A Selective Bibliography for Electromagnetic Compatibility in Audio Systems

The publications listed below are recommended by the AES Technical Committee on EMC as representative of good practice and current knowledge.

AES PUBLICATIONS

AES STANDARDS

AES48-2005: AES standard on interconnections — Grounding and EMC practices — Shields of connectors in audio equipment containing active circuitry

This standard specifies requirements for the termination, within audio equipment, of the shields of cables supporting interconnections with other equipment, taking into account measures commonly necessary for the preservation of EMC (electromagnetic compatibility) at both audio and radio frequencies. The shielding (or screening) of audio equipment, cables, and microphones can be critical for EMC.

The improper connection of these shields can cause common-impedance coupling in equipment. From XL connector usage, where Pin 1 is standardized as the designated shield contact, this has been identified as the “Pin 1 problem.” [http://www.aes.org/publications/standards/]

ARTICLES PUBLISHED IN THE JOURNAL OF THE AES (JAES) are available from the Publications section of the AES website. JAES is also archived by most technical libraries. Vol 43, Number 6 of the Journal (June 1995) was dedicated entirely to EMC, and can be purchased from the AES at a nominal cost.

Noise Susceptibility in Analog and Digital Signal Processing Systems

A demonstrable cause-and-effect relationship between a popular and widely employed equipment design practice and electrical noise problems in audio systems of all kinds is examined. A means of identifying equipment that may exhibit noise problems due to this design practice is outlined. The relationship between the physical construction of shielded twisted-pair cable and induced noise in a signal circuit due to cable shield current is explored. Established “rules” for equipment installation are reexamined. It is shown that noise problems due to this design practice could be eliminated at the manufacturing level at almost negligible net cost. JAES Vol 43, No. 6, 1995 June Author: Neil Muncy

Balanced Lines in Audio Systems: Fact, Fiction, and Transformers

The theoretical benefits of balanced audio interconnection schemes are discussed as well as fundamental but widely unrecognized mechanisms that limit real-world performance. The venerable audio transformer enjoys several inherent advantages over the so-called active circuits offered to replace it in audio equipment. Today, as improved digital recording systems demand increased system dynamic range, these advantages are becoming ever more important. JAES Vol 43, No. 6, 1995 June Author: Bill Whitlock

Grounding Systems and Their Implementation

The isolated star ground system is the most popular implementation of technical grounding for the purposes of grounding sensitive equipment. This approach has been in practice for many years, and while it is not a perfect solution, it is the solution that presents the least compromises. The current approach as implemented in a number of large installations is described as part of an ongoing AES effort to document appropriate practices with regard to the control of noise in audio systems. JAES Vol 43, No. 6, 1995 June Authors: Philip Giddings and Charles Atkinson
Considerations in Grounding and Shielding Audio Devices

Many audio manufacturers, consciously or unconsciously, connect balanced shields to audio signal ground. This is the source of many audio interconnection hum and buzz problems. The options available to manufacturers who follow this improper practice are discussed. Both balanced and unbalanced schemes and their incompatibilities are covered. Many manufacturers may already follow proper interconnecting practices. Those who are not have many options, including doing nothing. JAES Vol 43, No. 6, 1995 June Author: Stephen R. Macatee

An Easily Implemented Procedure for Identifying Potential Electromagnetic Compatibility Problems in New Equipment and Existing Systems: The Hummer Test

A test procedure is outlined which can be used to identify quickly audio equipment that may be susceptible to hum, buzz, or radio frequency interference. The procedure is simple and straightforward. The equipment does not require removal from an installed system. The construction of the test equipment, which can be built easily using available parts, is described. JAES Vol 43, No. 6, 1995 June Author: John Windt

Automated Test and Measurement of Common Impedance Coupling in Audio System Shield Terminations

The 'pin 1 problem” identified by Muncy has been with us since the shift to the design of cost-effective audio processing equipment on printed circuit boards. This design and manufacturing methodology and technology, however, also is the root cause of more than one type of system interference problems, including common impedance coupling and susceptibility to radio frequency interference. Various test and measurement techniques are presented using the automated test features of the Audio Precision System One for both engineering design and the verification of the manufacturing integrity. High-speed automated testing necessary to ensure a high level of product quality on the manufacturing floor is also described. JAES Vol 43, No. 6, 1995 June Author: Cal Perkins

Fundamentals of Grounding, Shielding, and Interconnection

The ultimate performance of modern audio systems may be significantly constrained by signal contamination introduced by inappropriate grounding and interconnection practices. Fundamental principles of electromagnetism and linear circuits are reviewed. From this, a body of good engineering practice for grounding, shielding, and interconnection methods is developed. A logical, consistent grounding scheme is presented which strictly conforms to the requirements of the National Electrical Code, a model safety code widely adopted in jurisdictions in North America. Conventional grounded neutral conductors mains power distribution is used, which may be single phase, polyphase, or multiple derived polyphase systems without constraint. The fundamental principles may be applied to mains power distribution systems conforming to other internationally established safety standards. JAES Vol 43, No. 6, 1995 June Author: Kenneth R. Fause

CONVENTION PREPRINTS are available from the Publications section of the AES website. In some cases, unofficial versions of these papers may be downloaded from the author’s website.

New Understandings of the Use of Ferrites in the Prevention and Suppression of RF Interference to Audio Systems

Building on the work of Muncy, the author has shown that radio-frequency current on cable shields is often coupled to audio systems by two mechanisms - "the pin 1 problem" and shield-current-induced noise (SCIN). An improved equivalent circuit for a ferrite choke is developed that addresses both dimensional resonance within ferrites and the self resonance of inductors formed using those materials, then compared with measured data. Field tests show that chokes formed by passing signal cables through ferrite cores can significantly reduce current-coupled interference over the range of 500 kHz to 1,000 MHz. Guidelines are
presented for diagnosing the causes of EMI from sources as diverse as AM broadcast transmitters and cell phones. Solutions are presented for use in new products and for RFI suppression in field installations. Preprint Number: 6564 Convention: 119 (October 2005) Author: Jim Brown

**A Better Approach to Passive Microphone Splitting** While there are clear technical advantages to active microphone splitting, operational considerations dictate the use of passive splitting of microphones in most sound reinforcement applications. Modern microphones generally require a load impedance greater than 1,000 ohms, and performance often degrades significantly with heavier loading. Since mix desk input impedances rarely exceed 1,500 ohms, passive splitting utilizing 1:1 turns ratio transformers can seriously degrade microphone performance when driving two or more mix desks. Transformers designed to operate in stepdown mode solve this problem and offer other benefits. This paper reviews current practice, studies stepdown-mode splitting, and recommends that mix desks be designed with higher input impedances and that microphones be designed to work with lower impedance loads. Preprint Number: 6338 Convention: 118 (May 2005) Authors: Jim Brown, Bill Whitlock

**Radio Frequency Susceptibility of Capacitor Microphones** Neil Muncy has shown that improper termination of shield wiring, commonly called the pin 1 problem, couples noise currents flowing on a cable shield into audio circuitry through common impedance coupling. This paper examines the susceptibility of modern microphones, describes a simple test to find problems, and offers simple solutions. Preprint Number: 5720 Convention: 114 (February 2003) Authors: Jim Brown, David Josephson

**Common-Mode to Differential-Mode Conversion in Shielded Twisted-pair Cables (Shield-Current-Induced Noise)** Neil Muncy has shown that audio frequency current flowing on the shield of balanced audio wiring will be converted to differential mode voltage by any imbalance in the transfer impedance of cables, and hypothesized that the effect increases linearly with frequency. Whitlock has shown that conversion also occurs with capacitive imbalance. This paper confirms Muncy's hypothesis, and shows that shield current induced noise can be significant in the MHz range. Preprint Number: 5747 Convention: 114 (February 2003) Authors: Jim Brown, Bill Whitlock

**Testing for Radio-Frequency Common Impedance Coupling (the "Pin 1 Problem") in Microphones and Other Audio Equipment** The author has shown that a primary cause of VHF and UHF interference to professional condenser microphones is inadequate termination within the microphone of the shield of the microphone's output wiring, a fault commonly known as the pin 1 problem. Tests using only audio frequency test signals generally fail to expose susceptibility to radio frequency (RF) interference. Simple RF tests for pin 1 problems in microphones and other audio equipment are described that correlate well with EMI observed in the field. Preprint Number: 5897 Convention: 115 (September 2003) Author: Jim Brown

**A Novel Method of Testing for Susceptibility of Audio Equipment to Interference from Medium and High Frequency Radio Transmitters** The author has shown that radio frequency (RF) current flowing on the shield of balanced audio wiring will be converted to a differential signal on the balanced pair by a cable-related mechanism commonly known as Shield-Current-Induced Noise. This paper investigates the susceptibility of audio input and output circuits to differential signals in the 200 kHz - 2 MHz range, with some work extending to 300 MHz. Simple laboratory test methods are described, equipment is tested, and results are presented. Laboratory data are correlated with EMI observed in the field. Preprint Number: 5898 Convention: 115 (September 2003) Author: Jim Brown
A New Balanced Audio Input Circuit for Maximum Common-Mode Rejection in Real-World Environments

A new patented balanced input circuit emulates the extremely high common-mode input impedances which give a quality audio transformer its hum and buzz rejecting advantage in real-world audio systems, where driving source impedances are rarely perfectly balanced. Compared to traditional “active-balanced” circuits, the new circuit can produce CMRR improvements up to 80 dB but is only slightly more complex and requires no additional closely matched components. Preprint Number: 3917 Convention: 101 (October 1963)  Author: Bill Whitlock

New Balanced Input Integrated Circuit Achieves Very High Dynamic Range in Real-World Systems

Limited Common-Mode Rejection Ratio (CMRR) in balanced interfaces often limits dynamic range in real-world audio systems. Conventional differential amplifier input circuits suffer serious CMRR degradation when driven by real system signal sources instead of laboratory generators. An ideal audio transformer, because of its extremely high common-mode impedances, is virtually immune to this degradation. A new Integrated Circuit (IC) is described that uses a patented topology to achieve common-mode impedances comparable to those of an ideal transformer. As a result, the IC enables signals with very high dynamic range to be transported without contamination by system ground voltage differences or other sources of common-mode interference. Other features of the IC, relating to audio signal quality and reliability, are also detailed. Preprint Number 6261 Convention:117 (October 2004)  Authors:  Bill Whitlock, Fred Floru

Other Publications


Audio System Design and Installation  Focal Press, 1990  Author: Phil Giddings  This book is out of print

Power and Grounding For Audio and Audio/Video Systems -- A White Paper for the Real World  This applications note describes the architecture of power systems both inside and outside of buildings, addresses the power requirements of audio systems, grounding for safety, including lightning protection, grounding for compliance with North American building codes, grounding practices to minimize noise in audio systems (technical grounding), surge suppression, troubleshooting methods, and other installation-related issues.  The Audio Systems Group, Inc.  2006  Author: Jim Brown

Answers to Common Questions About Audio Transformers  Jensen Applications Note AN-002  Author:  Bill Whitlock
