CJS Labs

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Lab Notes

Volume 1, Issue 1 **February 2008**

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ALMA Seminar Success

Just a note to let you know the reviews of the CJS Labs Electroacoustics training class at the ALMA Symposium in January were very positive, indeed:

http://www.almainternational.org/2008_symposium_training_post-show.php

Look for our 2 page ad for seminars in the April g.r.a.s. newsletter.

Future Seminars

We will be giving a two-part Tutorial session on Electroacoustics at the AES in Amsterdam

http://www.aes.org/events/124/

We will also be at the AES in San Francisco in October http://www.aes.org/events/125/

We are also planning a 2-day seminar in conjunction with Klippel http://www.klippel.de/ in Los Angeles 8-9 October 2008. Details will appear on our website in the upcoming weeks.

Standards Work

We continue to be actively involved in standardization in the telecom (IEEE) and hearing (ANSI) industries. Stay tuned for information regarding soon to be released new or revised standards.

Website Update

Our website has recently been revised and refurbished, with new graphics showing applications we are currently involved with, additional useful downloads, and useful links to other sites. The graphics have also been optimized for faster loading. Please have a visit at:

http://www.cjs-labs.com

Please contact us and let us know if we can be of any service to you.

Best regards,

Christopher J. Struck

CEO & Chief Scientist

CJS Labs

Audio & Electroacoustics

- *Consulting*
- *Design*
- *Training*

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Loudspeaker Performance Seminars with Klippel

"Loudspeaker Performance: Measurement, Analysis & Diagnostics" will be the focus of a 2-day joint seminar in conjunction with Klippel at the Embassy Suites Los Angeles, 8-9 October 2008. For more information, click on the link below:

http://cjs-labs.com/db4/00368/cjs-labs.com/_download/LoudspeakerTestSeminar8-9Oct08.pdf

Fee: $1095-

Space is limited. Email cjs@cjs-labs.com or phone (415) 923-9535 today to reserve your place. Your space is not guaranteed until payment is received. The course fee includes beverages, lunches, and a printed set of the course notes. Discounted parking and room rates are also available.

Upcoming Tutorials in Amsterdam

We will be giving a two-part Tutorial session on Electroacoustics Measurements at the AES 124th Convention in Amsterdam. Please plan on attending.

Part 1, 9:00 Sun. 18 May 2008

http://www.aes.org/events/124/tutorials/session.cfm?code=T5

Part 2, 11:30 Mon. 19 May 2008

http://www.aes.org/events/124/tutorials/session.cfm?code=T13

Test System Calibration

Are you calibrating your test system before measuring every day? Although most measurement microphones and test systems are designed to be quite stable, a quick check with a pistonphone or calibrator is cheap insurance, saving you time and ensuring valid data. In particular, microphone measurements require a well calibrated sound source. The response of even the best loudspeakers can drift over time or change as it heats up after prolonged use. Since the pistonphone or acoustic calibrator is your primary reference, you should also remember to send those units in for traceable NIST calibration once per year. Contact us for more information.

Recent Projects

Recent CJS Labs projects have included transducer design and evaluation for a hearing screening product. Mechanical layout, self-noise, efficiency, and backward/forward compatibility were design issues that were addressed.

Another project involved the design of a test fixture for an IC microphone array.

At the AES 122nd Convention in Vienna last year, we co-authored a paper on loudspeaker modeling: *"An Improved Electrical Equivalent Circuit Model for Dynamic Moving Coil Transducers"*, convention paper 7063. A copy is available from the AES or from us, upon request.

We performed impedance measurements and small signal parameter calculations on some headphone transducer samples for another client.

We also worked on a hearing instrument design, measuring its in-situ response and evaluating laboratory and QC test methods according to ANSI and IEC.

Please contact us and let us know if we can be of any service to you.

Best regards,

Christopher J. Struck

CEO & Chief Scientist

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CJS Labs is a consulting firm based in San Francisco, California. We specialize in audio and electroacoustics applications. We have over 22 years of industry experience in engineering and technology management. Areas of expertise include transducers, acoustics, system design, instrumentation, measurement and analysis techniques, hearing science, telephonometry, speech intelligibility, and perceptual coding. We also offer project management, technology strategy, and training services

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Voltage & Power Summations

In many measurement applications, it is necessary to reduce data to a single figure of merit. Often this is simply the appropriate summation of spectral values. But how should these values be summed, as dB or as Volts (or Pascals), and what is the difference?

For a so-called "power summation", the assumption is that the spectra (or responses) are orthogonal (i.e., independent, and *uncorrelated*). An example would be two independent sound sources both contributing to an overall sound pressure level. In this case, the overall level is found by adding the *powers* of each individually measured source. Note that in a power summation, the squaring of the signals effectively removes the relative phase. So, if both sources radiate the same amount of energy at a point in the sound field, then the sound intensity at that point will be twice as high as when only one source is radiating. Since sound intensity is proportional to power (pressure squared), a doubling in intensity results in an increase in power of 2 times, corresponding to an increase in level of 3 dB. To obtain the **power summation** of levels reported in dB, the dB values are converted back to physical units (e.g., Pascals or Volts), squared, and then summed before converting back to dB. The dB values may also be converted directly back to power. Eq. 1 shows the overall level obtained from a power summation of multiple dB values:

$$L_{Total} = 10\log_{10}\left(\sum_{n=1}^{N} 10^{\frac{L_n}{10}}\right) \qquad \text{Eq. 1}$$

Example 1:

Power summation of 20 dB SPL + 20 dB SPL

$$\begin{aligned} L_{Total} &= 10\log_{10}\left(10^{\frac{20dBSPL}{10}} + 10^{\frac{20dBSPL}{10}}\right) \\ &= 10\log_{10}\left(10^2 + 10^2\right) \\ &= 10\log_{10}(200) \\ &= 10\cdot(2.3) \\ &= 23\ dB\,SPL \end{aligned}$$

For spectra, this operation is performed band-by-band.

In the case of a "voltage summation", the relative phase of the signals to be summed must be considered. An example would be two identical loudspeakers, each fed the same signal from a single generator. In this case, the overall level is found by adding the *pressures* of each individually measured source. The result will depend upon the relative phase of the loudspeakers. If the loudspeakers are *in phase* (perfect constructive interference) at a point in the sound field, the sound intensity will be four times as high as when only one source is radiating. Again, since sound intensity is proportional to power (pressure squared), quadrupling the intensity results in an increase in power of 4 times, corresponding to an increase in level of 6 dB. Of course, if the loudspeakers are exactly *out of phase*, then the signals will exactly cancel (complete destructive interference) and the total output will be zero (- ∞ dB). Most often, the relative phase is somewhere in between, one source leading or lagging. Therefore, technically, it is the complex spectra (real & imaginary parts OR magnitude and phase) that should be summed. Often, the phase information is lost once the magnitude is reported in dB. In these cases, the spectra to be summed ***are assumed to be in phase***. To obtain the **signal or voltage summation** of levels reported in dB without phase information, the dB values should be converted back to physical units (e.g., Pascals or Volts), and then summed before converting back to dB. Eq. 2 shows the overall level obtained from the signal or voltage summation of multiple dB values:

$$L_{Total} = 20\log_{10}\left(\sum_{n=1}^{N} 10^{\frac{L_n}{20}}\right) \qquad \text{Eq. 2}$$

Example 2:

Signal or Voltage summation of 20 dB SPL + 20 dB SPL

$$\begin{aligned} L_{Total} &= 20\log_{10}\left(10^{\frac{20dBSPL}{20}} + 10^{\frac{20dBSPL}{20}}\right) \\ &= 20\log_{10}(10+10) \\ &= 20\log_{10}(20) \\ &= 20\cdot(1.3) \\ &= 26\ dB\,SPL \end{aligned}$$

Again, for spectra, this operation is performed band-by-band.

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KEMAR joins CJS Labs Team

A KEMAR test manikin was acquired in April. The device was completely rebuilt and instrumented, updating it to current standards. The device is now equipped with a Brüel & Kjær IEC 711 Ear simulator and a g.r.a.s. preamp, but can also be fit with a Zwislocki coupler or 2nd ear simulator for binaural testing. This enables testing of headphones, headsets and hearing aids and adds In-Situ, directional, and polar measurements to our test capabilities.

KEMAR Manikin, smartly clad.

Success of AES Tutorials

The 2-Part Electroacoustics Measurements tutorials at the AES 124th Convention in Amsterdam were a huge success, drawing over 150 attendees during the 18-19 May sessions. Another Tutorial on Electoacoustic measurements will be given at the 125th Convention in San Francisco on 3 October 2008 http://www.aes.org/events/125/tutorials/session.cfm?ID=1556

Please plan on attending.

Electroacoustics Measurements Book Now Available

A 300+ page, bound, fully annotated compendium of slides and information from the CJS Labs Electroacoustic Measurements training seminar. Covers all topics from the course. Literature references for each chapter are also included. An essential reference for making proper transducer measurements.

Ordering information:

http://www.cjs-labs.com/sitebuildercontent/sitebuilderfiles/OrderingCourseNotes.pdf

Space Still Available for LA Loudspeaker Performance Seminar

Limited space is still available for the *Loudspeaker Performance: Measurement, Analysis & Diagnostics"*, a 2-day joint seminar in conjunction with Klippel at the Embassy Suites Los Angeles, 8-9 October 2008. For more information, click on the link below:

http://cjs-labs.com/db4/00368/cjs-labs.com/_download/LoudspeakerTestSeminar8-9Oct08.pdf

Fee: $1095-

The class is quickly filling up and space is limited to 35 persons. So Email cjs@cjs-labs.com or phone (415) 923-9535 today to reserve your place. Your space is not guaranteed until payment is received. The course fee includes beverages, lunches, and a printed set of the course notes. Discounted parking and room rates are also available.

We look forward to seeing you in Los Angeles.

Please contact us and let us know if we can be of any additional service to you.

Best regards,

Christopher J. Struck

CEO & Chief Scientist

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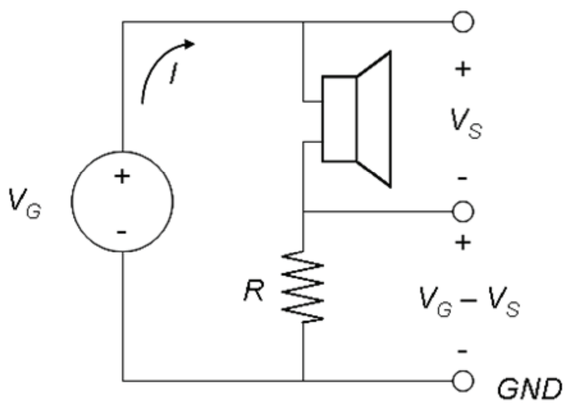
Calibrating for Impedance Measurements

Impedance is a standard measurement in the test battery for loudspeakers and other transducers. From this measurement, the small signal parameters (a.k.a., Thiele-Small Parameters) can be calculated and used to model the low frequency behaviour of a system. The measurement generally requires a test circuit, feeding an analyzer or test system. Voltage dividers or large resistor (constant current) circuits can be used to measure the electrical impedance of a transducer. However, the most common method is to use a small value series resistor (constant voltage) circuit, as shown in Fig. 1.

Fig. 1 Impedance Test Circuit



Constant voltage is also most similar to the actual use conditions of most loudspeakers driven by typical amplifiers. In general, the value of the resistor is chosen to be an order of magnitude less than the minimum expected modulus of the loudspeaker impedance. Simultaneous measurements at both nodes or sequential measurements at each node can be performed. From this data, the impedance vs. frequency is easily determined from the equation below.

$$Z(f) = \frac{V_S(f)\,R}{V_G(f) - V_S(f)}$$

It can easily be seen that the choice and value of the reference resistor, R is critical. Clearly, inductive or wire-wound resistors must be avoided. Although it is common practice to use a precision resistor (< 1%) the precise value of the reference resistor must be known for the impedance calculation to be accurate. Given that the range of loudspeaker impedance modulus values is approximately 1-100 ohms, the typical value of R is chosen to be 0.1 ohm. Interestingly, 0.1 ohm is generally the precision limit on most digital multimeters.

So, how does one go about accurately determining the value of the reference resistor R? One method would be to set up an old fashioned "Wheatstone Bridge" arrangement (remember your first college EE lab class?). This is a 4 resistor balanced circuit, similar to a full wave rectifier, that attempts to null an imbalance. The difference in the adjustment to produce the balance returns the value of the unknown resistance. However, there is an easier method, using your available (calibrated and accurate…) digital multimeter and just one additional resistor. Using this method, neither resistor needs to be precision (or expensive), just stable over time. Choose the second resistor to be in the mid-range of the expected loudspeaker impedance, e.g., 47 ohms. Measure the value of this resistor to the limit of accuracy of your digital multimeter and record the value. Next, construct the loudspeaker impedance test circuit shown in Fig. 1 and connect it to your test system or analyzer to measure impedance versus frequency. Many test systems have macro or automation features for user input of the value of the reference resistor and automatic calculation of the impedance. Substitute the 47 ohm resistor for the loudspeaker. Check the wattage of your resistors and set the test level appropriately — you don't want any smoke! Since the voltage across the reference resistor is quite small, we want enough level to give a good measurement S/N ratio, without burning up the resistors or driving the device under test into non-linearity. Remember, the subsequent calculations are of *"Small Signal Parameters"*! Using Ohm's Law, we quickly discover that with the 47 ohm and 0.1 ohms resistors, our limit is 3.5 volts — but even that is rather high, so start with 250mV and increase it if necessary. Measure the impedance vs. frequency of the 47 ohm resistor. Your measurement system should show a flat — possibly slightly noisy — impedance vs. frequency curve, equal to the value you measured with the digital multimeter. Autorange on the display will exacerbate this "noisiness" visually… Go for a 25 ohm display range instead. Check it with the cursor to read the value at 1 kHz. Alternatively, set up your test system (or export the values) to calculate the average impedance magnitude across the frequency range (10 Hz-20 kHz). If this does not equal the DMM measured-value, simply adjust the assumed value of the reference resistor up or down slightly and re-measure until the desired accuracy is achieved (my 1% 0.1 ohm resistor turned out to be 0.117 ohms…). Now connect the loudspeaker under test and you're ready to go. This iterative approach makes no assumptions about the value or precision of the reference resistor and produces correct results every time. And you don't have to go back to your old college text books to look up "Wheatsone Bridge", either...

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CJS Labs / Klippel Seminar Success!

Loudspeaker Performance: Measurement, Analysis & Diagnostics" , a 2-day joint seminar in conjunction with Klippel was held in Los Angeles on 8-9 October 2008. 18 persons from companies in the loudspeaker and pro audio industries were in attendance. The 2-day session successfully combined measurement theory with practical demonstrations and real-world applications. Beside the lectures, discussion among the attendees during the breaks was highly animated, revolving around the many practical issues in product development everyone seemed to have in common. Feedback from the attendees was overwhelmingly positive.

Success of AES 125th Tutorial

Over 120 persons attended the Electroacoustics Measurements tutorial at the AES 125th Convention in San Francisco on October 3rd. The focus was on the practical aspects of Simulated Free Field Testing. The audience was engaged throughout the session, which concluded with a lively round of Q&A.

Electroacoustics Training Seminar at ALMA Winter Symposium

I will again be at the ALMA Winter Symposium in Las Vegas, 5-7 January 2009. Given the success of last year's half-day seminar — and the numerous requests from participants — the Tuesday January 6th session has been expanded to a full day. This will be a 2-part class, and participants may attend either the morning, the afternoon, or the full day. The AM session will be a review of acoustics, sound fields and sources, psychoacoustics, measurement microphones, and frequency analysis. The PM session will cover simulated free field techniques, and distortion measurements.

More information is available at the ALMA website:

http://www.almainternational.org/2009_winter_symposium.php

I look forward to seeing you in Las Vegas in 2009.

NCAC Membership for CJS Labs

CJS Labs became a member of the National Council of Acoustical Consultants in August. NCAC info at

http://www.ncac.com/

Please contact us and let us know if we can be of any service to you and your organization.

Best regards,

Christopher J. Struck

CEO & Chief Scientist

CJS Labs

Order Your Copy of "Electroacoustics Measurements"

This essential reference for making proper transducer measurements is a 300+ page, bound, fully annotated compendium of slides and information from the CJS Labs Electroacoustic Measurements training seminar. Covers all topics from the course. Literature references for each chapter are also included.

Ordering information:

http://www.cjs-labs.com/sitebuildercontent/sitebuilderfiles/OrderingCourseNotes.pdf

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Log Frequency: Octaves and Decades

This question came up in a discussion regarding proper graphing of a frequency response. On the graph, the aspect ratio (x/y) should be: 1 decade = 50 dB. However, the x-axis was labeled in octaves. Hence, the question:

How many octaves in a decade?

The formula for octaves as a fractional change in frequency is

$$X = \sqrt[N]{2}$$

where X is the proportional change and N is the fractional octave. So, when N is 1 (1 octave), X is 2; when N is 1/2 (2 octaves), X is 4; when N is 12 (a 1/12 octave), X is 1.0595, etc. Therefore, $1/N$ is the number of octaves. An octave is a doubling (or halving) in frequency. The semitones (half-steps or a chromatic scale) in music are 1/12 octaves. A decade is a multiplication by 10 in frequency.

Therefore, X is 10 and we have

$$10 = \sqrt[N]{2}$$

$$\log_{10}(10) = \frac{1}{N}\log_{10}(2)$$

$$N = \log_{10}(2)$$

$$N = 0.301$$

$$\frac{1}{N} = \frac{1}{0.3} = 3\,{}^{1}\!/_{3}\ octaves$$

or ten 1/3 octaves. Therefore,

1/3 *octave* = 1/10 *decade*

In another application, a standard allows for the shifting of a frequency response tolerance mask by ±10% in frequency. Therefore, the following question was posed:

What fractional octave is a 10% change in frequency?

Again, the formula for octaves as a fractional change in frequency is

$$X = \sqrt[N]{2}$$

A 10% percent increase is a multiplication by 1.10, so

$$1.10 = \sqrt[N]{2}$$

$$\log_{10}(1.10) = N\log_{10}(2)$$

$$N = \frac{\log_{10}(1.10)}{\log_{10}(2)}$$

$$= \frac{0.0414}{0.301} \approx 0.1375$$

$$1/7 \approx 0.143$$

$$1/8 = 0.125$$

or ***slightly less than 1/7 octave***.

The upper cutoff frequency of an octave band filter is twice the lower cutoff frequency, a 2:1 ratio. Sometimes, however, filters are designated by the ratio of bandwidth to centre frequency. In the case of an octave band filter, this is

$$\frac{B}{f_0} = 0.7 \approx 70\%$$

For a 1/3 octave filter, the ratio of upper cutoff frequency to lower cutoff frequency is

$$f_2 = \sqrt[3]{2} \times f_1 \approx 1.2599\, f_1$$

However, we know that 1/3 octave is also 1/10 decade, so this could also be written as

$$f_2 = 10^{\frac{1}{10}} \times f_1 \approx 1.2589\, f_1$$

Note the slight error between these calculations. The ratio of bandwidth to centre frequency for a 1/3 octave filter is

$$\frac{B}{f_0} = 0.23 \approx 23\%$$