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INSIDE PQ

Observations on Supplemental Grounding and Bonding Systems: Part 1

Going beyond typical low-cost electrical "safety" requirements

By William Bush, Panduit

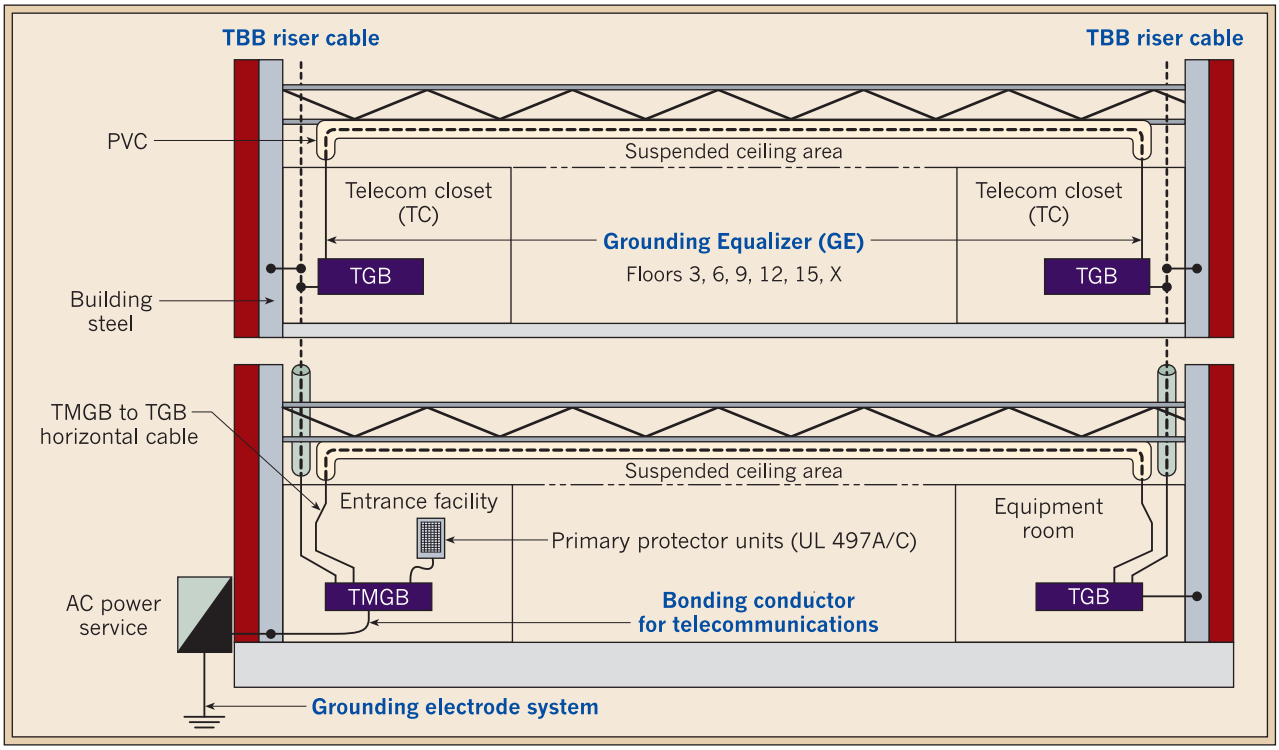


Fig. 1. *Major components of the grounding/bonding infrastructure for telecommunication systems (IEEE Std 1100-2005). "TMGB" denotes the Telecommunications Main Grounding Bus Bar, "TBB" denotes the Telecommunications Bonding Backbone, and "TGB" denotes the Telecommunications Grounding.*

Site power and grounding audits/evaluations of commercial and industrial locations routinely identify electrical power system grounding and bonding problems. According to S. Frank Waterer, an electrical engineering IEEE Fellow at Schneider Electric with more than 30 years of experience, approximately 70% of all anomalies, dysfunctions, or problems associated with power distribution systems are directly or indirectly related to bonding and grounding issues.

To maintain the safety of use and acceptable performance of connected equipment, we typically design and install grounding and bonding of the building structure (building steel) and certain conductive parts of these systems. In fact, we assume that safety grounding and bonding of the electrical power system and the load equipment are inherent parts of the design and installation so that both meet applicable codes and product safety standards. As electrical engineers, plant/facility electrical maintenance personnel, and electrical installers, this is part of doing business. However, this assumption can be risky.

Factors affecting performance. Ideally, properly designed, installed, and maintained electrical system grounding and bonding in a commercial building would suffice (via feeder

and branch circuits) for connected electronic load equipment. In practice, however, economic constraints typically render the electrical installation as the lowest cost (lowest bid) endeavor required to meet the "safety" requirements of the applicable electrical code. Because the National Electrical Code (NEC) is not a design document, installation considerations prevail — at the expense of designing and installing for performance. Furthermore, even if design considerations were incorporated with safety requirements, other considerations would bring the adequacy of such an installation into question. For example, consider the following:

- Voltages (lightning and power faults) developed across electronic equipment interconnected across different floors of a building.
- Voltage offset (ground potential difference) between different power systems serving interconnected electronic equipment.
- Electromagnetic interference (EMI) filter currents on the equipment grounding conductors of the power circuits serving electronic equipment.
- Continuity of the power system(s) equipment grounding conductors and grounding electrode conductors (during damage from power fault, maintenance, accident, or other).
- Adequacy of power system ground-fault protection and overcurrent protection (for example, will breakers actually operate when they have not been exercised for years?).

To be sure, the efficacy of the power system equipment grounding system to serve as the single grounding reference for the telecommunications electronic equipment was thoroughly discussed during the formulation meetings preceding publication of TIA/EIA 607-1994. (See **Telecom/IT Systems Convergence.**) Many aspects of the problem were considered before a recommended practice was determined — including the significant need for uniformity of application. (Note: Such activity on grounding and bonding to serve different industry sectors is not restricted to the telecommunications industry. For example, industry sectors serving building automation and industrial control systems routinely specify a distinct grounding and bonding system.)

In essence, a multi-tenant commercial building is expected to provide for grounding and bonding infrastructure in accordance with ANSI J-STD-607-A and IEEE Std 1100-2005, "Recommended Practice for Powering and Grounding Electronic Equipment." Note also that these standards cover small commercial buildings whereby recommendations are somewhat scaled down for increased practicality.

Supplemental grounding and bonding components. Relative to the electrical power system, we can consider the major components shown in **Fig. 1** on the previous page as supplemental. The power system equipment grounding conductor serving the electronic equipment (placed into locations as shown in Fig. 1) is intended to provide the required safety ground (product safety). Other identifiable supplemental grounding and bonding entities at such a location may include:

- Additional connections to building steel.
- Additional "made" earthing electrodes such as rods/plates bonded to equipment grounding conductors (NEC 250.54).
- Surge protective devices (SPDs) during time of their operation.
- Additional equipment grounding conductors (insulated preferred) placed into the metallic conduits and raceways of the serving power system.
- Equipment bonding topologies, such as for multi- or single-point grounding (to be covered in Parts 2 and 3 of this article).
- A lightning protection system (LPS) installed to lower the risk of lightning and surge damage to the structure and its contents, which include electronic equipment.

Figure 2 illustrates how complexity enters into the application of supplemental grounding and bonding entities. It is a limited illustration and does not show all components (such as the AC power distribution wiring and its grounding and bonding). The complexity identified is the use of one versus two ground rings. Suppose Ground Ring 1 was previously installed as recommended in IEEE Std. 1100-2005 for promoting intersystem bonding of multiple service provider systems into the building. In doing so, the NEC "takes over" the ground ring, and it becomes part of the grounding electrode system (GES) for that building. For the LPS, the NEC defers to NFPA 780-2004.

Interestingly, Clause 4.13.1.3 in NFPA 780-2004 requires the grounding electrodes for the LPS to be separate entities from the building (electrical) grounding electrode system. Where real estate is scarce, one can envision Ground Ring 2 for the LPS being placed very close to the pre-existing ground ring for the GES and bonded to the electrical ground ring. This seems to be a perplexing juxtaposition of two needed codes/standards. (Why can't one ground ring suffice when in such close quarters?) You can imagine the confusion at such a job site. Now, add to that confusion the fact that neither ground ring is considered supplemental by its controlling code or standard.

This complexity illustrates that "supplementing" the NEC required GES with additional grounding and bonding entities, which are not considered by their controlling standard to be supplemental, requires careful consideration.

Supplemental grounding and bonding infrastructure entities. The discussion here will not address technical development. For further technical information, refer to IEEE Std 1100-2005 and similar documents.

Supplementary grounding electrode. Section 250.54 of the NEC permits a grounding electrode to be connected to an equipment grounding conductor, as described in 250.118. Essentially, this allows for localized earthing to hold the electronic equipment ground to the same value as the local ground nearby that equipment.

You can consider this application as an added value for safety grounding (voltage equalization) at or nearby the equipment. However, the NEC doesn't mention EMI considerations for this application. As the terminology implies, the NEC considers this application only as a *supplement* to all other grounding and bonding requirements that apply. The supplementary grounding electrode should *never* be used as the sole grounding means for the equipment.

Lightning protection system (LPS). Generally, there is little argument for not using a properly designed and installed LPS where risk analysis indicates the need. The LPS grounding and bonding is supplemental relative to the electrical power system GES in a commercial building. Generally, the LPS can serve to keep the majority of the lightning current from dissipating within the building. The positive benefits are obvious — fire protection of the building and its contents (including electronic equipment). Regrettably, some negative issues may also arise. Consider a bonding conductor placed from an LPS down conductor to a metal object within the arcing area of the down conductor (formula given in NFPA 780-2004). Such bonding prevents a side flash to the metal object. However, it also extends the lightning voltage to the bonded object. Thus, a new concern arises over the arcing area to metal objects in proximity to the first metal object. Conceivably, the lightning voltage could be "bonded" deep into the building, which is one reason electronic equipment shouldn't be located near conductors carrying lightning currents.

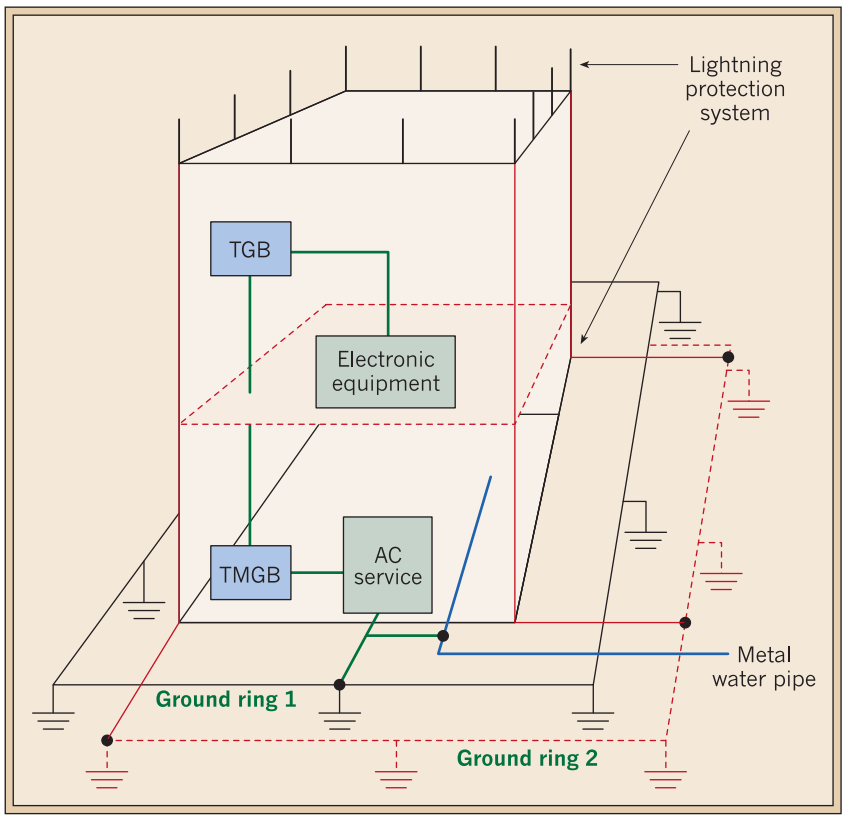


Fig. 2. *Example of the complexity of coordinating multiple grounding and bonding entities.*

Additional equipment grounding conductor (preferably insulated – green wire). This supplemental grounding and bonding entity has provided countless benefits since its inception in the 1960s and is highly recommended as a standard practice. Excellent technical validation is contained in IEEE Std 142-1991, "Recommended Practice for Grounding of Industrial and Commercial Power Systems" (Green Book), IEEE Std 1100-2005, and the International Association of Electrical Inspectors' "Soares Book on Grounding," Edition 9. The green wire concept is so vital that recognized industry documents mandate or "strongly recommend" the use of a green wire. Prime examples are Telcordia generic requirements documents (GRs), ANSI T1 standards, and numerous ITE power quality guidelines. But even with the green wire, you must not relax the bonding and grounding requirements for the metal conduit or raceway (which is also an NEC requirement). Over time, even initially and properly installed metal conduit and raceway can sometimes be found in an "unbonded" condition at one or more locations. Until repairs are made, the green wire serves an invaluable backup function. The green wire definitely promotes the operation of circuit protective devices to remove the voltage to the faulted circuit in a timely manner. In so doing, the fault current has less time to influence the operating performance of electronic equipment. The green wire also contributes to the EMC functionality of the electronic equipment due to its EMI filters being referenced to equipment ground. Note that for non-metallic conduit and raceway, the green wire function becomes a requirement and is no longer considered supplemental. **Figure 3** shows the green wire in a standard circuit and also in an isolated (insulated) grounding receptacle circuit (IGR).

Taken to another level, yet another insulated green wire provides a so-called "isolated" function for the isolated (insulated) grounding receptacle circuit described in the NEC. In this wiring configuration, the IG green wire is *not* supplemental because it is the *only* equipment grounding conductor available at the outlet for connection to the electronic equipment. However, the "regular" green wire in the same circuit is installed as a *supplemental* grounding and bonding conductor to the metallic conduit or raceway. The IG green wire can be carried all the way back to the serving power source within the same building before being grounded. Purportedly, this arrangement provides a "non-influenced" ground reference for the connected electronic equipment. Despite good

intentions, this circuitry can bring unexpected problems that may be worse than those purportedly cured. IEEE Std 1100-2005 provides excellent critique on this circuit. Generally, such a circuit is not recommended. **Figure 4** shows how the IGR circuit can be subjected to induced currents by interconnected electronic equipment.

ANSI J-STD-607-A. This supplemental infrastructure should be viewed as a single entity. Telecommunications is intended to account for any electronic equipment. Industrial electronic equipment is not specifically addressed. Generally, this infrastructure is intended to:

- Provide a uniform grounding application known and expected by the building owner, tenant and equipment supplier.
- Follow the pathways and spaces (ANSI/TIA/EIA 569-B-2004) corridors provided for information technology and telecommunications cabling systems.
- Be readily identifiable and accessible at (equipment) rooms.
- Be administered under ANSI/TIA/EIA 606-A-2002.
- Last the lifetime of the building.
- Be distinct from but bonded (equipotential) to the serving electrical power system equipment grounding conductor(s) [typically panelboard(s)] at the room containing the electronic equipment.
- Be adequately sized to provide equalization and reduction of steady state and surge voltages between several consecutive floors (via TBB and GE) — equalization effectiveness is dependant on the frequency and magnitude of the equalizing currents (note that equalization is intended to reduce electrical stress on interconnected links of electronic equipment across several floors or adjacent TBB corridors); basis for the sizing is not readily apparent from the standard, as AC fault currents are not anticipated on the defined infrastructure. Presently, a maximum required size is 3/0 AWG as this size is also acceptable to control voltage drop on a nominal 48V telecommunications centralized DC power plant serving adjacent floors.
- Provide earthing reference from the TMGB to any TGB (via TBB) – reference dependant on the frequency of any currents on the TBB (note that electronic equipment on that floor may or may not need such reference).
- Provide additional information in Annexes on topics related to grounding and bonding.

Generally, this infrastructure is *not* intended to:

- Replace grounding and bonding required by the electrical power system (NEC and design requirements).
- Replace the need for "decoupling" of electronic equipment from other equipment served by a different (or too distributed) grounding system.
- Replace the need for "decoupling" of electronic equipment from other equipment served by a different power system.
- Replace the need for an LPS. Furthermore, the intended pathways location for the TBB is generally in a central corridor and away from components of the exterior LPS.
- Adequately control electromagnetic interference. For example, susceptible links may need to be decoupled or shielded.
- Dictate the choice of electronic equipment bonding topology desired by the equipment manufacturer or the user (such as a mesh common bonding network [MCBN] or an isolated [insulated] bonding network [IBN]).
- Replace the need for a shielded (or screened) cabling system.
- Function as an equipment grounding circuit to clear electrical system ground faults (due to intentional separation from power circuit conductors, the impedance to the TBB circuit severely limits current levels.
- Serve as an MCBN or signal reference structure grid for susceptible electronic equipment as described in IEEE Std 1100-2005.
- Serve as the grounding and bonding system described in ANSI/NECA 331-2004 Standard for Installing Building and Service Entrance Grounding. Indeed, this NECA standard recognizes ANSI J-STD-607-A-2002 and IEEE Std 1100-1999 (replaced by 2005 Edition).

Note that ANSI J-STD-607-A-2002 is not a panacea for power quality and electromagnetic compatibility (EMC) issues related to the electronic equipment. Even with its best feasible installation, this standard doesn't account for grounding-related issues such as surge protection and control of EMI.

This caveat is stated in the scope of the standard. However, you should intentionally coordinate the solutions to power quality- and EMC-related issues with the grounding and bonding infrastructure described in this standard. One of the hidden pitfalls in using this standard is the standard's bundling with the TIA suite of cabling standards. By bundling, the electrical and electromagnetic environments are assumed to be properly addressed alongside all other cabling issues. In reality, recognized subject-matter expertise is still required. Even so, this standard does promote uniform application requirements and recommendations that lessen the application skills needed for writing specifications on grounding and bonding for a commercial building. Considering the complexity involved in both understanding and properly applying grounding and bonding principles, the designer/specifier for telecommunications is well advised to fully apply the standard - knowing that the many complexities were entertained and addressed by subject-matter experts and the best compromise afforded (all things considered). Without this generalized approach, the application process can become unwieldy as a myriad of site variables must otherwise be tediously resolved.

Due to its lifecycle status and previously noted issues, a revision process is currently being launched for ANSI J-STD-607-A-2002. Many industry concerns are recognized for possible discussion. The scope of the document may be enlarged to include expanded coverage of grounding and bonding from the Telecommunications Main Grounding Bus Bar (TMGB) to the equipment unit; modern data centers as described in ANSI/TIA 942-2005; low-wide buildings; grounding between buildings in a campus environment; surge protective devices; and industrial circuit links

used in a commercial environment.

In summary. Supplemental grounding and bonding for telecommunications and information technology equipment in a commercial building is based on proven historical development from the telephone industry. Coupled with industry-promoted supplemental grounding and bonding for electrical circuits (green wire) and a proper LPS, modern electronic equipment is more easily placed into a uniform and adequate grounding and bonding infrastructure within a commercial building, thanks primarily to ANSI J-STD-607-A-2002 and IEEE Std 1100-2005. However, don't confuse the application of ANSI/NECA 331-2004 or the NEC with ANSI J-STD-607-A-2002. The intent of the telecommunications grounding and bonding infrastructure is to "supplement" rather than replace (or be replaced by) electrical/lightning grounding and bonding codes and standards. This approach is harmonized to that taken in international telecommunications (ITU-T-K series) documents and European standards on earthing and bonding.

By following the Telecommunications pathways and spaces corridors (described in ANSI/TIA 569-B-2004), the grounding and bonding infrastructure is more "centralized" within the building. This location promotes decreased influence from lightning events and the larger power system fault currents. Above all, the "need for uniformity" of the grounding and bonding infrastructure must be honored. Next month we'll examine supplemental multi-point grounding and bonding topologies for electronic equipment. **EC&M**

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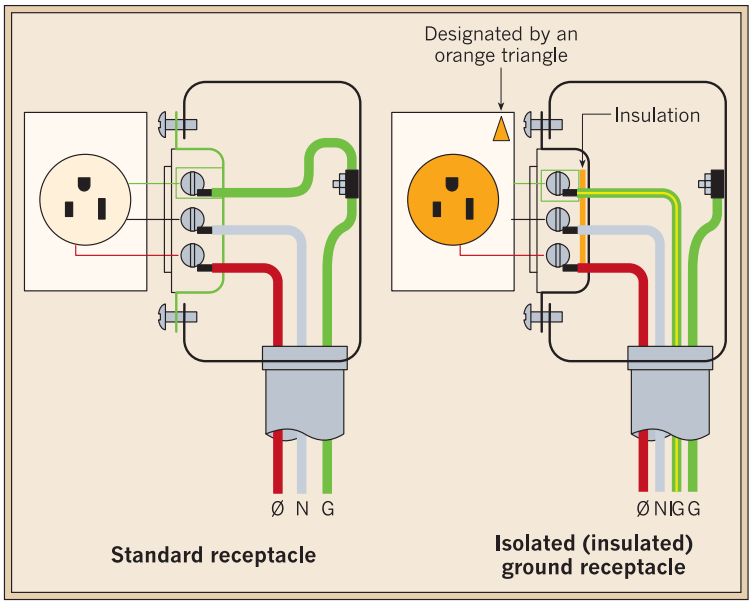


Fig. 3. *Examples of a standard and isolated (insulated) ground receptacle circuit.*

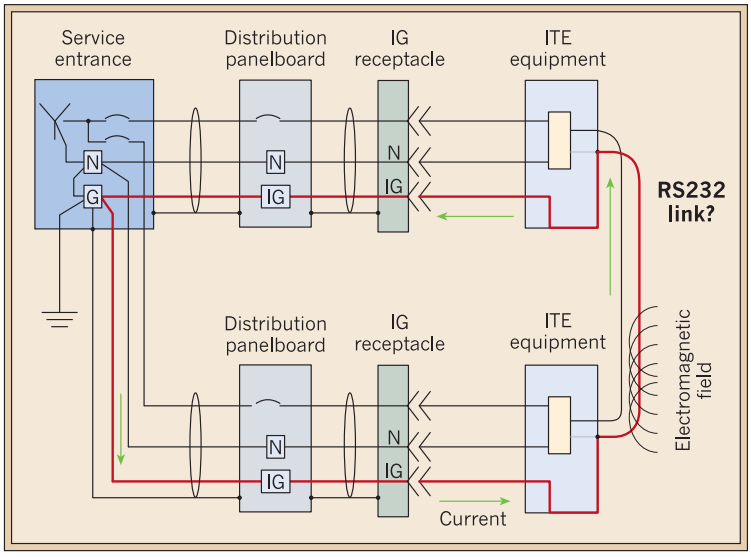


Fig. 4. *Example of induced current on an IGR circuit.*

Telecom/IT Systems Convergence

This industry has historically recommended a distinct (but not isolated) grounding and bonding infrastructure since the earliest deployments of electronic equipment. Such recommendations were described in AT&T Bell Labs system practices (BSPs) and (after the 1984 deregulation of the telephone industry) by incorporation into Bellcore (now Telcordia) generic requirements (GRs) and ATIS Committee T1 national standards (ANSI T1.xxx). Such practice is industry-recognized for contributing to the reliability of the public telephone network.

With the convergence of telephone and computer technology now well realized, reliability of the same or similar systems in a commercial building is a similar concern. In the spirit of harmonization, the Telecommunications Industry Association (TIA) developed a distinct grounding and bonding infrastructure in its document TIA/EIA 607-1994, "Commercial Building Grounding and Bonding. Requirements for Telecommunications." In 2002, ANSI J-STD-607-A, "Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications," superceded TIA/EIA 607-1994 and carried forward the same distinct grounding and bonding infrastructure.

Part 2

By William Bush, Panduit

In Part 1 of this article, we described (per the Emerald Book and ANSI J-STD-07-A) supplemental grounding and bonding from the grounding electrode system (GES) to the telecommunications main grounding bus bar [T(M)GB]. Note: The notation "T(M)GB" indicates that the bar may be either the TMGB or TGB, depending on the location within the building. Looking forward from the T(M)GB, there's still a need for supplemental grounding and bonding between the T(M)GB and the telecommunications and information technology equipment systems, which we'll refer to in this article as ITE.

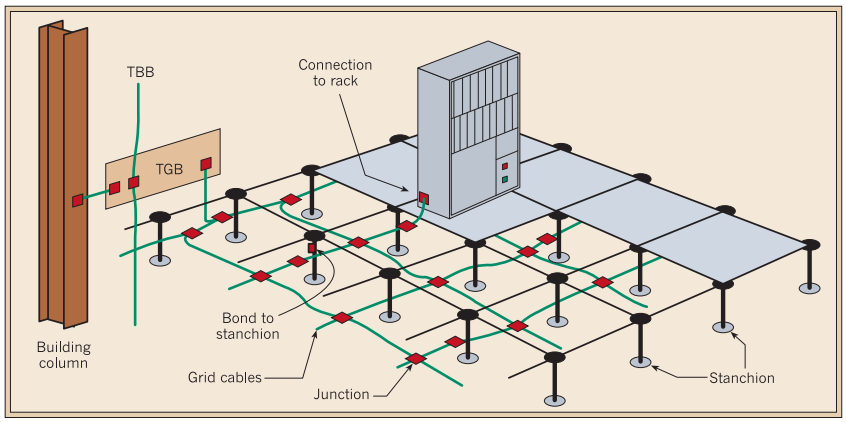


Fig. 1. Example of a mesh common bonding network in a raised-floor environment.

Just as identifiable supplemental grounding and bonding entities exist for the power distribution system, they also exist for ITE, which inherently incorporates supplemental grounding and bonding as provided in the design of the equipment and typical installation recommendations from the manufacturer. This ensures the ITE operates properly. Furthermore, the manufacturer may assemble ITE into functional blocks by including cabinets, racks, or units into a specified grouping. However, supplemental bonding and grounding contained in such a block is outside the scope of this article.

Multipoint or common-type bonding networks. These bonding networks (BNs) for ITE are specific arrangements that are intended to reflect the grounding and bonding philosophy chosen by the manufacturer or end-user for that specific application or location. Industry-recognized bonding networks are generally equally applicable to AC- or DC-powered ITE.

IEEE Std 1100 (2005), the "Emerald Book," in Sec. 9.9.17.1, informs (by reference): "For equipment bonding networks, lightning and both AC and DC power faults are the energy sources that cause the greatest concern. Of less concern are quasi-steady-state sources, such as AC power harmonics and function sources, such as clock signals from digital ITE. The energy sources that cause concern are referred to as emitters. The ITE that can suffer adversely from these emitters are referred to as susceptors. The coupling between the emitter and a susceptor is characterized as a transfer function. Therefore, the purpose of a BN is to reduce the magnitude of the transfer function by controlling the design of how the BN is attached to the CBN."

Essentially, two attachment methods are employed: diverting or shunting (common galvanic connections) and blocking (isolated to one galvanic connection).

Note that these connections are at the "systems" level and primarily only address the galvanic connections. Parasitic capacitance and inductance are not specifically addressed. These are more important in the sub-system and board levels of the ITE and would be addressed by the manufacturer. (See Bonding Network Interference).

The Emerald Book describes both multipoint bonding networks and single-point bonding networks. It's important to recognize that these bonding networks are harmonized with international and national standards. The **Table on the last page** provides identification and a brief description of four variations of common-type BNs. The distinction of these four variations allows all interested parties to readily identify the variation(s) of BNs addressed at a given location.

Note that bandwidth describes a range of frequencies over which the structure is said to operate at nearly constant low impedance. The declared bandwidth of a signal reference grid (SRG) is often not readily declared or even known. Verbiage such as "handles high frequencies" is more often offered in writings. However, it seems somewhat reasonable to assume that the intent is to "handle" conducted power line emissions (up to 30 MHz). Let's take a look at these ITE supplemental grounding and bonding entities in more detail.

Common bonding network. The infrastructure, discussed in Part 1, is part of the common bonding network (CBN) as described in the Emerald Book. Historically, the CBN was developed by the telecommunications industry, supporting two equipment bonding networks (EBNs) deemed acceptable for high-availability installations, such as in a public switched telephone network (PSTN).

Due to the rapid convergence of technology and markets for telecommunications and computing, commercial and regulated installations are no longer so easily distinguishable.

For example, regulated installations now often deploy soft switches that use Internet Protocol (IP) and are planning the next-generation network (NGN), which is also based on IP. Of course, IP is dominant in data center installations. Furthermore, telecommunications network (regulated) equipment (sometimes referred to as telecommunications load equipment or TLE) can be installed within the data center. Thus, it's important to become knowledgeable of CBN and EBNs — even for commercial locations. In many instances, the ITE/TLE may have similar characteristics.

ANSI T1.333-2001, "Grounding and Bonding of Telecommunications Equipment," describes a CBN as "the principal means for effecting bonding and grounding inside a telecommunication building. It is the set of metallic components that are intentionally or incidentally interconnected to form the principal bonding network (BN) in a building. These components include: structural steel or reinforcing rods, metallic plumbing, AC power conduit, AC equipment grounding conductors, cable racks, and bonding conductors. The CBN always has a mesh topology and is connected to the grounding electrode system."

The CBN is three dimensional. The key point here is that there are many conducting "loops" intended within each of the three dimensions that collectively promote electromagnetic compatibility (EMC) via shielding. The prime example of a CBN component is the multi-grounding and bonding that normally occurs when the AC power system is installed into the commercial building in accordance with the NEC and industry-recommended practices. The grounding electrode system, although a separate entity, becomes a part of the CBN because the CBN must always be grounded. As contributors to the electromagnetic shielding capability of the CBN, multiple interconnections of metallic structures and objects are desirable and increase the utility (density) of the CBN.

A CBN is typically more explicit and visible in a restricted access area, such as a dedicated equipment room. Compare this to a typical office area in a commercial building where the CBN components may be sparse (limited number of grounding and bonding conductors).

This distinction regarding the density of the CBN is important. To accomplish the EMC objectives cited in the originating documents for a CBN, you must consider the density and placement of the CBN components. If not, you may unwittingly build the CBN to a layout and density below original objectives.

The usefulness of the CBN/EBN concept was adopted in the 1999 edition of the Emerald Book, in Chapter 9, and recognized via reference in ANSI J-STD-607-A in 2002 for commercial buildings. This harmonization of standards means the concept is now the international basis for describing grounding and bonding networks in both regulated and commercial ITE environments.

Although the CBN was developed under considerations for EMC, the CBN by itself does not ensure ITE will meet EMC requirements or objectives. ITE having a regulatory mark (such as CE) does not ensure its electromagnetic immunity when placed into the CBN. The CBN and the chosen EBN perform as a system, and you must coordinate the desired immunity margin to accomplish EMC. Supplemental grounding and bonding provided by the CBN and EBN are key factors in achieving acceptable EMC.

Sparse common bonding network. A situation where ITE in a CBN becomes effectively single-point grounded (IBN equivalent) is known as a worst-case or sparse CBN (SCBN). In this arrangement, only single-point grounding is afforded the ITE from the serving power distribution circuit. This situation is likely more prevalent in small commercial office spaces, smaller wooden framed buildings, or residential home offices.

Note that the SCBN is not intended, it just happens as a result of the installation characteristics. Therefore, a CBN cannot be readily assumed for all situations. For example, consider the multitude of personal computers in a commercial office environment. Many may be single-point grounded via:

- An isolated grounding receptacle (IGR) circuit,
- A power outlet unit or a multiservice-multiport surge protection unit, which, in turn, is connected by its "single" power cord, or
- Branch circuits made up with non-conductive (plastic) conduit or raceway.

Mesh common bonding network. For increased density within the ITE area, a nested CBN can be intentionally "meshed" by the manufacturer(s) or end-user onto the ITE at the deployment area. This variation is known as a mesh common bonding network (MCBN or MESH-BN) and is typically designed into the ITE complex by means of metal racks, cable tray, raceway, etc. The MCBN can be arranged for installation under the raised floor, at the floor level (metal structure of the raised floor), or above the cabinet or rack (i.e., superstructure). You can also describe such structures as mats.

Figure 1 illustrates an MCBN superstructure arranged for both under-floor and at-floor level installation. This superstructure is effectively a "dual entity," as it depicts inter-bonding at several stanchions. Essentially, they can be considered single superstructure entities. The under-floor superstructure is a grid network of copper conductors that may be within a few inches of the at-floor level or placed onto the under floor, which is usually concrete. The at-floor superstructure is a grid network comprised of the raised floor stanchions, stringers, and, to some extent, the panels. Usually, the at-floor superstructure is supplemented by the under-floor superstructure due to construction issues in maintaining proper grounding and bonding or for improved access for connecting to the ITE.

The figure also illustrates some important points and raises some concerns. First, the raised floor stanchion-and-stringer system is usually not considered robust enough (mechanically and electrically) to stand alone as an MCBN superstructure. Second, the under-floor copper grid is intended to improve the electrical capability of the at-floor metal grid. Third, both the raised floor stanchion

and stringer system, and the underfloor copper grid must be inter-bonded at least once (for safety). Typically, they are inter-bonded periodically (for performance) within the grid pattern. Finally, the perimeter of the MCBN superstructure grid can be distinguished as a ring-bonding conductor (RBC) to provide placement for easy attachment to the CBN [such as at the T(M)GB].

The following statements regarding MCBNs are generally supported in the Emerald Book:

- Cabling routes should avoid significant electromagnetic interference sources, such as motor drives.
- ITE should be located a distance from the perimeter due to probable lightning and power fault currents occurring at higher amperages in those areas.
- The MCBN should always be grounded/bonded at the T(M)GB and any accessible building steel and metal piping, etc., near the T(M)GB. For the other three sides of the MCBN, bonding to the building steel and metal piping, etc., is recommended unless the MCBN is separated by around 6 feet to prevent a lightning side flash or shock hazard.

An MCBN provides these benefits:

- A supplemental grounding and bonding medium over and above that afforded by the serving power system distribution circuits to the ITE.
- Localized grounding and bonding of "dead" metal (non-powered cabinets, racks, wireways, ducts, etc.).
- Multiple bonding "straps" to the ITE to be connected close to the MCBN.
- Multiple paths for discharging static electricity (reduced current density on any one path; better EMI control).
- Easy structure to inter-bond raised floor pedestals or above rack/cabinet metal work or troughs.
- Reduction of transient voltage between ITE cabinets or racks where such transients are caused by the power system.
- Reduction of interference from nearby TV/radio transmitters.
- Electromagnetic shielding.

Signal reference structure. You can further arrange the MCBN superstructure into a design that more intentionally accounts for the effects of different frequencies along the grounding and bonding conductors. The typical form of the signal reference structure (SRS) is an SRG, such as shown in **Fig. 2.**

The electronic equipment can use the SRG as its return path for the signal to return to its source. This type of circuit is typically designated as "single-ended" because the signal wire can be placed as a single wire (return signal by an available ground system). A prime example of a single-ended circuit is the traditional RS232 circuit and cabling design whereby grounded wiring is used as a common signal reference path for several signals.

Figure 2 illustrates single-ended circuits where the ground path is used for the (logic) signal return path. The ground path represents common

Bonding Network Interference

The quasi-steady-state sources (such as AC power harmonics) and function sources (such as clock signals from digital ITE) can be classified as interference sources. Other sources of electromagnetic interference (EMI) may originate from power electronic devices, motors, etc. These devices can influence the grounding system, primarily by passing through common-mode currents at higher frequencies.

In addition to grounding and bonding, it is vital to recognize other means of improving power quality and attaining electromagnetic compatibility (EMC). These include the following methods or components: 1) separation and shielding of input and output power cables, 2) shielding of control and interface cables, 3) separation of power and signal leads, 4) proper layout of power electronics and controls, 5) high-frequency bypass capacitors, 6) reactors (inductive chokes), 7) EMI filters on power and signal leads, and 8) shielded isolation power transformers.

Immunity of electronic equipment (including ITE) to interference within the bonding network can be traced to two factors:

1. Universal design of products to meet the regulatory environment of locations requiring certain levels of inherent immunity to EMC. Items addressed include electrostatic discharge (ESD), radiated electromagnetic fields, conducted disturbances, electrical fast transient (EFT), surge from lightning, and voltage sag.

2. Predominant use of twisted-pair (TP) data cabling (Ethernet) with significant immunity advantages. Generally:

- *At up to at least 30 MHz, impressed common-mode voltages sufficiently cancel out due to "significant balance" of paired conductors.*
- *Metal shielding (such as aluminum foil) is sometimes added to the construction of the cabling to further control its common-mode impedance and to prevent electromagnetic penetration at around 30 MHz or higher (via foil thickness); the metal shield is grounded/bonded for safety, performance, and continuity across the structured components of the cabling system.*

The grounding and bonding network is certainly part of the mitigation mix for interference control within the bonding network. Generally, fewer currents in the bonding network are favored as less current equivocates to lower levels of EMI and less voltage buildup along the network. This brings into consideration important issues addressed in The Emerald Book, such as:

- *Extension of the bonding network between rooms, floors, and buildings, and*
- *Location and connection of surge protective devices (SPDs) within the bonding network.*

Variation	Acronym	Description
Common bonding network	CBN	A common bonding network (CBN) is the default multipoint grounding and bonding system at the building and enlarges any intentional equipment multipoint bonding variation (such as SRS or MCBN).
Sparse common bonding network	SCBN	A sparse common bonding network (SCBN) is the default multipoint grounding and bonding system at the building where the CBN is severely limited in its bonding capability.
Mesh common bonding network	MCBN	A mesh common bonding network (MCBN) is where the ITE is inter-bonded in a mesh pattern to augment the existing CBN. No bandwidth of frequencies is declared.
Signal reference structure	SRS	A MCBN with a certain bandwidth of frequencies declared. In a data center, the SRS is typically identified as a signal reference grid (SRG).

Variations of common bonding networks (CBNs).

impedance whereby noise voltages can be developed when extraneous currents (common-mode currents) flow along the ground path. These noise voltages are a source of noise for the communication path and can influence susceptible equipment such as RS232 links.

However, modern data cabling such as Ethernet (twisted-pair) terminates into a balanced transformer. Common-mode interference is primarily handled by grounding the center tap of the transformer. Common-mode currents can exist between transformers of the Ethernet circuit. However, this situation was recognized during the IEEE 802.3 standards development, and adequate specifications were created to address this issue.

To reduce problems of maintaining a common signal reference for both ends of a single-ended circuit, a (restricted-length) common SRG is admittedly somewhat useful. It helps to reduce the offset of ground voltage between the ends of the wiring (grounded at each end). Notice that these types of circuits are relatively low frequency compared to modern data circuits such as 1,000 Base-T Ethernet over UTP cabling. Although the contribution by the SRG is acknowledged, it's impractical for the SRG to provide a "proper" signal return path. Along with several other issues, the expansive loop area (inductive by nature) between the signal wire and signal return path violates signal-integrity design concepts. This becomes more of a problem as the operating frequency increases to the speeds seen in today's data centers.

Where the connecting cabling is closely coupled to a conductive plane, interference into the cabling is limited. Since the close coupling is dependent upon loop area, routing of the cabling away from an SRG negates the contribution of the SRG to controlling interference coupling. In most data centers, such close-proximity routing isn't routinely performed. Thus, because most data centers are not reporting such problems, the issue of common-mode coupling to modern data cabling must not be notable. This implies there is sufficient common-mode rejection in modern data circuits.

As noted, modern data circuits commonly use highly complex balanced circuits such as Ethernet-over-twisted-pair cabling. The emphasis is on "balanced" as this technology affords much higher data rates due to increased immunity to electromagnetic influences. With the predominance of immune cabling circuits (including fiberoptic cabling) in use and still growing, the usefulness and applicability of the SRG should be questioned and not "routinely" specified over an MCBN.

The Emerald Book provides significant guidance on grounding and bonding electronic equipment and is a recommended practice. ITE should use supplemental grounding and bonding for improving performance and safety, especially for a multipoint grounding arrangement, such as an MCBN. Next month, we'll discuss supplemental grounding and bonding using single-point grounding topology (SPG). EC&M

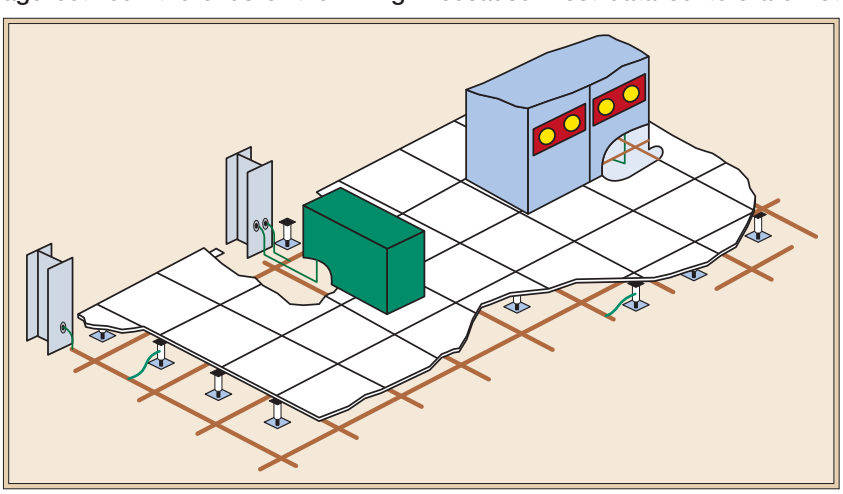


Fig. 2. *Typical signal reference grid layout (adapted from the Emerald Book).*

Bush is director of research — power & grounding for Panduit in Tinley Park, Ill. For an extensive treatment on this subject, see white paper titled "ITE Grounding and Bonding - Multipoint" at http://www.panduit.com/resources/whitepapers.asp.

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