ISSUE: October 2017

Understanding LISNs Is Essential To EMI Pre-Compliance Testing

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A line impedance stabilization network (LISN) is a circuit used for testing power supply line conducted emissions produced by either a power supply or some other type of product that contains a power supply. The network is inserted into the power supply lines to determine if the product is emitting unwanted high frequencies that will interfere with other products plugged into the same outlet or power source. Since there are multiple standards that require conducted emissions testing, if you are designing power supplies, chances are you'll need to meet some of these requirements and you'll need to know enough about LISNs to perform pre-compliance testing of your product.

The same may be true even if you're applying someone else's power supplies in your system designs. In general, it's strongly recommended that electronic equipment manufacturers perform pre-compliance testing for conducted emissions before the final product is ready for production. This can eliminate many issues that may otherwise crop up when you go to do your final compliance testing and reduce your product's time to market.

Understanding how to apply LISNs in pre-compliance testing is important, yet often challenging. That's because the composition of the LISN is specified differently by different standards. So engineers need to know not only how to use the LISN, but also which LISN is required by which test. This applies whether you're specifying and purchasing the LISN, or building your own.

In this column, we explain the basics of how LISNs work and are used, identify some of the applicable standards, and then analyze the differences between the LISNs specified by two FCC (Part 15.207 and Part 18.307 of Title 47) standards. The LISNs are shown in ANSI C63.4-2017 and IEEE Std. 1560TM-2005. In our analysis, we'll discuss the implications of the component differences in their LISNs so engineers can understand when these differences affect testing and when they don't. This analysis also illustrates a basic approach to evaluating LISN requirements for other standards.

LISN Basics

The standards for power supplies, lighting ballasts, and LED power supplies use the LISN to measure emitted frequencies from 150 kHz to 30 MHz or from 9 kHz to 30 MHz. The LISN is a piece of test equipment that is connected between the ac power source and the equipment-under-test (EUT). The LISN captures the undesired frequencies and sends these signals to a special RF receiver or a spectrum analyzer with the correct bandwidth. The output impedance of the LISN is to be connected to the 50-Ω input of the RF receiver or spectrum analyzer. The LISN does have a small ac impedance less than 0.12 Ω which will be discussed later.

Each power line is tested separately as illustrated in Fig. 1. So, when one line is being tested the other LISN output is terminated into 50 Ω, as shown. This particular setup shows a three-wire power cable system. When using a two-wire power cable, the LISN chassis box is earth or safety grounded and only the ac hot and ac return are connected to the EUT. The two-wire power cable is often used when the end product has no exposed metal like heat sinks which might be connected to the earth ground. Many products that use a two-wire line cord have a double insulated case. (The subject of two-line versus three-line power supply cables is beyond the scope of this article.)

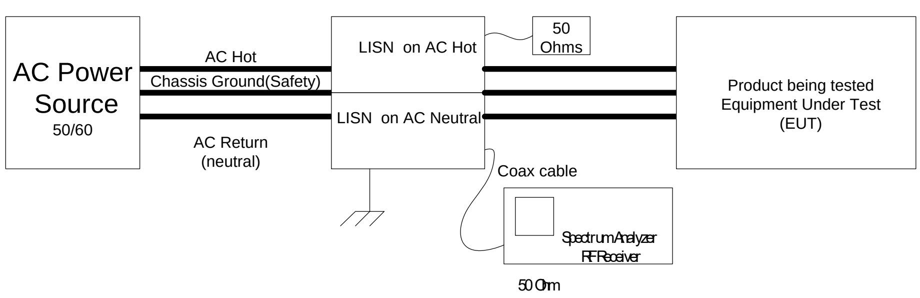

Fig. 1. Line conducted noise test setup. The setup shows a three-wire power cable system. When using a two-wire power cable, the LISN chassis box is earth or safety grounded, and only the ac hot and ac return are connected to the EUT.

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LISN Differences

There are many LISN networks and many standards specify their own networks. For example, the FCC (in Parts 15 and 18 of Title 47) appear to have circuits, CISPR has several standards (European Standards), as do the military and the Society of Automotive Engineers (SAE). This article is examining two specific standards: ANSI C63.4-2017 and IEEE Std. 1560-2005.

These are considered 50-µH LISNs because L1 in both Fig. 2 and Fig. 3 is shown as 50 µH. The FCC only mentions a 50-µH inductor while ANSI specifies it in Fig. 2 and Fig.3. So what are the differences between these two LISNs and do they really matter in terms of the test results? Of course, the specifications say that when the line-conducted testing results are required down to 9 kHz a circuit like Fig. 2 is required. If the frequency limits are from 150 KHz to 30 MHZ either circuit can be used. But let’s look a little more closely at the differences in these two LISNs.

First, the coupling capacitor C1 is different. For the applications testing at 150 kHz and above, C1 is a 0.1 µF while in the network for testing from a 9-kHz lower limit, C1 is 0.25 µF. Then for the 9-kHz to 30-MHz applications, a second filter is added consisting of L2, C2 and C3. Each of the capacitors has a series resistor to dampen any high-frequency interaction with the inductors. A series winding resistor for each of the inductors is not mentioned.

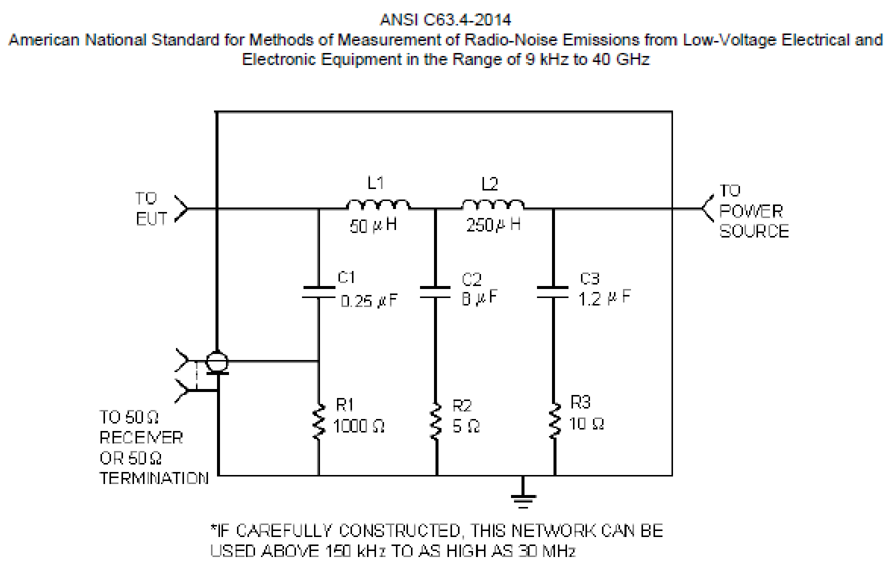

Fig. 2. ANSI and FCC network used between 9 kHz and 30 MHz.

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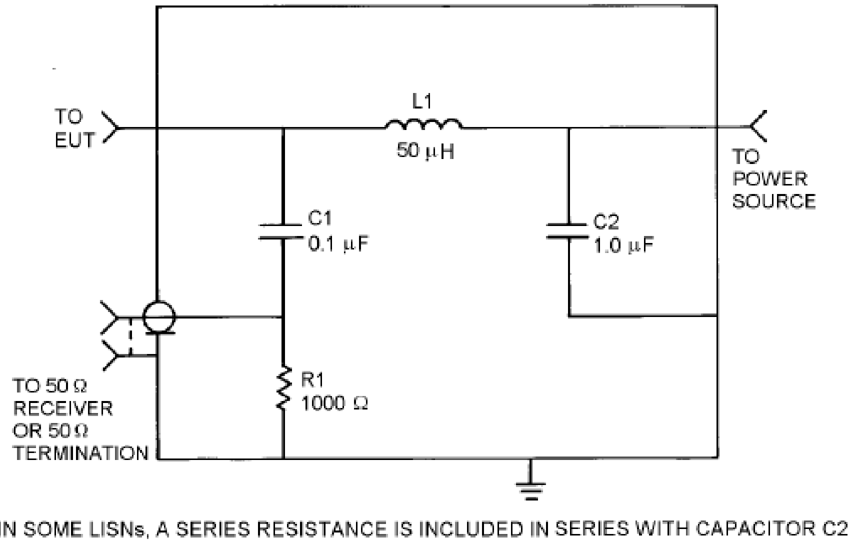

Fig. 3. FCC network used from 150 kHz to 30 MHz.

An LT-SPICE simulation was run to determine if there was any difference in the actual performance of the two circuits. The LT SPICE simulation circuits for the two networks are shown in Fig. 4. The inductors are labeled L1, L2, and L3 and, as shown, a small-value series winding resistance was added to each inductor make a more realistic model. These inductors are wound with large wire like 12 AWG to be able to handle 20 Aac or more of current at 50 Hz or 60 Hz. Further details on the design of these inductors are beyond the scope of this article.

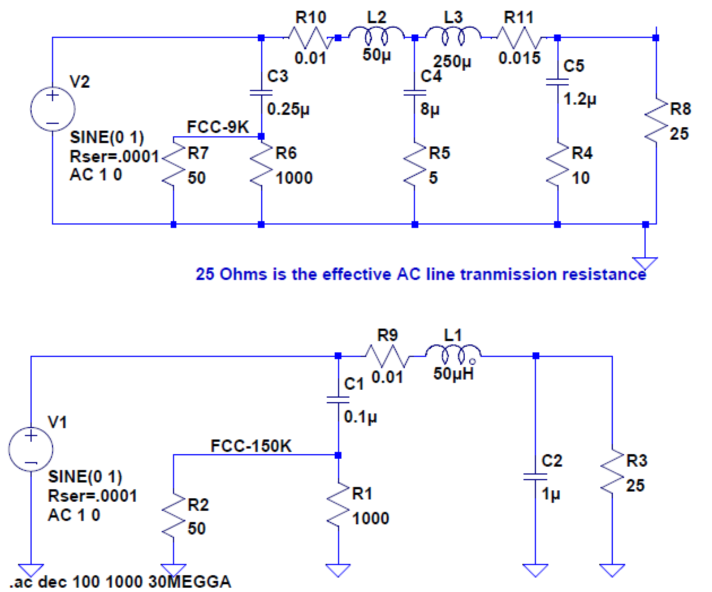

Fig. 4. LT SPICE circuits used for simulation of the LISNs in Figs. 2 and 3.

Note that the simulation of the circuits in Fig. 4 are being run simultaneously in order to not cause any interference with each other. The two circuits are kept separate by using two separate ac generators, V1 and V2. V1 and V2 represent the noise generated by the power supply. The two circuits each have a 50-Ω resistor that is the input to the spectrum analyzer or RF receiver. The high frequency is blocked by the inductors L1 in the lower circuit of Fig. 4 and a combination L2 and L3 in the upper circuit of Fig. 4 forcing the noise to flow through the coupling capacitors C1 in the lower circuit and C3 in the upper circuit.

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There is also a special 25-Ω ac transmission line resistor added in each circuit (these are labeled R3 and R8). In prior engineering work using the ac power line as a transmission line for communications, it was determined that the ac power line acts as a 25-Ω transmission line. It is beyond the scope of this article to describe this work used in common-carrier transmission line communications.

The simulation results are shown in Fig. 5. The blue trace is for the lower circuit in Fig. 4 (corresponding to the LISN in Fig. 3) showing FCC-150k while the green is for the upper circuit in Fig. 4 with FCC-9k (corresponding to the LISN in Fig 2). The two circuits show no simulation difference at 200 kHz and just a small difference of 0.5 dB at 150 kHz. So either circuit can be used when testing down to a lower frequency of 150 kHz.

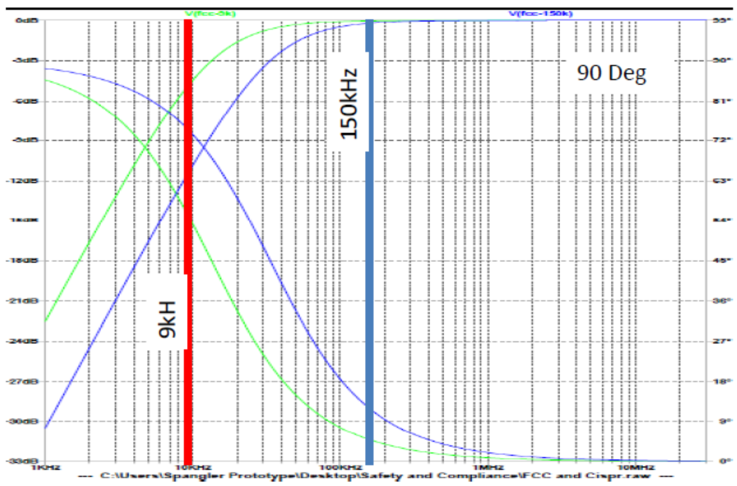

Fig. 5. Simulation results for both LISNs from 100 Hz to 30 MHz.

Earlier in the article the inductor impedance was mentioned. The inductors in Fig. 2 and Fig. 3 each handle the ac power current. The value of the 50-µH inductor provides little power line current to the load. The 50-µH inductor shown in Fig. 3 and Fig. 4 has a j0.0157-Ω impedance at 50 Hz and j0.0188-Ω impedance at 60 Hz. The 250-µH inductor shown in Fig. 3 has a j0.07853- Ω impedance at 50 Hz and a j0.09424-Ω impedance at 60 Hz. Therefore the series inductor provides little ac current limiting for testing.

In Fig. 1, two separate LISNs were shown. There are commerical available LISNs that have two LISNs in the same box and the operator switches between the ac hot and ac return for measurement. The reader can do a "Google Search" to find available LISNs. The LISN should be a 50-µH type for FCC compliance and a 50-µH type with an additional 250-µH inductor for CISPR conpliance.

The authors do not wish to recommend one LISN manufacturer over another which is why there is no comparison of companies and products here. Note that some selector guides will show MIL standard LISNs that have 5-µH inductors. Many of these are for 400-Hz power systems like those on aircraft.

There is enough information in ANSI C63.4-2017 and IEEE Std. 1560TM-2005 to build and calibrate your own LISN. The LISN information is not shown in the FCC (Part 15.207 and Part 18.307 of Title 47) standards. Many consultants have built their own LISN networks and have compared their LISNs with those from a certified test house. The commecial LISNs should all be calibrated with a certification.

Building your own LISN is fine for pre-compliance testing. Howerever it is recommended that a certified testing house review your work for line-conducted emissions. Line-conducted emissions is only part the the testing. There still is the radiated emissions testing.

As an additional comment, the authors purchased the above standards: ANSI C63.4-2017 and IEEE Std. 1560TM-2005. To have all the standards and regulations and knowledge of how to apply the standards is often a full-time postion along with the calibrated test equipment needed. To save money and time, it is recommended that engineers have their pre-compliance testing performed at a certified test house. Spending the time to learn which standards and regulations apply to your product or products is also recommended.

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About The Authors

Kevin Parmenter has over 20 years of experience in the electronics and semiconductor industry. Kevin is currently vice president of applications engineering in the U.S.A. for Excelsys, an Advanced Energy company. Previously, Kevin has served as director of Advanced Technical Marketing for Digital Power Products at Exar, and led global product applications engineering and new product definition for Freescale Semiconductors AMPD - Analog, Mixed Signal and Power Division based in Tempe, Arizona.

Prior to that, he worked for Fairchild Semiconductor in the Americas as senior director of field applications engineering and held various technical and management positions with increasing responsibility at ON Semiconductor and in the Motorola Semiconductor Products Sector. Kevin also led an applications engineering team for the start-up Primarion where he worked on high-speed electro-optical communications and digital power supply semiconductors.

Kevin serves on the board of directors of the PSMA (Power Sources Manufacturers Association) and was the general chair of APEC 2009 (the IEEE Applied Power Electronics Conference.) Kevin has also had design engineering experience in the medical electronics and military electronics fields. He holds a BSEE and BS in Business Administration, is a member of the IEEE, and holds an Amateur Extra class FCC license (call sign KG5Q) as well as an FCC Commercial Radiotelephone License.

Jim Spangler is a Life Member of the IEEE with over 40 years of electronics design experience and is president of Spangler Prototype Inc. (SPI). His power electronics engineering consulting firm's priority is helping companies to place products into production, assisting them to pass government regulations and agency standards such as UL, FCC, ANSI, IES, and the IEC.

For many years, he worked as a field applications engineer (FAE) for Motorola Semiconductor, On Semiconductor, Cirrus Logic, and Active Semiconductor, assisting customers in using semiconductors. He published numerous application notes and conference papers at a variety of conferences: APEC, ECCE, IAS, and PCIM. Topics included power factor correction, lighting, and automotive applications. As an FAE, he traveled internationally giving switch-mode power supply seminars in Australia, Hong Kong, Taiwan, Korea, Japan, Mexico, and Canada.

Jim has a Master's Degree from Northern Illinois University (NIU), and was a PhD candidate at Illinois Institute of Technology (IIT). He taught senior and first-level graduate student classes: Survey of Power Electronics, Fields and Waves, and Electronic Engineering at IIT and Midwest College of Engineering.

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