

Isolation:

While shields provide effective isolation from all types of electromagnetic interference, including alien crosstalk, UTP cabling and components rely on separation and isolation strategies in addition to balance. The diagonal orientation of the IDCs provides for optimal spatial

Figure 9: *Z-MAX Supports 24- and 48-port Patch Panel Density in 1 RMS for both UTP and Shielded*

separation between pairs on the back of adjacent Z-MAX outlets to specifically ensure maximum alien crosstalk isolation (see figure 8). As a result of the effectiveness of this design, extremely high density port configurations can also be achieved (48 ports in a 1 RMS panel for both UTP and shielded - see figure 9).

While high density is a key consideration when designing cabling systems, Siemon Engineers also wanted to ensure that side-stacked components do not pose the risk of inadvertent shield connections between adjacent outlets. (This is a particular benefit for shielded systems in that there is complete assurance that no direct coupling can occur from one outlet to another at mounting locations that are not intentionally bonded to ground) To satisfy this requirement, an innovative asymmetry was used in the Z-MAX kernel and bezel construction to ensure that side-stacked shielded outlets do not touch each other when mounted. This design feature supports the densest port configurations. While the separation between outlets is so precisely controlled that it is difficult to see with the naked eye, Z-MAX side-stacked components exhibit full DC isolation between shields.

	Z-MAX (UTP)	Z-MAX (F/UTP)
Insertion Loss	3%	3%
NEXT Loss	3 dB	3 dB
PSNEXT Loss	3.5 dB	3.5 dB
ACR-F	7 dB	7 dB
PSACR-F	10 dB	10 dB
Return Loss	3 dB	3 dB
PSANEXT Loss	1 dB	10 dB
PSAACR-F	1 dB	5 dB
ACR-N	6 dB	6 dB
PSACR-N	6.5 dB	6.5 dB

Figure 10: *Z-MAX Guaranteed Channel Headroom (1-500 MHz)*

Unprecedented Transmission Headroom:

The individual elements that comprise the Z-MAX modular plug and outlet feature stable and consistent plug performance, repeatable and low-crosstalk IDC terminations, and state-of-the-art compensation circuitry. In channel and permanent link configurations, the Z-MAX solution delivers unprecedented headroom to the category 6A transmission requirements (see figure 10). These performance levels could not be realized by simply tweaking and adjusting individual elements; they are the result of a complete and precise overhaul of each component that comprises a modular plug and jack system. The system is also capable of meeting category 6A and class E_A performance requirements for links and channels less than 15 meters in length.

MECHANICAL ENHANCEMENTS

Jack Pin Contacts:

The pin contacts in the modular jack play a key role in the electrical and reliability performance of the mated plug jack connection. Historically, modular jacks have been manufactured with cost rather than performance as the primary consideration. Typically, jack contact pins designed to accommodate the jack orientation relative to the PCB and are subject to permanent deformation when out-of-specification (e.g. 6 conductor) plugs are inserted. They are often constructed from beryllium copper, which has favorable mechanical properties, but is not an ecologically-friendly material. While the traditional modular jack may be simple to manufacture, it has functional deficiencies, such as variability in contact position and excessive contact movement that result in unreliable electrical and mated performance.

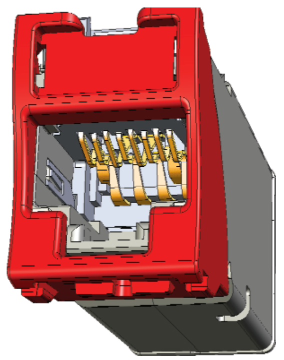


Figure 11: *Z-MAX Jack Contact Pins*

The innovative Z-MAX jack pin contact design takes advantage of the performance benefits of short electrical paths and a stable and repeatable contact geometry using ecologically-friendly materials and manufacturing processes. The first step in realizing these capabilities was to identify a material that delivers optimum effective normal force over the entire range of contact deflection, including out-of-spec plugs. Since the copper alloy used exhibits the best ratio of yield stress to modulus of elasticity, which defines the working range of a spring contact, this alloy was selected to ensure the optimum balance between jack contact strength and durability. Z-MAX contacts are specifically designed for ecologically-friendly selective plating processes (for controlling the properties of the contact in key areas such as the initial and fully mated contact mating zones) and they use compliant pin (commonly referred to as "press-fit" or "eye-of-needle") connections to the PCB in place of solder to eliminate hazardous materials such as beryllium copper and lead from the outlet assembly.

By utilizing an alloy that more easily accommodates the full outlet contact deflection range, Siemon Engineers were able to design contacts capable of accepting the full range of mated modular plug crimp heights, as well as being interoperable with both 6 and 8 conductor modular plugs (see figure 11). Z-MAX contacts are electrically short and exceed the most demanding life cycle requirements. The resiliency of the material also ensures that the contacts do not easily deform or deflect out of position. Z-MAX contact pins are precisely positioned when fully mated to the plug to minimize crosstalk coupling between adjacent pins. The resulting highly reliable and consistent outlet contact geometry ensures that the compensation circuitry employed in the outlet is working optimally for at least 2500 plug mating cycles.

Contact Wipe:

Even in the most benign environments, plug and jack contacts can be contaminated with liquid and solid debris. As a Z-MAX modular plug and outlet are mated, the contacts of each component wipe against each other in an area that is outside of the final mated contact position. This wiping action ensures a clean, uncontaminated connection after every plug insertion. The Z-MAX contact design also ensures that potential contact damage due to arcing when a circuit carrying power (e.g. Power over Ethernet and Power over Ethernet Plus applications) is connected or disconnected at the modular outlet. Such arcing is limited to a predetermined area outside of the fully-mated contact zone.

Hybrid Modular Configuration:

A challenge in developing a new connecting hardware design is how to satisfy the wide variety of customer needs with a product that performs consistently. To overcome this obstacle, Siemon Engineers developed one Z-MAX fully-functional outlet core or "kernel" subassembly that can be used in conjunction with modular bezels to accommodate the widest range of customer needs. For example, flat/angled, and keystone outlet configurations, as well as color-coding, is simply enabled through the use of the appropriate bezel (see figure 12). Note that the UTP Z-MAX kernel subassembly features a molded dielectric housing, while the shielded Z-MAX kernel subassembly features a die cast metallic housing. This approach ensures that the entire product line performs consistently and that manufacturing process variations are reduced to the lowest level possible.

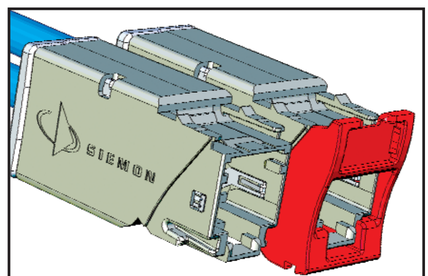


Figure 12: *Z-MAX "Kernel" Subassembly next to Z-MAX Outlet with Hybrid Flat/Angled Color-coded Bezel*

The bezel itself is an important Z-MAX design innovation with a hybrid version capable of both flat and angled mounting in a standard panel or faceplate opening (see figure 13). Color coding is provided for both shielded and UTP outlets through bezel color options and separate printed icon provisions. The compact kernel and bezel design allows the outlet to pass through the panel or faceplate opening for front or rear mounting. All panel latch features are self contained, meaning that they do not require icon tabs or doors to secure the outlet to the panel. Even the colored icon has been redesigned to be highly visible, easy to use and recyclable.

Figure 13: *Z-MAX Hybrid Flat/Angled Outlet*

Figure 14: *Z-MAX Outlet and Z-TOOL™ Termination Device*

Fast Termination:

In the field, quicker termination times translate to cost savings and a network infrastructure that can be available sooner and with less troubleshooting. Based on feedback from hundreds of installers, Siemon recognized the need to deliver "best-in-class" termination times with the Z-MAX outlet. While many of the Z-MAX features that maintain pair symmetry and eliminate split and crossed pairs inherently improve termination time, Siemon targeted reducing the termination time of a Z-MAX outlet to 1 minute. In order to achieve this target, the Z MAX outlet utilizes a optimized workflow that includes fast and repeatable cable preparation; one-step cable strain relief and shield/screen termination; linear, single-axis pair lacing; and the new Z-TOOL termination device (see figure 14). The resulting Z-MAX termination time, including cable preparation, has been reduced to as little as 55 seconds for UTP outlets and 60 seconds for shielded outlets!

SUMMARY

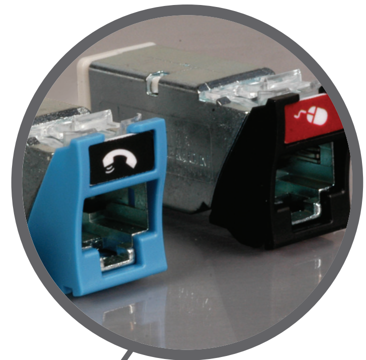
Siemon's new Z-MAX UTP and shielded solution is the culmination of a total and much-needed overhaul of existing modular RJ-style plug and outlet technology and completely revolutionizes the category 6A industry. No other connecting hardware solution can claim the following features:

1. PCB-Based smart plug technology that eliminates split pairs, crosses and termination variability.
2. Unique plug design and termination schemes on each end of modular cord to minimize performance variations induced by the end-dependent orientation difference of the pairs within the cable.
3. Cord performance that consistently hits the "sweet spot" of the TIA and ISO test plug range.
4. A Zero-Cross™ IDC termination module that eliminates split and crossed pairs, while maintaining minimum pair untwist to eliminate variability.
5. Sophisticated magnitude and phase compensation circuitry that delivers unsurpassed channel performance.
6. UTP and shielded outlet isolation that minimizes alien crosstalk, while supporting extreme density (48 ports in a 1U panel).
7. Channel to channel shield isolation at all connection points that are not intentionally bonded to ground.
8. Environmentally-friendly materials and high reliability construction.
9. Resistance to damage from energized Power over Ethernet and Power over Ethernet Plus channels.
10. Capable of UTP and shielded termination times of less than 1 minute.

Welcome to the Z-MAX Revolution!

E-Catalog

Z-MAX™ Information



WEB RESOURCES

Please visit us online for more Z-MAX information, tools and resources:

- Video instructions
- Detailed e-catalog data and spec sheets
- Informational whitepapers
- Technical briefs

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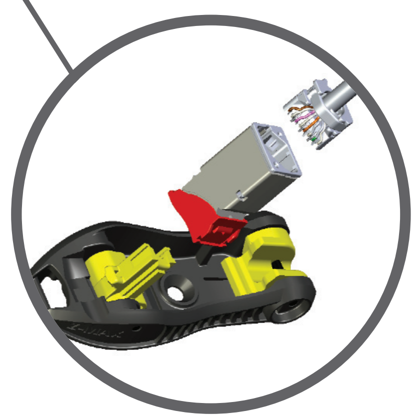

Video Instructions

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