TEMPEST

TEMPEST is an unclassified name referring to investigations and studies of compromising emanations. It is sometimes used synonymously for the term "compromising emanations", e.g., TEMPEST tests or TEMPEST inspections. TEMPEST approved equipment or systems are those which have been certified under past or existing TEMPEST specifications or standards.

Historically NAG-1A/TSEC was the earliest TEMPEST standard. NAG-1A was superseded in 1965 by Federal Standard 222, "Radiation Standard for Communication and Other Information Processing Equipment." In 1970 a new series of documents entitled, "National COMSEC/EMSEC Information Memoranda (NACSEM)" replaced Federal Standard 222. These new documents are applicable to equipments in the development stage, during and subsequent to production, and after any modification.

The Defense Communications Agency (DCA) issued a series of TEMPEST documents concerned with RED/BLACK engineering. The DCA series of documents have been replaced by a new Military Handbook (MIL-HDBK-232), Military Standardization Handbook RED/BLACK Engineering—Installation Guidelines, prepared by the Naval Electronic Systems Command.

Since the above TEMPEST documents carry security classifications, they are available only to qualified contractors with security cleared facilities and an established need-to-know. The need-to-know must be established with the contracting Government Organization who will authorize the release of the TEMPEST documents to the contractor. The need-to-know can be established when there is a contract for equipment which must meet TEMPEST requirements. If there is no contract of this type, the contractor must be able to show that the release of TEMPEST documents to him would be of direct benefit to the Government in the future.

Commercial firms with TEMPEST related Government contracts should address inquiries pertaining to TEMPEST to their contracting Government Department or Agency. Commercial firms with no TEMPEST related contracts should address inquiries pertaining to TEMPEST to a Government Department or Agency with whom they have (or have recently had) a classified contract, or (if no such contract exists or has recently existed) to the Director, National Security Agency, ATTN: S22, Fort George G. Meade, MD 20755.

The Air Force is conducting a school on NACSEM at their Cryptologic Depot in San Antonio, Texas. This is open to employees of private organizations under contract with the Air Force. An Air Force contractor desiring training for his employees must forward a written request to the major air command or designated subcommand supervising the contract for which the training is necessary, at least 30 days before the date training should begin (refer to paragraph 112, AFT 205-1). If the contractor does not have a current contract but can show that the training would be of direct benefit to the Government in the future, he may forward his request to Headquarters, U.S. Air Force Security Service, ATTN: SRE, San Antonio, Texas 78243. They will evaluate each request on a case by case basis. It should be pointed out that generally the Government will not pay for such training.

TEMPEST TERMS AND DEFINITIONS

Alternating Current (AC) Protective Ground System . . . A ground system which provides a low resistance electrical connection to Earth Ground for the protection of personnel and equipment from AC power potentials, lightning hazards, and electrical circuit failures. The integrity of the system is normally insured by the connection of an insulated green colored conductor between the cases and frames of equipments afforded AC power service. The AC protective ground system is therefore often referred to as the Green Wire Protective Ground.

Black Designation . . . A designation applied to wirelines, components, equipment, and systems which handle only unclassified signals, and to areas in which no classified signals occur.

BLACK Equipment Area(s) (BEA) . . . The space within a Limited Exclusion Area (LEA) which is designated for installation of BLACK information-processing equipment, power, signal, control, ground feeder and distribution facilities

Classified Intermediate Distribution Frame (CIDF) . . . An Intermediate Distribution Frame used for RED wiring.

Combined Distribution Frame (CDF) . . . A distribution frame which serves as both a Main Distribution Frame and Intermediate Distribution Frame.

Communications Security . . . The protection resulting from all measures designed to deny unauthorized persons information of value which might be derived from the possession and study of telecommunications, or to mislead unauthorized persons in their interpretations of the results of such possession and study.

Compromise . . . Any occurrence which results in unauthorized persons gaining access to classified or other information requiring protection.

Compromising Emanation . . . Unintentional data-related or intelligence-bearing signals which, if intercepted and analyzed, disclose the classified information transmitted, received, handled or otherwise processed by any information-processing equipment.

Conducted Signals . . . Electromagnetic or acoustic signals propagated along wirelines or other conductors.

Controlled Access Area (CAA) . . . The complete building or facility area under direct physical control which can include one or more Limited Exclusion Areas, Controlled BLACK Equipment Areas, or any combination thereof. Spaces within a facility which are not under direct physical control but to which access is controlled (administration offices, halls, restrooms) are not a part of the actual Controlled Access Area but are considered as a part of the overall Physical Control Zone.

Controlled Black Equipment Area(s) (CBEA) . . . A BLACK Equipment Area which is not located in a Limited Exclusion Area but is afforded the same physical entry control which would be required if it were within a Limited Exclusion Area.

Equipment Radiation TEMPEST Zone (ERTZ) . . . A zone established as a result of determined or known TEMPEST equipment radiation characteristics. The zone includes all space within which a successful hostile intercept of Compromising Emanations is considered possible.

Fortuitous Conductor . . . Any conductor which may provide an unintended path for intelligible signals; for example, water pipe, wire or cable, metal structural members, and so forth.

Intrusion-Resistant Communications Cable (IRCC) . . . A cable designed to provide substantial physical protection and electrical isolation for the wirelines making up the information-carrying core. When the protective measures used are devices which detect slight changes in the physical or electrical state of the cable and which provide visible or audible indications at a central control point of attempted intrusion, the cable is known as an Alarmed Cable. When the protective measures used are physical protection to provide a penetration delay factor, the cable is known as a Hardened Cable Path.

Limited Exclusion Area (LEA) . . . A room or enclosed area to which security controls have been applied to provide protection to a RED information-processing systems equipment and wirelines equivalent to that required for the information transmitted through the system. An LEA must contain a RED Equipment Area.

Off-Line Crypto-Operation . . . Encryption or decryption performed as a self-contained operation distinct from the transmission of the encrypted text, as by hand or by machines not electrically connected to a signal line. See On-Line Cypto-Operation.

On-Line Crypto-Operation . . . The use of crypto-equipment that is directly connected to a signal line, making encryption and transmission, or reception and decryption, or both together, a single continuous process. See Off-Line Crypto-Operation.

Physical Compromise . . . The compromise of information through loss, theft, capture, recovery by salvage, defection of individuals, unauthorized viewing or photography, or by any other physical means.

Physical Control Zone (PCZ) . . . The space surrounding equipment processing classified information, which is under sufficient physical and technical control to preclude a successful hostile intercept of any classified information from within this space.

Protected Wireline Distribution System . . . A communications system to which electromagnetic and physical safeguards have been applied to permit secure electrical transmission of unencrypted classified information, and which has been approved by the cognizant department or agency. The associated facilities include all equipment and wirelines so safeguarded. Major components are wirelines, subscriber sets and terminal equipment. Also known as Approved Circuit.

RED/BLACK Concept . . . The concept that electrical and electronic circuits, components, equipments, systems, and so forth, which handle classified plain language information in electric signal form (RED) be separated from those which handle encrypted or unclassified information (BLACK). Under this concept, RED and BLACK terminology is used to clarify specific criteria relating to, and to differentiate between such circuits, components, equipments, systems, and so forth and the areas in which they are contained.

RED Equipment Area (REA) . . . The space within a Limited Exclusion Area (LEA) which is designated for installation of RED information processing equipment, power, signal, control, ground feeder and distribution facilities.

Signal Ground Point . . . A single designated point in a station to which all RED/BLACK grounds are either directly or indirectly connected. This point serves as the common zero potential reference for the station.

Signal Ground Reference Plane . . . An intermediate focal point between an equipment and the Signal Ground Plane for terminating an equipment's or Terminal System's RED or BLACK ground circuits. The Signal Ground Reference Plane is isolated from the equipment's AC Protective Ground and is connected to the Signal Ground Plane by a Signal Ground Bus.

Signal Ground Reference Point . . . Same as a Signal Ground Reference Plane but serving one of several Limited Exclusion Areas device or equipment or Terminal System.

Signal, Quasi-Analog . . . A quasi-analog signal is a digital signal, after conversion to a form suitable for transmission over a specified analog channel. The specification of an analog channel would include frequency range, frequency bandwidth, signal-to-noise ratio and envelope delay distortion. When this form of signaling is used to convey message traffic over dialed-up telephone systems, it is often referred to as voice data.

Single Point Ground . . . The basic technique used in RED/BLACK installations in which separate ground conductors are used for the various grounding functions (signal, power, hazard, and so forth) with each conductor connected directly or indirectly to a single point (Signal Ground Point).

Spurious Signals . . . Undesired signals appearing external to an equipment or circuit. They may be harmonics of existing desired signals, high frequency components of complex wave shapes, or signals produced by incidental oscillatory circuits.

TEMPEST . . . An unclassified short name referring to investigations and studies of compromising emanations. It is sometimes used synonymously for the term "comprising emanations"; for example, TEMPEST tests, TEMPEST inspection.

TEMPEST Approved Equipment or Systems . . . Equipment or systems which have been certified under existing (NACSEM 5100, KAG-30A, or DCAC 370-D195.2) or past (FED-STD-222) TEMPEST specifications as determined by the command or agency concerned.

TEMPEST Inspection . . . A general term which encompasses various means for conductng facility evaluations to determine the adequacy of TEMPEST control measures; for example, installation-engineering surveys.

TEMPEST Test . . . A laboratory or on-site (field) test to determine the nature and amplitude of conducted or radiated signals containing compromising information. A test normally includes detection and measurement of these signals, and analysis to determine correlation between received signals and potentially compromising transmitted signals.

POWER LINE IMPEDANCE STABILIZATION NETWORKS FOR TEMPEST TESTING

INTRODUCTION

TEMPEST test specifications require that each side of the power line of an equipment under test (EUT) be terminated in an impedance having a magnitude of 50 ± 10 ohms over the test frequency range. This is to be accomplished by connecting the EUT to a power line impedance stabilization network (PLISN) which is placed between the EUT and the power source. The PLISN passes main power (50/60 Hz or d.c.) to the EUT with very little loss while coupling the EUT-generated spurious signals to a 50-ohm detection system. The PLISN is designed to present a relatively constant impedance of 50 ohms to the EUT regardless of local power line conditions. Of course, a constant 50-ohm impedance level is a poor simulation of the actual mean a.c. power line impedance over the usual TEMPEST test frequency range.[1] However, the purpose of the TEMPEST PLISN is not to simulate the actual power line impedance, but is to provide a standard impedance level that can be duplicated by any testing laboratory. In this way, the unknown impedance variations normally present in different a.c. power mains can be eliminated from the TEMPEST test setup. The PLISN used to power the EUT must have a specific known impedance level so that meaningful comparisons can be made between test results obtained by different testing laboratories. Since 50-ohm detection systems and cables are most frequently used in TEMPEST testing, the most practical standardized value of EUT power line impedance is 50 ohms.

The usual starting test frequency for the typical EMI/RFI test is 150 kHz. In comparison the TEMPEST test specification is considerably more stringent and consequently, the starting test frequency for a TEMPEST test is much lower than 150 kHz. If, for example, a starting test frequency of 6 kHz is specified, the presently available commerical PLISNs will not provide the required input impedance at this low frequency and the PLISNs will also have a substantial signal loss in the detection system coupling network. For example, the loss at 6 kHz can be as much as 15 dB and a correction factor (CF) will be required to determine the actual level of EUT-generated power line conducted signals.

No information has been published on the deficiencies associated with the PLISNs now being used in TEMPEST testing. This article will discuss these deficiencies and will propose a new design with component values, expected performance specifications, and other details to facilitate the construction of a PLISN which will comply with the TEMPEST test specifications.

PLISN DEFICIENCIES

A typical low frequency PLISN circuit is shown in Figure 1. The plug-in isolation coils are manufactured for use as RFI filter chokes. The low distributed capacity of these coils and their correspondingly high self-resonant frequency make them very suitable for use as the PLISN isolation inductor. The signal coupling network consists of a 0.1 μF capacitor and 1 K-ohm resistor. To provide some filtering of the power source, a 1 μF capacitor (with a 1-ohm series resistance to limit charging current) is connected across the power input receptacle. The 47 K-ohm 1-W resistors provide a discharge path for the 1 μF capacitors. In the discussion to follow, the "PLISN input impedance (PLISN Z_{in})" is the impedance relative to ground at each side of the PLISN female power receptacle to which the EUT power line plug is connected. That is the PLISN Z_{in} is the impedance to ground seen by each side of the EUT power line when looking into the LOAD side of the PLISN. For this condition to be obtained, both PLISN signal output ports associated with the high and low sides of the power line must always be terminated in a 50-ohm detection system or a 50-ohm resistive termination.

Above 180 kHz, the input impedance of this PLISN circuit complies with the TEMPEST PLISN Z_{in} specification. However, below 180 kHz there are deficiencies which can be best appreciated by referring to Figure 2. Here the calculated PLISN Z_{in} is plotted for the four plug-in coils over the 10 kHz to 1 MHz range. These curves provide a good indication of the actual PLISN Z_{in} values because the frequency range of interest is sufficiently low enough to permit all component parts of the PLISN to be treated as lumped elements, i.e., the stray capacitances and inductances can be ignored below 200 kHz because their effect on the PLISN Z_{in} is not significant. The **MIN** and **MAX** limits of the four curves indicate the range of impedance variation that occurs when the power source impedance is either zero or high. From these curves, it is obvious that below 65 kHz none of the plug-in coils provides the 50 ± 10 ohm PLISN Z_{in} required by the TEMPEST specifications.

Of less importance but still of interest is the need for signal level correction due to losses in the detection system coupling circuit. Figure 3 shows the CF needed for the PLISN circuit of Figure 1. The maximum CF at 6 kHz is 15 dB and if the EUT internal resistance is 50 ohms, the CF becomes smaller (9 dB at 6 kHz). The elimination of the need for this correction factor would be very desirable.

It appears obvious that a new low frequency PLISN design is needed to allow TEMPEST testing to be performed down to frequencies considerably lower than 150 kHz while providing each side of the EUT power line with a 50 ± 10 ohm impedance termination. Also, it would be very desirable for the new low frequency PLISN design to have a signal coupling loss of less than 1 dB at the starting test frequency so the CF may be omitted altogether. The upper frequency limit of the new PLISN need be no greater than 3 MHz because above this frequency the commercially available high frequency PLISN (using a 5 uH isolation inductor) may be used. The commercial PLISN circuit is specified in MIL-I-6181D, MIL-I-16910A, and ASA C63.4-1963. The circuit diagram of this PLISN is shown in Figure 4 and its input impedance is shown in Figure 5. The input impedance of this PLISN circuit was recently published and the published data[2] agrees with the Z_{in} curve shown in Figure 5. Although the PLISN Z_{in} is acceptable for TEMPEST testing above 2.4 MHz, the user should be aware that above 20 MHz, resonances in the isolation coil may cause the PLISN Z_{in} to fall outside the acceptable impedance range at certain frequencies. The deficiency of the high frequency PLISN is indicated in a plot of Z_{in} versus frequency up to 100 MHz which appeared in an article by R.B. Cowdell[3]. Since the most significant deficiencies of the presently used PLISN circuits occur in the low frequency range, the range above 3 MHz will not be considered in this article.

PLISN DESIGN PROPOSAL

PERFORMANCE SPECIFICATIONS: The PLISN design to be proposed is to have the following performance characteristics: (a) a termination of 50 ± 10 ohms impedance for each side of the EUT power line over the frequency range of 6 kHz to 3 MHz; (b) a sufficiently low value of loss in the signal coupling circuit when terminated in a 50-ohm detection system so no correction factor is required; (c) some degree of filtering of the EUT power source; and (d) a maximum line current capability of 10 amperes (a.c. or d.c.).

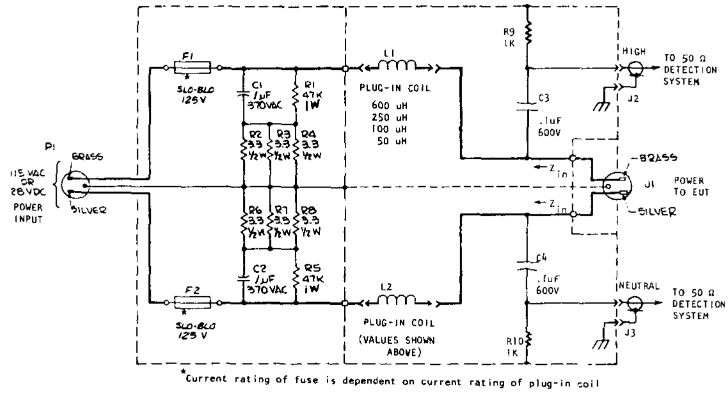


Figure 1. Schematic Diagram of Typical Low Frequency PLISN

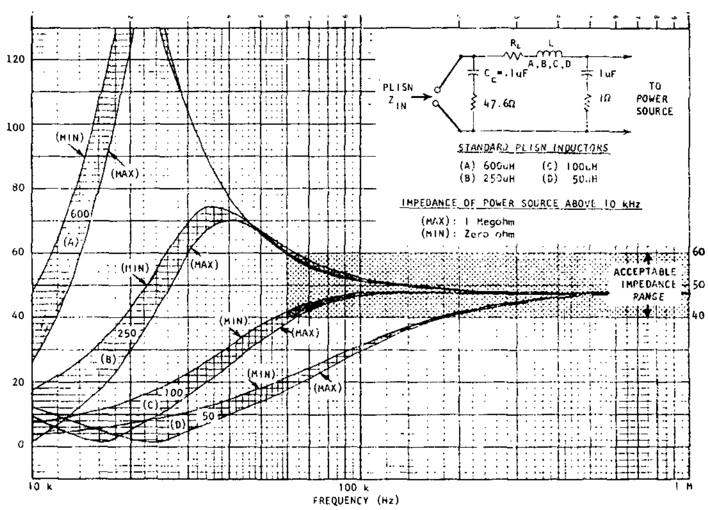


Figure 2. Calculated Input Impedance for Standard Low Frequency PLISN.

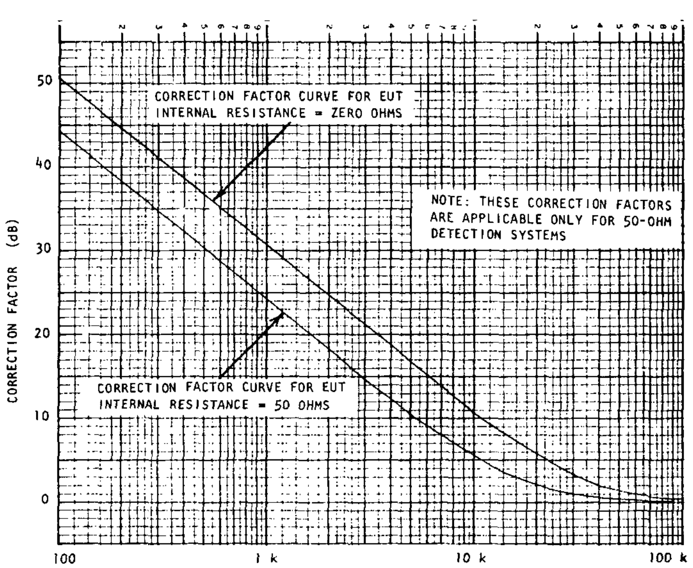


Figure 3. Correction Factors for Standard Low Frequency PLISN

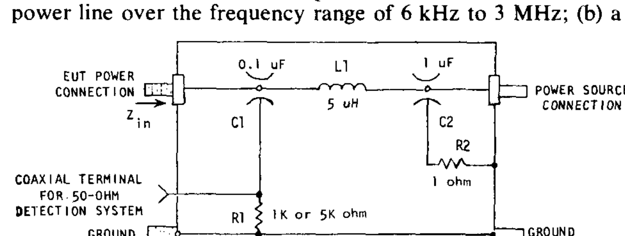


Figure 4. Schematic Diagram of Typical High Frequency PLISN

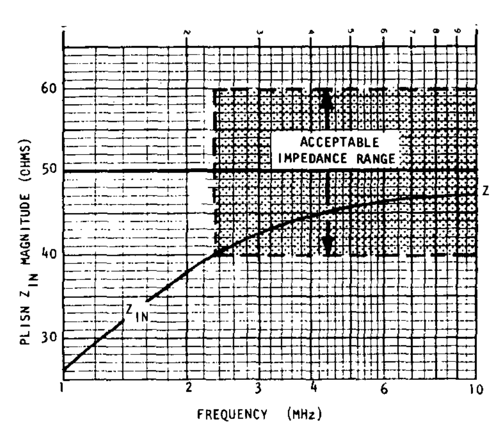


Figure 5. Input Impedance of Typical High Frequency PLISN

DESIGN PROCEDURE: All PLISNs consist basically of three elements: (1) a signal coupling circuit between the EUT and an output port which is either terminated with a 50-ohm detection system or with a 50-ohm load; (2) an isolation inductor having an impedance sufficient to isolate the EUT from the variable impedance of the power source; and (3) a large filter capacitor connected between the power input terminal and ground to attenuate spurious signals that might be present on the power input line (this capacitor also provides a near-ground reference impedance for one side of the isolation inductor). These three elements must be suitably combined to obtain the desired PLISN performance. The three elements of the PLISN design will be individually discussed in the following paragraphs.

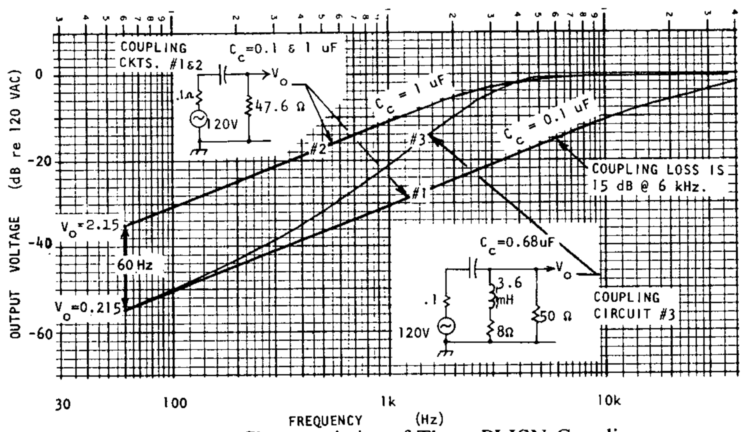


Figure 6. Response Characteristics of Three PLISN Coupling Networks

PLISN Coupling Circuit: The function of the coupling circuit is to couple any EUT-generated spurious signals above 6 kHz to the 50-ohm detection system while (in the case of an a.c. powered EUT) greatly attenuating the 60 Hz power line fundamental signal. Figure 6 shows the signal coupling loss associated with three PLISN coupling networks. Curve 1 shows the coupling loss of the standard low frequency PLISN ciruit (see Figure 1) in which the coupling capacitance is 0.1 μF. Response curve 1 is identical to the CF curve of Figure 3 for an EUT internal impedance of zero ohms. The high impedance of the 0.1 μF capacitor at 60 Hz adequately protects the detection system input from an excessive level of 60 Hz power line fundamental. In this case, the 60 Hz fundamental level is 55 dB below the 120V r.m.s. level and a 60 Hz voltage of 0.215V is present at the detection system input terminals. Although this is a satisfactorily low 60 Hz level, the coupling loss at 6 kHz is 15 dB which requires that a correction factor be applied to any signals detected up to 60 kHz. Above 60 kHz, the CF becomes less than 1 dB and it can be ignored. The need for the CF could be eliminated simply by increasing the coupling capacitor from 0.1 μF to 1 μF as shown by curve 2 in Figure 6. Here the signal coupling loss at 6 kHz is about one dB, and it becomes insignificant above 8 kHz. Unfortunately, the higher capacity also allows the 60 Hz fundamental level to be increased from 0.215V to as high as 2.15V at the receiver input terminals. This relatively high level may cause problems not previously experienced with the lower 60 Hz levels associated with the 0.1 μF coupling capacitor. Coupling circuit, associated with curve 3 in Figure 6, is proposed to provide satisfactory coupling above 6 kHz, and also to provide about as much attenuation to the 60 Hz power line fundamental and its harmonics as did the original PLISN coupling circuit. At 60 Hz, the attenuation of the proposed coupling circuit (circuit 3) is the same (55 dB) as the standard low frequency coupling circuit using the 0.1 μF capacitor. At 300 Hz (the fifth harmonic of the 60 Hz fundamental), the attenuation of the proposed coupling circuit is 3 dB less than that of the standard circuit. Thus, the attenuation of the proposed circuit to the a.c. power line fundamental and its harmonics is essentially the same as the standard low frequency coupling circuit. The superior performance of the proposed coupling circuit is due to the 0.68 μF coupling capacitor and the 3.6 mH inductor. The 0.68 μF capacitor reduces the coupling loss above 6 kHz to less than 1 dB while the 3.6 mH inductor attenuates signals below 3 kHz. The change in slope of curve 3 is due to the winding resistance of the 3.6 mH inductor which becomes significant for frequencies below 1 kHz.

The component values of the proposed coupling circuit (3) were approximated from a design based on a singly-loaded 2-pole Butterworth lossy-L highpass filter. Since the proposed coupling circuit meets both the low and high frequency coupling requirements, the remainder of this PLISN circuit will be selected to work with the coupling circuit.

PLISN Power Line Filter Capacitor: A power line filter capacitor is included in the PLISN to provide some degree of isolation between the power line ambient signals and the PLISN signal output port. The ambient signals must be sufficiently attenuated above 6 kHz so they will not mask the EUT-generated PLC signals that are being sought. However, for this filter capacitor to be effective in reducing the power line ambient levels, a series inductance of more than one milli-henry is required between each line of the a.c. mains and the APLISN power input receptacle. This inductor should be of the air-core type for minimum noise and can be part of the line filter normally included with each test room. Because of the relatively low starting test frequency, a larger filter capacitance than that previously used (see C1 and C2 in Figure 1) will be required. This capacitor has a current rating of ten amperes, a capacitance of 10 μF ± 10%, and a 50/60 Hz RMS voltage rating of 125 volts. This capacitor was developed for use in radio interference reduction in electronic equipment and has an attenuation performance closer to that of a theoretically ideal capacitor than that of any other capacitor ever made. The maximum shunt reactance (from line to ground) at 6 kHz is 3.0 ohms (at 9.0 μF) and this is adequate for this purpose. A value of 10 μF will therefore be used in determining the optimum value of the isolation inductor.

Isolation Inductor: The isolation inductance must be such to maintain a PLISN Z_{in} for the EUT at 50 ± 10 ohms from 6 kHz to preferably 3 MHz. The smallest acceptable value of inductance is desired to minimize the IR drop at high line currents and also to minimize the distributed capacity of the coil so as to maximize the upper frquency limit of the PLISN. Although an iron-core inductor has a much smaller resistance compared to an equivalent air-core coil, an air-core inductor must be used in this application because an iron core causes spurious ambient signals to be generated up to 150 kHz when 60 Hz line current passes through the coil. Several values of inductance were evaluated in combination with the 0.68 μF and 3.6 mH coupling circuit components and with the 10 μF power line filter capacitor (C_i) using a computer analysis of the circuit. The computer calculated PLISN Z_{in} versus frequency for isolation inductance values of 1.2, 1.4 and 1.6 mH is shown by the curves of Figure 7. In this figure, L_i represents the isolation inductance and C_i represents the 10 μF power line filter capacitor. The 120V a.c. power line input is connected at the junction of L_i and C_i. The signal coupling circuit and load are the same as shown in Circuit 3 of Figure 6. The shaded area in Figure 7 represents the acceptable range of PLISN input impedance. It is obvious that any L_i inductance value between about 1.1 and 2.0 mH is acceptable as all produce a PLISN input impedance within the acceptable range. The value of 1.4 mH was selected as the preferred value because with this value of L_i, a Z_{in} curve is obtained nearest to 50 ohms over the widest frequency range. Even if the inductance is reduced after installation in a metal shield case, the lower inductance value will still be sufficient to assure the PLISN input impedance does not fall below 40 ohms at 6 kHz. The desired inductance can be reduced by as much as 15% because of winding variations or shield coupling, and the isolation inductance will still be adequate. To assure that the 1.4 mH value will be satisfactory for all values of power line impedance, computer calculations were made for the power line short-circuited (C_i = infinite capacity) and open-circuited (C_i = 9 μF to simulate a 10% low capacitor). The results of these calculations are shown by the dashed curves in Figure 7. It is obvious that for any value of power line impedance the PLISN input impedance will remain within the acceptable range. For L_i = 1.4 mH and C_i = 10 μF, the Z_{in} phase angle at frequencies of 5 kHz, 7 kHz, 9 kHz, and 18 kHz is +39, 25, 19, and 10 degrees. As the frequency continues to increase, the phase angle continues to approach zero.

The signal coupling performance of the entire PLISN was again tested to establish that the addition of the 1.4 mH isolation inductor did not adversely affect the response characteristic as shown in curve 3, Figure 6. The signal loss above 6 kHz was claculated to be less than 1 dB for any EUT source impedance that will normally be encountered.

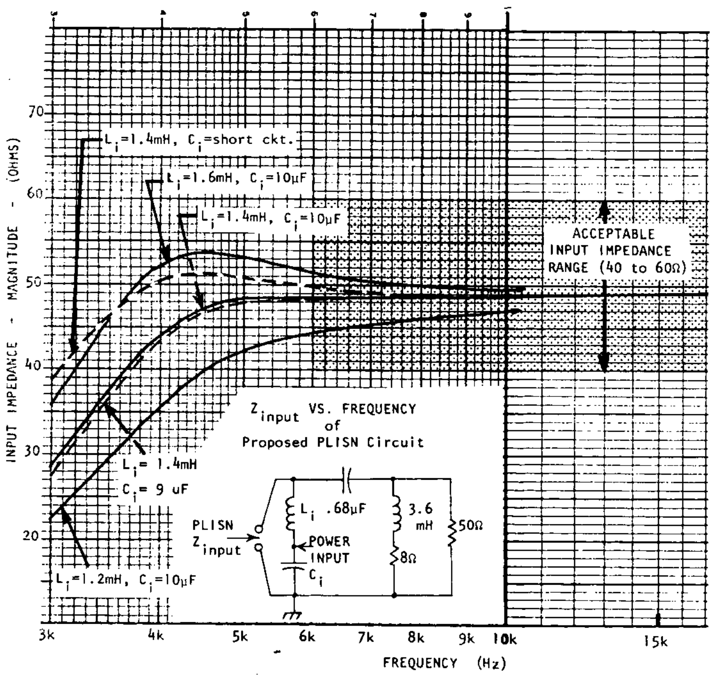
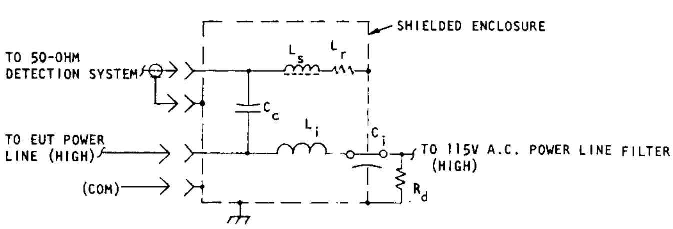


Figure 7. PLISN Input Impedance for Several Values of Isolation Inductance

PROPOSED NEW PLISN DESIGN: The various component values of the proposed PLISN circuit have been chosen and the final schematic diagram is shown in Figures 8 and 9. The circuit is expected to meet all the TEMPEST test specifications for a.c. and d.c. power line conduction testing from 3.7 kHz to about 3 MHz. The upper frequency limit wil depend on the isolation inductor distributed capacity and other stray capacities in parallel with the isolation inductor and the 50-ohm load. Above 3 MHz, the standard HIGH-FREQUENCY PLISN circuit (with the 5 μH isolation inductor) may be used; however, unless a coaxial-type connector is provided on the PLISN case for the EUT power lines, the maximum useable frequency may be limited to about 20 MHz because the r.f. discontinuity associated with the 3-prong parallel blade a.c. power connector will cause reflections which will affect the input impedance of the PLISN.



L_i Isolation inductor, 1.4 mH air-core coil (See Table 1 for details)

C_i Isolation capacitor, 10 uF ± 10%, 125V a.c., 60 Hz, 10A Bulkhead-mounted feedthrough, Sprague Catalog No. 629P10692T26

C_c Coupling capacitor, 0.68 uF ± 10%, 600V d.c., Mylar tubular

$L_{s,r}$ Toroidal inductor, 3.6 mH ± 5%, 8 ohm resistance, C_d = 17 pF Q > 20 from 10 kHz to 1.5 MHz, Torotel Part No. U73-27

R_d Resistor (Capacitor discharge), 47k, 1-W, 10%, composition

Figure 8. Simplified Schematic Diagram and Component Listing of Proposed PLISN

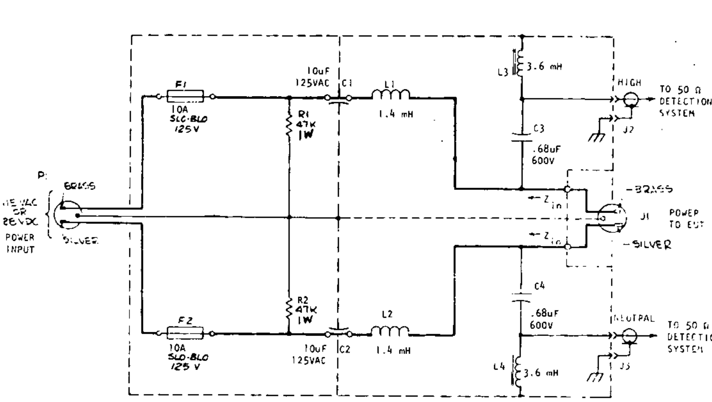


Figure 9. Schematic Diagram of Proposed Low Frequency PLISN

PLISN CONSTRUCTION

It is suggested that the circuit of Figure 9 be assembled in a steel box having a steel partition separating the two isolation coils. For minimum coupling between the coils, they should be mounted with their axes mutually perpendicular. The placement of the other components is not critical and may be arranged in any convenient manner. Except for the isolation coils, all components are commerically available as standard catalog items and there should be no difficulty in obtaining them. The metal case containing the PLISN may be assembled from two BUD steel 10 x 10 x 8 inch utility cabinets which are bolted together along their longest sides.

It is expected that the TEMPEST test engineer will find it more convenient to assemble the 1.4 mH inductor himself rather than have it manufactured by an outside source. Of primary importance is the minimizing of the coil resistance so as to minimize the IR drop and the temperature rise at high line currents. To achieve the coil characteristic where a minimum length of wire is required for a given inductance, a coil shape factor was used where the coil width and thickness were both equal to one-half of the coil inner diameter.[4] Three coil designs were calculated in accordance with this shape factor criteria using #10, 12, and 14 AWG polythermaleze high temperature wire. The coil parameters are given in Table 1. The user should select that particular design which meets his load current and regulation requirements.

Table 1. Recommended Dimensions for 1.4 mH Minimum Resistance Inductor

WIRE SIZE (AWG)	APPROX. WIDTH & THICKNESS (Inches)	COIL INNER DIA. (Inches)	NO. LAYERS	TURNS PER LAYER	TOTAL TURNS	WIRE LENGTH (Feet)	WEIGHT COPPER (LB)	COIL RESIS. (Ohm)	LOAD* CAP. (Amp)
10	1.25	2.50	11.8	11	130	130	4.13	0.13	11
12	1.10	2.20	11.67	12	140	125	2.49	0.20	7
14	0.875	1.75	13.0	12	156	110	1.38	0.28	5

*Approximate line current for a 2.5% IR drop (relative to 120V) for two coils.

SUMMARY

The important TEMPEST specification related to power line conduction testing has been noted and the deficiencies of presently used PLISNs have been discussed. A new PLISN design has been proposed and its advantages explained. Brief directions were given for the construction of the proposed PLISN and its isolation coil.

It is hoped this information will be useful to those involved in TEMPEST test work. Any comments, suggestions, or criticisms will be appreciated, and should be directed to the author, E.E. Wetherhold, HONEYWELL INC., Aerospace Division, POB 391, Annapolis, Maryland 21404.

REFERENCES

[1] J.R. Nicholson and J.A. Malack, "RF impedance of power lines and line impedance stabilization networks in conducted interference measurements," IEEE Transactions on Electromagnetic Compatibility, vol. EMC-15, pp. 84-86, May 1973.

[2] J.A. Malack, "Power line conducted interference measurement differences using U.S. and CISPR line impedance stabilization networks," IEEE Transactions on Electromagnetic Compatibility, vol. EMC-17, No. 2, May 1975.

[3] R.B. Cowdell, "The evoluation of conducted interference measurements," FREQUENCY TECHNOLOGY, July 1970.

[4] E.S. Purington, "Simplified inductance chart for multilayer coils," ELECTRONICS FOR ENGINEERS, edited by Markus & Zeluff, McGraw-Hill, 1945.

RFI/TEMPEST ISOLATION

The need for an isolation device arises from the requirement to remove from a communications signal all other signals, both transverse (across pair) and longitudinal (between the pair and ground) (common-mode), which should not pass between the signal source and its load or pass beyond a specified point in the signal route. This general requirement would be typical of radio frequency interference (RFI) and TEMPEST problems.

Since the unwanted signals and noise may fall within the band-pass of the desired signal, it is not desirable to employ passive filters. The patented technique employed by Versitron, Inc. consists of interposing an isolation device in the signal line to propagate the signal by optical means, thus breaking the electrical conductor path. Almost complete isolation against longitudinal (common-mode) unwanted signal coupling is obtained.

Each isolation unit is housed in two separate modules marked "Input" and "Output". A non-metallic light guide is then placed between the two modules, thus propagating signals without a metallic path. Circuit techniques are employed for digital units in order to suppress transverse noise levels. In addition, time regeneration is available on digital units, while the bandwidth can be restricted as required in analog units. Therefore, with proper installation and choice of model, the isolation device becomes a unidirectional signal repeater covering practically all communications frequencies and isolation requirements.

Common-Mode Isolation:

Common-mode signal isolation, for the purposes of the isolation devices discussed here, is defined as the signal attenuation between the shorted input and the shorted output of an isolation device when the generating source is between the shorted input and a ground reference, and the detecting instrument is between the shorted output and the same ground reference. (See figure 1).

Isolation devices accomplish this common-mode isolation by the use of seperate input and output module chassis. The input module converts the input electrical signal to a modulated light beam and the output module converts the light signal to an output electrical signal. Therefore, no electrical conductor exists by which to conduct the undesired common-mode signal. To complete the isolator installation, a grounded shield most be interposed between the input and output modules in order to eliminate space radiated coupling. This ground plane is normally a chassis wall or shielded room wall. The light beam is passed through the ground plane by means of a waveguide penetration. The dimensions of the waveguide are chosen so that its cut-off frequency is above the highest frequency of interest. This waveguide penetration must be chosen with two factors in mind. First, the wavelength of the highest frequency of interest must be large compared to the diameter of the waveguide. Second, the ratio of the length of the waveguide to the diameter determines the amount of attenuation below the cut-off frequency.

A formula containing these factors but excluding the low frequency "H" wave would take the following form:

$$A = 32 \frac{L}{d} \left[1 - \frac{f^2}{f_c^2}\right]^{1/2}$$

Where:
- A — Attenuation (dB) of waveguide
- L — Length of waveguide in meters
- d — Diameter of waveguide in meters
- f_c — $\frac{3 \times 10^8}{2d}$ (cut-off frequency)
- f — Any frequency below f_c for which A is computed

The above formula assumes worst-case criteria such as: Diameter = ½ cut-off wavelength: dielectric constant = 1.

For frequencies significantly below cut-off, A = 32 L/D.

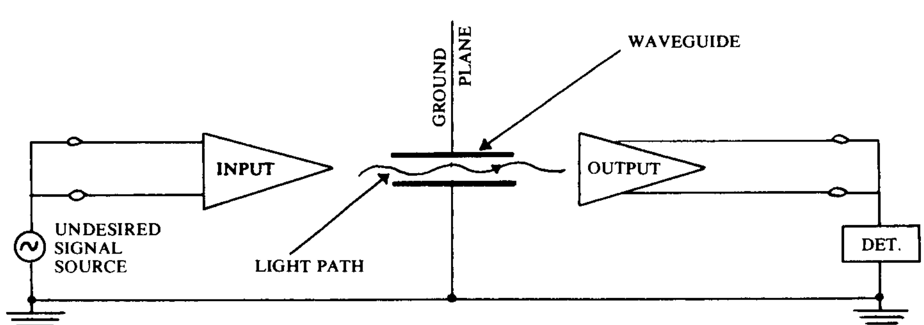
In view of the above and the fact that the light guide is a non-conductor, it is obvious that the common-mode isolation is independent of the electronic circuitry of the isolator. This, assumes, of course, that the power sources for the isolator modules are properly isolated or filtered. Photon couplers that do not use the above technique do not provide the highest degree of EMI or TEMPEST protection. They provide only DC and low-frequency isolation.

Transverse-Mode Isolation:

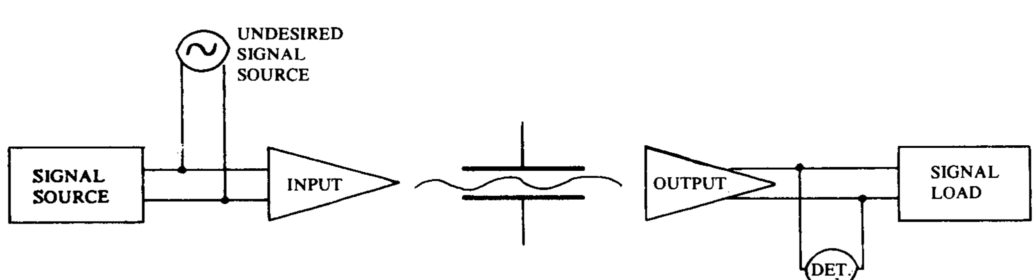
Since the common-mode rejection (balance) of practical circuits and wiring are never perfect and since cross-talk is a danger in multicircuit situations, it is often necessary to provide suppression of unwanted signals and noise in the transverse-mode. This mode is defined as the signal across the input or output terminals of the isolator, minus the desired signal. In the case of digital isolators, the input module light source circuitry is electrically saturated in the ON or OFF state and therefore, does not respond to superimposed undesired signals as long as the total instantaneous value does not exceed the threshold point for the opposite transition. (See figure 2).

Where the undesired signal takes the form of phase or frequency modulation, time regeneration of the desired signal is used.

This article was written by David C. Sherrick, Vice President, Versitron, Inc., Washington, D.C.



COMMON MODE Figure 1



TRANSVERSE MODE Figure 2