White Paper

Center Tuned Category 6 Connectivity

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Since the introduction of the TIA/EIA 568 cabling standards, connectivity manufacturers have pursued two main goals–component compliance and elevated link and channel performance. While these two goals are related, they are not always complementary.

Manufacturers and third party independent test laboratories conduct component compliance testing in order to confirm that individual cables, connectors, blocks and cords meet minimum performance requirements for a particular category. Link and channel performance is usually measured in the field with portable test equipment to confirm the acceptability of an installation to the installer or end-user. Manufacturers and third party test labs also conduct link and channel testing to understand how product will perform in simulated field installation scenarios.

When designing cabling systems, standards mandate that the selection of cable and connectivity individually meet the performance threshold of component compliance, identified in the TIA/EIA 568B standard for the required category (5e or 6). However, to optimize installed channel performance, the products selected must share a harmonized design. This paper will define one approach to harmonized system design–"center tuning".

Component specification – "The Minimum Benchmark"

Since the introduction of Categories 3, 4 and 5, followed by Category 5e and now Category 6 (in 2002), component compliance has remained a cornerstone of the TIA 568B cabling standards. The inclusion of individual component specifications was deemed critical to ensure the backwards compatibility and interoperability of individual cables, connectors, blocks and cords necessary for true open architecture.

Backwards compatibility ensures that installed cabling systems of any category will operate with any lower category cable or connectivity at least to the link/channel performance level of the lowest level component. Interoperability ensures that a cabling system assembled from components from different manufacturers will pass a field test to the category of the lowest level component installed.

The resulting standard characterizes a minimum level of acceptable performance for an installation. Component compliance ensures this minimum level of installed performance while maintaining backwards compatibility and interoperability. However, if improving the performance of the entire channel is more critical to optimizing equipment performance, then component compliance should only be weighted as a pass/fail requirement.

The component's role in optimizing channel performance

The influence of connectivity/connections in a channel lies in the performance characteristics of the mated connector unions. The focus of this paper is the mated unions of plugs and jacks that exist within a cabling system.

It has long been recognized that the cable was one of the more robust elements of the channel. Cable

construction reflects designs which insure balanced pairs (matched insulated conductors, consistent twist rates within pairs), and designed pair separation (varied twist rates among pairs and center cable members). These designs have proven very successful at protecting against noise and the loss of signal strength.

It has also been understood that the connections in a cabling system can be a significant contributor to performance degradation. With modular plugs and jacks, there are several contributing factors. One is the innate weakness to noise generation of the center (nested) pairs (positions 3, 6 and 4, 5) within the 568A and B wiring of modular plugs and jacks. The TIA's initial decision to standardize on the 8-position plug and jacks and the referenced wiring formats was intended to provide compatibility with existing voice and data systems. At that time, Category 5 performance had not yet been accomplished and it was questioned whether these connections would be able to achieve that benchmark. Today, we have met the tightened 100 MHz specifications of Category 5e and the 250 MHz of the soon to be ratified Category 6. During this time, many improvements and methodologies have been introduced for controlling the unbalances that occur on plug and jack positions 3, 4, 5 and 6 where the pair located on positions 3 and 6 is separated by pair 1 on positions 4 and 5.

We have also come to understand the advantages of tuning plug and jack connections to make this transition more seamless to the channel. Prior to achieving Category 6 component compliance, most Category 6 channel solutions relied on tuning connectivity to achieve a Category 6 field pass. The approaching ratification of the Category 6 component specifications requires that any tuning must also be compatible with the TIA component specifications for backwards compatibly and interoperability

A narrowed target

To qualify connectors (jacks and panels) to the TIA Category 6 component specification, parts are tested and must pass with a high and low range of test plugs (de-embedded plugs). This high and low range of test plugs determines the window of inter-operability and backwards compatibility for the connectivity. For Categories 5e and 6 connectors, six pairings are tested for cross-talk (pairs at positions 1&2, 1&3, 1&4, 2&3, 2&4, 3&4). *See Chart 1.* Four of these pairs (1&2, 1&4, 2&3, 3&4) are tested with high and low value plugs and the pair at positions 1&3 is tested with two ranges (a range within a range) of high and low value plugs. This requires 12 test configurations over the entire tested frequency and is intended to represent the range of plugs with which these jacks or panels might be connected in the field. Links, channels and assembled components that meet these specs are assured to meet minimum Category 6 field requirements for cross-talk. This testing has also shown that tuned connectors will perform more optimally with specific de-embedded plug values

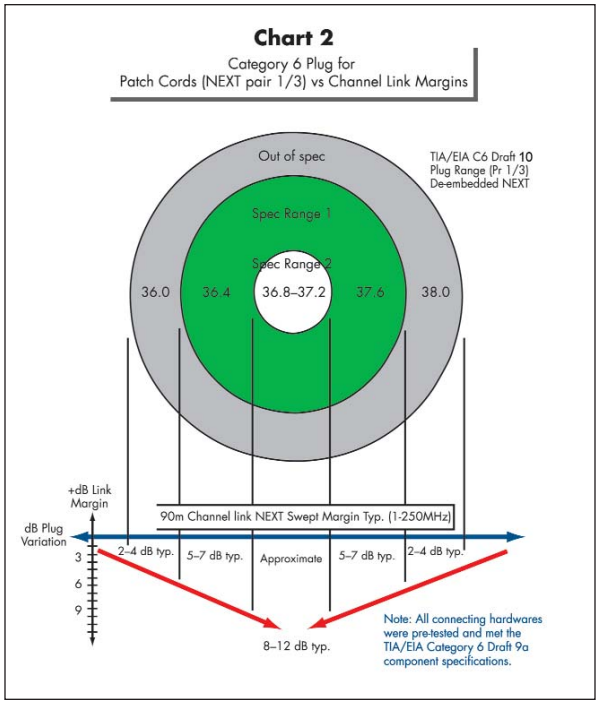
Products designed to optimize installed performance must pass all component requirements while attaining maximum headroom when installed together as a system. This can be accomplished by tuning all connector elements to the common center values of the TIA de-embedded test plugs. Tuning all connectivity to this standards-defined center target of the de-embedded plug range eliminates incompatibility of noise compensation techniques. All jacks, patch panel ports and patch cord terminations share the same precise target. The result is viewable in the lab or in the field with improved cabling system performance.

It is equally important that tuning shows its benefits across all types of installation configurations, links and channels, short or long lengths. This balance must start with a uniform target and all connectors must be

Chart 1

De-embedded Test Plug NEXT Limits

Pair	1/2	1/3	1/3	1/4	2/3	2/4	3/4
Lower	1 -57	3 -36.4	5 ≥ -36.8	6 -57	8 -46.5	10 ≥ -65	11 -46.5
Upper	2 -70	4 -37.6	≤ -37.2	7 -70	9 -49.5	---	12 -49.5



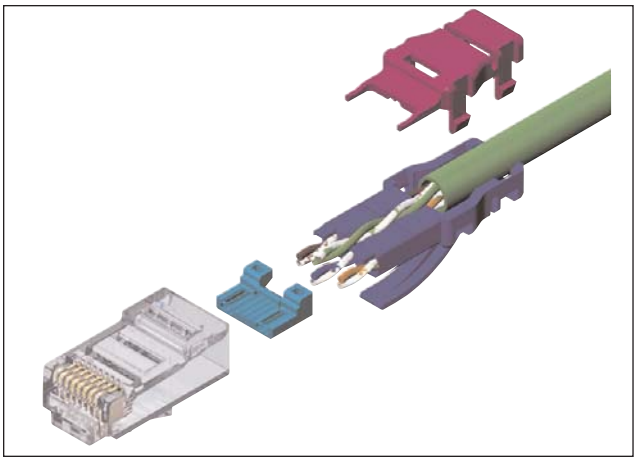
designed to these targets. It does no good to have jack and panel ports with different values since both need to connect with the same patch cord design. In fact, the patch cord terminated plug value should be the foundation value to which all other connectivity is built.

Starting with the patch cord

The perfect cord termination would fall right in the middle range of de-embedded test plugs that the TIA has specified to use in the component qualification of connectors (jacks, panels, etc.). To accomplish this, a design and manufacturing process needs to hold very tight tolerances, keeping each cord termination within this target.

To build these higher performing cords, some manufacturers work to control pairs after they exit the cable jacket, maintaining designed pair twist. The Ortronics Paralign II plug termination design keeps each pair in quadrant separated spacing as they approach the plug contact. This quadrant spacing matches the internal star construction of most Category 6 cables. Prior to being placed under the contacts, conductors are oriented to a plug wiring format using a balanced separation sled. This sled compartmentalizes and segregates each pair minimizing the cross-talk effect of adjacent pairs. Lastly, the cords are terminated with a plug designed with a proprietary balanced contact array centered to the TIA Category 6 performance values.

Success is a finely controlled and repeatable termination resulting in greatly improved cord consistency. Each cord termination presents an electrical profile that is centered to the TIA test plug values. This significantly improves a cord's ability to pass the TIA/EIA Category 6 patch cord specification.



Additionally, this cord termination approach provides a consistent centered target to which connectors can be designed. The more controlled the plug termination is, the more accurately tuned the jack can be, thus reducing the occurrence of overcompensation or unbalance. This increases in importance as you test at the higher frequencies of Category 6 (up to 250 MHz).

Tuning the connector

Historically, the connector design has compensated for noise (cross-talk) introduced by the plug termination. However, compensation that is disproportional or not precisely tuned to the noise characteristics of the plug will make cross-talk worse. Designing to common center de-embedded plug values allows the utilization of targeted noise elimination techniques that minimize the introduction of unbalance into the system. Center tuned connectivity also performs with greater consistency, showing less degradation at higher frequencies.

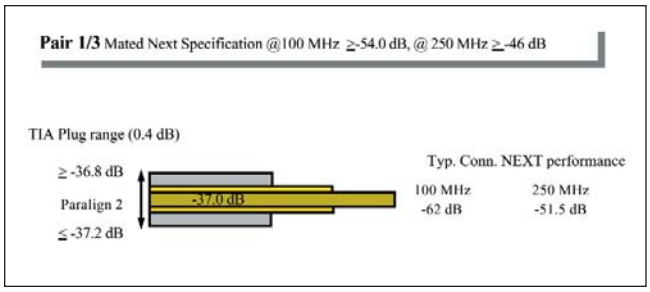
To accomplish this, Ortronics developed **Dual Reactance Technology** for its modular connectivity. In each port, the modular insert uses contact separation and positioning with the mating plug to provide compensation that is balanced to the cross-talk (NEXT) introduced by a center tuned plug. Dual reactance also helps by using the jack contacts to introduce inductive and capacitive reactance (compensation). Locating compensation closer to the noise source (the plug contacts) is a more effective method of controlling this noise, rather than having all compensation located on the printed circuit board of the jack. This marks a significant

improvement from previous noise compensation methods that degraded the overall balance of the connection, causing issues with return loss and FEXT that were especially viewable at higher frequencies.

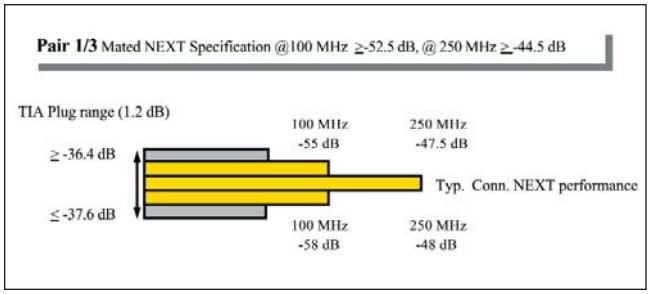
Test confirmation

The impact of center tuning is visible in the worst pair scenario – plug and jack positions 3, 4, 5, and 6, commonly described as pair relationship 1/3. For Category 6, the de-embedded NEXT plug values for this pair combination are greater than or equal to 36.4 dB and less than or equal to 37.6 dB. All Category 6 connectivity must pass when tested with these plug values for pairs 1 and 3.

When testing a connector tuned to the center of this plug range and tested with plug values 36.4dB and 37.6dB, the measured cross-talk at 100 MHz was -55dB with the low plug value and 58dB at the high plug value. All patch cords that meet the Category 6 component specification should have plug termination values within this range. The average de-embedded value of the Paralign II cord termination was 37.0dB. When the Ortronics Clarity[6] patch cord termination is mated with the center tuned connector, the cross performance improves to a value of 62dB.



Testing at higher frequencies (250 MHz) re-enforces the benefits of center tuning. NEXT values for positions 3, 4, 5 and 6 of the mated union of the centered connector and the 36.4dB plug termination were 47.5dB. For the mated union of the centered connector and the 37.6dB plug termination, the NEXT values were 48.0dB. Lastly, for the mated union of the centered connector and the centered plug termination of 37dB, the NEXT value was 51.5dB.



A center tuned system design for connectivity guarantees that the cable termination interface is the same, regardless of whether it is a jack or panel. A common target for jack and panel ports ensures that the performance will not differ when mated with the same patch cord. Performance is optimized when used with a centered cord termination technology. The result is visible with laboratory and field-testing, and becomes increasingly apparent when the lengths of the tested links or channels are shortened.

Benefits visible in short links

In the past, the industry has recognized that installed short links or channels have tested with measurably worse values than longer links and channels. This also identified that the 90-meter link or 100-meter channel did not represent the worst case in all situations. The cause of the "short link phenomenon*" is the closer proximity of the unbalance and additive noise from these connections to each other. This is part of the reason for testing Categories 5e and 6 with a high and low range of plugs

Connectors that are tuned to a narrower range of targets minimize cross-talk unbalance in a short link. The new Category 5e and proposed Category 6 component specificiations identify a narrowing range of performance targets. Improving balance in tandem with controlling noise minimizes the effect of locating connectors in closer proximity due to the shorter length of horizontal cable.

This identifies that any evaluation process must recognize the importance of testing short links and channels as well as maximum length links and channels in order to anticipate the potential range of field experiences.

Conclusion

The standards require that all elements of your cabling system meet all component requirements to insure minimum acceptable performance. Yet, it is only by tuning all plug and jack connector elements to common

center values that maximum headroom is attained when they are installed together as a channel. Tuning connector elements to the common center values of the TIA guidelines improves the transparency of these connections within the cabling system. Standards compliant "system solutions" will continue to outperform installations that are assembled from components that do not share the same target values. Jacks, patch panel ports and patch cord terminations must share the same precise target.

The improved performance of such a system will be viewable in the lab or in the field. This performance will be visible in 2, 3 and 4 connector channels, in permanent link tests and in both short (10-meter) and long (90-meter) configurations. Center tuned connectivity is the key to providing a cabling path that is more transparent to a signal.

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* For more information, refer to the "Short Link Phenomenon" white paper available from NetClear™, a Berk-Tek/Ortronics alliance, at www.netclear-channel.com.