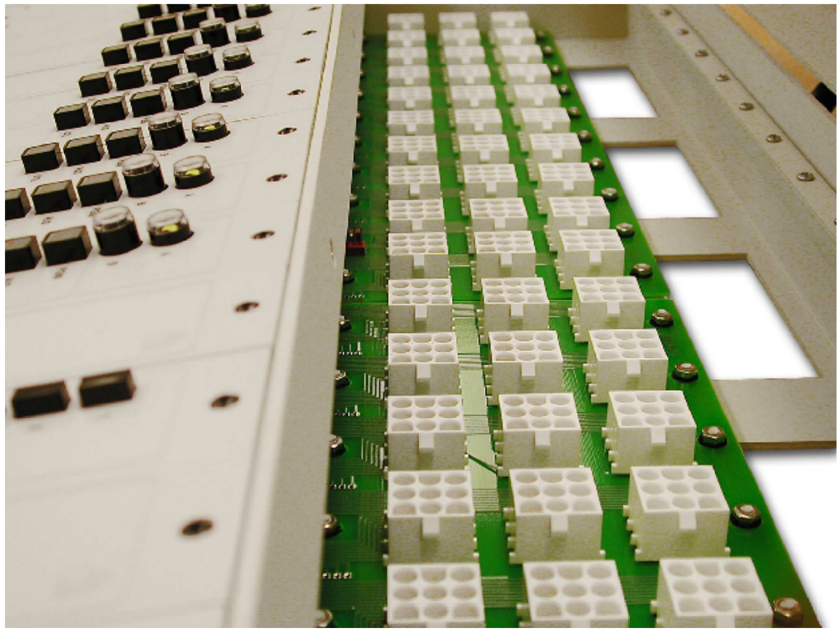
Audio Testing

Arrakis Systems inc.

application note



Purpose of this Ap Note

This application note is designed as a practical aid for designing, installing, and debugging low noise, high performance audio broadcast studios and facilities. It is intended for use by novice and experienced “technical” people alike, including managers.

The application note focuses on the basic principles of audio “systems” design. Simple mathematical models are used only as they illustrate a principle. We find that it is the proper understanding and application of basic principles that results in a professional audio installation. It is often only through an application of basic principles that a problematic installation can be corrected.

In preparation for writing this application note, we have performed an extensive review of available technical literature and product manuals on these subjects. The review underlined the complexity of modern audio systems design and that this is a field under constant change. Combining audio products from the broadcast, consumer, music, commercial sound, and now personal computer industries into a single facility is a challenge. These different industries have different product design goals that have resulted in an inability to simply “plug and play.” It would be thought that it would be possible to simply purchase equipment and off the shelf interconnection cables to assemble an audio facility. However, variations in audio levels, impedance, connector designs, AC and audio ground systems, and other factors make this difficult. The purpose of this application note is to help to provide enough of an understanding of the underlying principles to be able to overcome these obstacles.

Arrakis Systems has been building professional radio consoles since the late 1970‘s and digital audio source equipment since the early 1990’s. We are a leading manufacturer and innovator in the professional broadcast audio industry. We have accumulated experience with thousands of studios in diverse conditions around the world.

I- Important Information

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Important Disclaimer

Use of the information in this document is entirely at the reader's risk. Although precaution has been taken in the preparation of this document, Arrakis Systems inc. assumes no responsibility for errors or omissions. Neither is any liability assumed for damages resulting from the use of the information contained herein.

Danger- Shock & other hazards

Electronic products may contain potentially lethal voltages and currents and should be serviced by trained and experienced personnel only. Any installation, test, or calibration procedures in this document that require access to the interior of the equipment should be performed by qualified personnel only.

How to Contact Arrakis

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Having difficulty contacting Arrakis? Refer to the website (www.arrakis-systems.com) for current contact information

AUDIO TESTING

17.0 Introduction

a) PURPOSE OF THIS SECTION
The Specifications and Testing section of this manual is designed to provide a general description of the basic audio tests and procedures used to characterize an audio product. Information is also provided regarding variations in test data caused by differences in equipment and procedures.

b) TYPES OF TESTS
The performance tests described in this section are:

1) Frequency Response
2) Signal to Noise Ratio (Dynamic Range) (EIN)
3) Total Harmonic Distortion
4) Crosstalk (Stereo Separation)

While there are a great many other audio tests that can be performed on an audio product (such as Intermodulation distortion (IMD), Transient IMD, phase shift versus frequency, slew rate, common mode rejection (CMRR), to name just a few), the four key tests listed above remain the standard test suite for characterizing audio products.

c) TESTING DIGITAL INPUTS AND OUTPUTS
While it is possible to directly test an audio signal in the digital domain, such test equipment is not available for most field measurements. Also, the results of tests performed strictly in the digital domain are even less well understood and controversial than analog audio performance tests. Arrakis therefore recommends the use of high quality, external A/D and D/A converters and that the tests be performed with analog audio test equipment.

d) SCOPE OF THE TESTS
Many types of test equipment, test setups, test conditions, and test methods exist in our industry. It is impossible to provide information on all of the various combinations used in the real world. For this reason, all specifications listed in this manual, or in any other published literature on Arrakis products, are general. Specifications are subject to change without notice and may differ between this manual and other literature.

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17.1 Frequency Response

a) DEFINITION-The test measures audio bandwidth by measuring variations in the output level as a function of frequency. In consumer products, this test is typically from 20Hz to 20kHz. In broadcast products, this test is typically from 50 Hz to 15kHz. Generally the frequency response is referenced to an arbitrary level (0dB). Any variation from this 0dB reference is specified as plus and or minus dB over the measured bandwidth.

A frequency response measurement that is typically considered as professional quality is:
+(-) 0.5dB from 20Hz to 20kHz

b) EQUIPMENT- (1) Audio Signal Generator and (2) AC Audio Voltmeter
Many ac voltmeters measure in absolute and relative dB which simplifies this test

c) TEST PROCEDURE- The test is performed with an audio signal generator and a voltage measurement device such as an AC voltmeter or an oscilloscope. The signal generator is connected to a console input (balanced or unbalanced). The voltmeter is connected to the console output (balanced or unbalanced). The output level of the signal generator is set to a nominal output level (defined as 0dB). This level should be at approximately the normal input level for that type of input channel (Line level = +4dBu, Mic level = -50dBu). If the level were too low or too high, the test results could be inaccurate due to noise (too low) or due to saturation of an audio stage (too high). The frequency of the signal generator is varied over the audio frequency band of interest (20Hz-20kHz or 50Hz-15kHz) and any variation in output level is recorded.

d) TEST RESULTS- If you do not have a voltmeter that measures in dB, then you must calculate dB using the following formula.

$$dB = 20[\log(V1/V2)]$$

V2 is the 0dB reference voltage (usually at 1kHz)
V1 is the test voltage.

e) CAUTIONS- Many voltmeters are optimized for AC line measurements at 50-60 Hz and will not measure AC voltages accurately over the audio spectrum.

AUDIO TESTING

17.2 Signal to Noise Ratio (SNR), Dynamic Range, & EIN

a) DEFINITION-The purpose of this test is to measure the noise floor of the product and compare it to the nominal operating signal level (0dBr) of the product. If you test for the Headroom (dB to clipping above 0dBr) you can calculate the dynamic range. EIN is often used instead of SNR for a mic input They are defined below:

SNR =	Nominal Output level (dB) / Noise (dB),	
Dynamic Range =	Headroom(dB) + SNR(dB)	*Maximum signal swing in dB*
EIN=	Mic input level (dBu) - SNR(db),	*Mic test only, Equivalent Input Noise (EIN)*

b) EQUIPMENT- (1) Audio Signal Generator and (2) AC Audio Millivoltmeter.
Many AC millivoltmeters measure in absolute and relative dB which simplifies this test

c) TEST PROCEDURE-The signal generator is connected to an audio input. The signal generator is set to a defined level appropriate for the type and impedance of the input (mic or line level) so as to generate a normal operating level at the tested output. The AC millivoltmeter is connected to the audio output to be tested. The output level is recorded as the “Signal” portion of the test. The input signal is then removed and the “Noise” portion of the test is measured on the AC millivoltmeter. The ratio between the Signal and the Noise is the signal to noise ratio (SNR).

d) TEST RESULTS- If you do not have an AC audio millivoltmeter that measures in dB, then you must calculate SNR using the following formula.
SNR = 20[log(Vsignal/Vnoise)]

Vsignal is the nominal output level of the audio device (usually at 1kHz)
Vnoise is the residual signal left when the signal generator input s removed

e) CAUTIONS-
1) The Noise measurement is a function of the bandwidth and filter profile of the AC audio millivoltmeter.
2) Broadband noise measurements (> 30kHz) are NOT accurate for many audio measurements.
3) SNR tests with a 20kHz filter measure approximately 1.8dB better than with a 30kHz filter.
4) The Noise measurement is very sensitive to 60 cycle hum introduced by the test site and test setup.
5) Peak reading meters read 1.1dB higher that an RMS reading meter.

f) INPUT CONNECTION- If the signal generator is unbalanced, then connect the (+) input to ground and apply the signal to the (-) input. If signal is applied to the (+) input and the (-) input is grounded, then an active balanced amp will exhibit 6dB lower gain and the test will be inaccurate. If you have a balanced signal generator, then simply connect the signal generator to the (+) and (-) inputs and do not ground an input.

g) TESTING MIC INPUTS- Most microphones are low impedance (~150 ohms) and may require that the input impedance of the mic input channel match the mic impedance for optimal operation. Most modern mic preamps are high impedance and require a matching resistor (~150 ohms) to be placed across the mic input to match the mic. This should be a low noise resistor (1% metal film) connected across the (+) and (-) mic input. In testing mic inputs, -50dBu (2.4mVRMS) is the typical input signal level. Because many signal generators are calibrated in dBm (600 ohm impedance), -50dBm is NOT -50dBu at 150 ohms. You must use a millivoltmeter to measure the signal level at the mic input to confirm a -50dBu input signal. Adjust faders to in hand setting and mic trim levels so that +8dBu (1.95VRMS) is measured at the output. +8dBu is the traditional nominal broadcast output level (not +4dBu). To measure the residual noise level, remove the signal generator input but keep the 150 ohm resistor in place. The AC audio millivoltmeter will measure the total residual noise in the system.

h) TESTING LINE INPUTS- Apply +8dBu (1.95VRMS) to the line input. Adjust faders to in hand settings and calibration trimpots so that +8dBu (1.95VRMS) is measured at the tested output. No load is necessary on the output. An input terminating resistor is not necessary. Remove the input signal. The level that you read at the output is the noise.

AUDIO TESTING

17.3 Total Harmonic Distortion + Noise (THD+N)

a) DEFINITION-The purpose of this test is to measure the linearity of the audio product. Any nonlinearity in an audio product will add audio artifacts to the original signal as it passes through the product. These artifacts appear as multiples (harmonics) of the frequency of the original signal. The test is performed by applying a pure sinusoidal tone to the input and measuring the total sum of any extra artifacts (harmonics) at the output. The measurement is then defined as the total of the artifacts as a percent of the original signal.

The nature of this distortion test is that the measurement device at the output will measure any noise in the system as well as the harmonics. This is why the name of this test includes the noise parameter (THD+N).

It is generally accepted that less than 0.1% THD is inaudible because the harmonics are more than 60dB below the signal. (Note- that this is THD without noise)

b) EQUIPMENT- (1) Low Distortion Audio Signal Generator
(2) Audio Distortion Analyzer (or Spectrum Analyzer)
(refer to the Spectrum Analyzer's manual for specifics of that test procedure)

c) TEST PROCEDURE-The signal generator is connected to an audio input. The signal generator is set to a defined level appropriate for the type and impedance of the input (mic or line level) so as to generate a test level at the tested output. The Distortion Analyzer is connected to the audio output to be tested. The test is repeated as various audio frequencies and levels.

d TEST RESULTS- The distortion analyzer will read the THD in percent (%).

THD+N = Sum of the Harmonics at the output / Input Signal (%)

Note- an Audio Spectrum Analyzer can perform a THD test without Noise

e) CAUTIONS-
1) Because this test measures harmonics (multiples of the original signal frequency), this test is a function of the bandwidth and filter profile of the Distortion Analyzer.

2) Because this test measures harmonics (multiples of the original signal frequency), measured results are a function of the test frequency. If the test frequency is 1kHz and the bandwidth of the Distortion Analyzer is 20kHz, the test will measure harmonics between 2kHz and 20kHz, which will be reasonably accurate. If the test frequency is 15kHz and the bandwidth of the Distortion Analyzer is 20kHz, the test can not measure the harmonics because they start at 30kHz, which is above the filter frequency of the Distortion Analyzer. Depending on your personal opinion, a THD+N test may not be important above 10kHz because the harmonics are beyond the range of human hearing.

3) The THD+N measurement is limited by the noise in the system. If the system has a 60dB signal to noise ratio (noise is 1/1000 of the signal, then any THD+N test is limited to 0.1% even if there is zero actual distortion. If the system has an 80dB signal to noise ratio (noise is 1/10,000 of the signal, then any THD+N test is limited to 0.01% even if there is zero actual distortion.

4) Because this test is limited by the noise in the system, THD+N varies dramatically as a function of signal level. At low signal levels, the noise in the system dominates the measurement. For this reason, tests are typically performed near the maximum output of the audio system.

5) Because this test includes noise (THD+N), this test is strongly effected by stray 60 cycle hum, grounding, site specific conditions, test setup, and equipment.

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17.4 Crosstalk (& Stereo Separation)

a) DEFINITION-The purpose of this test is to measure the interaction (crosstalk) between various circuits in the audio product.

It is desired that crosstalk be inaudible so that audio in one circuit is not audible in another circuit. This requires that the crosstalk measurement be below your noise level or that the crosstalk be inaudible at the measured frequency.

A crosstalk of -80dB at 1kHz is generally accepted as inaudible because this is roughly the noise floor for 16 bit CD quality audio.

b) EQUIPMENT- (1) Audio Signal Generator and (2) AC Audio Millivoltmeter.
Many AC millivoltmeters measure in absolute and relative dB which simplifies this test

c) TEST PROCEDURE-The signal generator is connected to an audio input. The signal generator is set to a defined level appropriate for the type and impedance of the input (mic or line level) so as to generate a normal operating level at the tested output. The AC millivoltmeter is connected to the audio output to be tested. The output level is recorded as the reference level for the test (0dB). The AC millivoltmeter is then moved to the output circuit that is to be tested for crosstalk. The measured level is the crosstalk from the original circuit. It is expressed in dB below the reference level. An example would be -70dB below +8in

d) TEST RESULTS- If you do not have an AC audio millivoltmeter that measures in dB, then you must calculate crosstalk using the following formula.

Crosstalk = 20[log(Vcrosstalk/Vreference)]

Vcrosstalk is the output level of the test circuit that is being coupled from the main circuit
Vreference is the reference output level of the main circuit

e) TYPES OF CROSSTALK
There are two basic types of crosstalk: capacitive, ground coupled.

f) CAPACITIVE CROSSTALK- This crosstalk is created by capacitive coupling between circuits. This can be radiated by components or caused by power supply coupling. This type of crosstalk increases at 20dB per 10 times increase in frequency. As an example, if crosstalk was -70dB at 1kHz, it would be -50dB at 10kHz.

g) GROUND COUPLED CROSSTALK- This crosstalk is created by signal currents in the audio ground. In this way, one circuit can induce a signal into another circuit through the common ground. This type of crosstalk is independent of frequency and has a strong low frequency component.

h) CAUTIONS
1) Because crosstalk is by definition an interaction between one circuit and another, it can not be easily distinguished from crosstalk created by your test setup.
2) Crosstalk is level dependent because it is masked by the noise floor of your system. Crosstalk tests are usually conducted a few dB below maximum output of your audio product.
3) Most crosstalk in audio products is capacitive and therefore increases with frequency. A crosstalk measurement that is independent of frequency is an indicator that the crosstalk may be induced by your test setup.

AUDIO TESTING

17.5 Miscellaneous

a) TESTING DIGITAL INPUTS AND OUTPUTS

While it is possible to directly test an audio signal in the digital domain, such test equipment is not available for most field measurements. Also, the results of tests performed strictly in the digital domain are even less well understood and controversial than analog audio performance tests. Arrakis therefore recommends the use of high quality, external A/D and D/A converters and that the tests be performed with analog audio test equipment.