Acoustical Measurement of Sound System Equipment according IEC 60268-21

KLIPPEL LIVE

a series of webinars presented by

Wolfgang Klippel
1. Modern audio equipment needs output based testing
2. Standard acoustical tests performed in normal rooms
3. Drawing meaningful conclusions from 3D output measurement
4. Simulated standard condition at a single evaluation point
5. Maximum SPL – giving this value meaning
6. Selecting measurements with high diagnostic value
7. Amplitude Compression – less output at higher amplitudes
8. Harmonic Distortion Measurements – best practice
9. Intermodulation Distortion – music is more than a single tone
10. Impulsive distortion - rub&buzz, abnormal behavior, defects
12. Benchmarking of audio products under standard conditions
13. Auralization of signal distortion – perceptual evaluation
14. Setting meaningful tolerances for signal distortion

**15. Rating the maximum SPL value for product**
今日话题 Topics today:

• 简短概述行业中（IEC、CEA、其他准标准）使用的定义
  Short overview of the definitions used in the industry (IEC, CEA, other quasi standard)
• 如何选择满足需求的方法？
  How to choose the method satisfying my needs?
• 如何使测量简单、快速且有意义？
  How to keep the measurements simple, fast and meaningful?
• 如何确保日常的最佳实践？
  How to ensure best practice every day?
Poll:

您喜欢采用哪种定义来评定maxSPL？
Which definition would you prefer for rating maxSPL?

A. 带有明确定义细节的严格标准定义（任何修改均无或具有最小自由度）
A rigid standard definition with clearly defined details (no or minimum freedom for any modification)

B. 具有明确定义框架的标准定义，给予了足够的自由度来考虑目标应用中产品的特殊性
A standard definition with clearly defined framework giving enough freedom to consider the particularities of the product in the target application

C. 我想为maxSPL创建自己的定义
I would like to create my own definition for maxSPL

D. 我认为不需要maxSPL或类似术语
I think we do not need maxSPL or a similar term

E. 其他 other
如何根据IEC 60268-21评定$u_{\text{max}}$和$\text{SPL}_{\text{max}}$？

制造商可以根据以下要求自由评定$u_{\text{max}}$和$\text{SPL}_{\text{max}}$。

- 标准测量条件(额定频率范围、激励、评估点等)：
  
  *标准测量条件 (rated frequency range, stimulus, evaluation point, etc.)*

- DUT可以至少在100小时内以最大输入电压$u_{\text{max}}$重放激励：
  
  *DUT can reproduce the stimulus with maximum input voltage $u_{\text{max}}$ at least for 100 h*

- 满足特定应用的足够音质：
  
  *Sufficient sound quality for the particular application*

  - 有效频率范围对应额定频率范围：
    
    *Effective frequency range corresponds with the rated frequency range*

  - 可接受的常规非线性失真(谐波+互调)：
    
    *Acceptable regular nonlinear distortion (harmonic + intermodulation)*

  - 基波的轻度压缩(发热、机械限制、保护)：
    
    *Low compression of the fundamental (heating, mechanical limiting, protection)*

  - 可忽略的脉冲失真(由异常音或任何其他缺陷产生)：
    
    *Negligible impulsive distortion (generated by rub & buzz or any other defects)*
How to do the rating in practice?

1. **Collect background information**
   - Target application (customer expectations, typical usage)
   - Design details of the audio product (if possible)

2. **Specify standard test condition with performance limits**

3. **Find a test voltage** $u_{\text{test}}$ **as a candidate for maximum input voltage** $u_{\text{max}}$ **corresponding to maxSPL.**

4. **Apply the broadband stimulus at** $u_{\text{max}}$ **to at least 1 DUT for 100h.**

5. **Check that the properties of the DUT after power test are in agreement with the technical specification.** If check fails, repeat sequence 3 – 5 with lower test voltage $u_{\text{max}}$.

6. **Assign the test input voltage to the maximum input voltage** $u_{\text{max}} = u_{\text{test}}$. **Determine the corresponding value of the maximum SPL output.**

7. **Finished!**
利用背景信息 Exploiting Background Information

目标应用 Target application
- 竞争产品的市场营销和基准测试提供了客户期望（性能特征）Customer expectations (performance features) provided from marketing and benchmarking of competitive products
- 环境（房间、汽车）的声学特性 Acoustical properties of the environment (room, car)
- 音频设备的位置（聆听范围）Positioning of the audio device (listening area)
- 音频素材（语音、音乐）的特性 Properties of audio material (speech, music)
- …

设计细节 Design Details
- DSP功能可主动保护换能器和放大器 DSP functionality for active transducer and amplifier protection
- 声音整形、人工低音增强和其他心理声学处理 Sound shaping, artificial bass enhancement and other psychoacoustical processing
- 节能、降噪和其他智能功能 Power saving, noise muting and other smart capabilities
- 数字和无线传输的延迟和伪值 Latency and artifacts in digital and wireless transmission
- 最大信号输入（如24dBU） Maximum signal input (e.g. 24 dBU)
- 换能单元特性（如最大音圈温度）Transducer properties (e.g. maximum voice coil temperature)
- 功放性能（如最大峰值电压） Amplifier properties (e.g. maximum peak voltage)

→ 指定性能限制和测试条件的基础 Basis for specifying the performance limits and test conditions.
Essential Test according IEC 60268-21

PROPERTIES OF THE AUDIO DEVICE

- Endurance (climate, load)
- Fatigue, Aging
- Limitations, defects
- DSP (DRC, limiter, protection system)
- Heating and cooling
- Regular nonlinearities (transducer design)

IMPULSIVE DISTORTION (sinusoidal Stimulus)
AMPLITUDE COMPRESSION (Broadband Stimulus)
MULTI-TONE DISTORTION (Broadband Stimulus)

100h power test broadband stimulus at $u_{max}$

Test voltage $u_{test}$ (Broadband Stimulus)

Maximum test voltage $u_{max}$ (Broadband Stimulus)

MAX. SPL (Broadband Stimulus)

Performance Limits

KLIPPEL LIVE #14

KLIPPEL LIVE #15: Rating the maximum SPL, 9
Benchmarking by maxSPL rated by customer

Essential Metrics according IEC 60268-21

- Total SPL (Broadband Stimulus)
  - Impulsive Distortion (Chirp)
    - Limits IDR=-30 dB
    - And CID=12 dB
  - Limit 3 dB
  - Limit -30 dB
  - Multi-tone Distortion (Broadband Stimulus)

- Limit -30 dB
- Limit 3 dB

Discussed in KLIPPEL LIVE #12

KLIPPEL LIVE #15: Rating the maximum SPL , 10
Limits for Compression
caused by heat in different components

Other factors:
- Temperature distribution and heat flow
- Thermal dynamics (time constants)
- Forced convection cooling
- Thermal properties of other components
- Safety margin

Other components:
- Voice coil: Pro woofer with long coils, 150 - 400°C, 3 - 8dB, 2 - 5dB
- Diaphragm: Headphone, microspeaker, 100 - 200°C, 3 - 4dB, 2 - 3dB
- Magnet: Small neodymium magnet, 100 - 250°C, 3 - 5dB, 2 - 3dB
- Spider: Pro woofer, 150 - 300°C, 5dB, 2 - 4dB

\[ C(\Delta T_v) \approx 201 \log \left( \frac{R_E(\Delta T_v)}{R_E(0)} \right) \]
\[ = 201 \log \left( 1 + 0.0045 \cdot \Delta T_v \right) \]

→ \( C = 3.2 \, \text{dB for } \Delta T_v = 100 \, \text{Kelvin} \)
Separating Thermal and Mechanical Compression

Transfer Function $H(f)$ from sound pressure measurement

- 6V – measured in sound pressure
- 6V – thermal compression (based on impedance)

Dominated by thermal compression

Nonlinear and visco-elastic effects in the cone vibration

Increase of voice coil temperature

Thermal Compression based on Impedance

- $\Delta T = 10\, K$
- $\Delta T = 20\, K$
- $\Delta T = 30\, K$
- $\Delta T = 40\, K$
Limits for Compression

- Nonlinear compression
  - Occurs in a particular frequency band
  - Comes along with other nonlinear distortion
  - Can indicate mechanical overload of the suspension (impulsive distortion and fatigue)
  - In a port, also generates modulated noise

### Nonlinearity

<table>
<thead>
<tr>
<th>Nonlinearity</th>
<th>Critical frequency Band</th>
<th>Maximum compression in this band</th>
<th>Useless limit $L_C$ (mean value in this band)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiffness of suspension $K_{ms}(x)$</td>
<td>$f &lt; f_s$</td>
<td>$&lt; 7\text{dB}$</td>
<td>$2 - 4\text{dB}$</td>
</tr>
<tr>
<td>Force factor $B_l(x)$</td>
<td>$f &lt; f_s$</td>
<td>$&lt; 6\text{dB}$</td>
<td>$2 - 3\text{dB}$</td>
</tr>
<tr>
<td></td>
<td>$f &gt; f_s$ multitone</td>
<td>$&lt; 2\text{dB}$</td>
<td>$1\text{dB}$</td>
</tr>
<tr>
<td>Port resistance $R_p(v)$</td>
<td>$f = f_p$</td>
<td>$&lt; 10\text{dB}$</td>
<td>$2 - 5\text{dB}$</td>
</tr>
</tbody>
</table>

- Compression is a useful indicator in vented and bandpass systems

---

**Fundamental component**

- Linear model $u=10\text{V}$
- Measured $u=10\text{V}$

**Compression**

- Opens and bandpass systems compression is also a useful indicator

**Fundamental component**

- Linear model $u=10\text{V}$
- Measured $u=10\text{V}$

**Compression**

- Opens and bandpass systems compression is also a useful indicator
### Limits for Compression

**DSP Algorithms**
- 可提供更多输出(maxSPL) Can provide more output (maxSPL)
- 能可靠保护音频设备 Can protect the audio device reliably

**BUT**
- 增加延迟 Increase the latency
- 攻击阶段产生脉冲失真 Generate impulsive distortion during attack phase

### Control System | Critical frequency Band | Typical compression in this band | Useful limit \( L_c \) (mean value in this band) | Consequences on audio quality |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Range Compressor (DRC)</td>
<td>Full (or selected) band</td>
<td>&lt;15 dB</td>
<td>2… 8dB</td>
<td>impairs natural dynamics of audio input</td>
</tr>
<tr>
<td>Mechanical transducer protection</td>
<td>Low pass ( f &lt; f_s )</td>
<td>&lt;12 dB</td>
<td>2 - 7dB</td>
<td>Impairs bass performance</td>
</tr>
<tr>
<td>Thermal protection</td>
<td>Full band</td>
<td>&lt;8 dB</td>
<td>2 - 5dB</td>
<td>Minor impact</td>
</tr>
<tr>
<td>Power saving (noise suppression)</td>
<td>Full band, low pass</td>
<td>12 ... 20 dB</td>
<td>0dB</td>
<td>Should be deactivated in time (look ahead)</td>
</tr>
</tbody>
</table>

**界限值取决于期望音质！**
Limits depend on expected audio quality!
**Multi-Tone Distortion reveals**

- **Limits for Multi-Tone Distortion**

**Control System**

<table>
<thead>
<tr>
<th>Critical frequency Band</th>
<th>Typical distortion this band</th>
<th>Useful limit ( L_{MTD} ) (max. value in this band)</th>
<th>Consequences on audio quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspension Stiffness ( K_{MS}(x) )</td>
<td>Low frequencies ( f &lt; 3f_s )</td>
<td>(&lt; -15 \text{ dB} )</td>
<td>(-30 \ldots -20 \text{ dB} )</td>
</tr>
<tr>
<td>Force Factor ( B_l(x) ),</td>
<td>Full band</td>
<td>(&lt; -20 \text{ dB} )</td>
<td>(-40 \ldots -25 \text{ dB} )</td>
</tr>
<tr>
<td>Inductance ( L(x) )</td>
<td>Higher frequencies ( f &gt; 5f_s )</td>
<td>(&lt; -25 \text{ dB} )</td>
<td>(-40 \ldots -25 \text{ dB} )</td>
</tr>
<tr>
<td>Dynamic Range Compressor (DRC)</td>
<td>Full band, low pass</td>
<td>(&lt; -25 \text{ dB} )</td>
<td>(-40 \ldots -25 \text{ dB} )</td>
</tr>
</tbody>
</table>

**界限值取决于期望的音质！**

Limits depend on expected audio quality!
### Limits for Impulsive Distortion

**Pulse distortion limits**

- **Stimulus (chirp)**
- **Impulsive distortion ratio (IDR)**
- **Crest factor of impulsive distortion (CID)**

**Impulsive distorion reveal**

- **Irregular behavior of transducer (overload, defects)**
- **Artifacts of DSP (attack phase)**

---

**Cause**

<table>
<thead>
<tr>
<th>Defect in Woofer ( (f_s \approx 50 \text{ Hz}) )</th>
<th>Critical excitation frequencies</th>
<th>Typical impulsive distortion ratio (IDR)</th>
<th>Useful limits ( (\text{max. value in this band}) )</th>
<th>Consequences on audio quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defect in Microspeaker ( (f_s \approx 500 \text{ Hz}) )</td>
<td>200Hz – 2kHz</td>
<td>-50 ... - 20 dB</td>
<td>(-40 &lt; L_{\text{IDR}} &lt; -30 \text{ dB} ) (12 &lt; L_{\text{CID}})</td>
<td>Some masking by fundamental, regular distortion and hearing threshold</td>
</tr>
<tr>
<td>Mechanical Protection System for woofer with low latency</td>
<td>20 Hz – 200 Hz</td>
<td>-60 ... - 30 dB</td>
<td>(-40 &lt; L_{\text{IDR}} &lt; -30 \text{ dB} ) (12 &lt; L_{\text{CID}})</td>
<td>Low masking of impulsive distortion in worst case</td>
</tr>
<tr>
<td>Dynamic Range Compressor (DRC) or Limiter with low latency</td>
<td>Full band</td>
<td>-60 ... - 30 dB</td>
<td>(-50 &lt; L_{\text{IDR}} &lt; -30 \text{ dB} ) (12 &lt; L_{\text{CID}})</td>
<td>Low masking of impulsive distortion in worst case</td>
</tr>
</tbody>
</table>

**Limits depend on target application (positioning) and expected audio quality!**

**See KLIPPEL LIVE #10**

- **Setup (according IEC 60268-21)**
- **Stimulus (chirp)**
- **Impulsive distortion ratio IDR**
- **Crest factor impulsive distortion CID**
最大SPL的完整测试方案 Integral Test Solution for max. SPL
IEC 60268-21

步骤0：准备(如果声学条件不充分) Step 0: Preparation (if acoustical conditions are not sufficient)

a) 确保固定的房间校正曲线对音频设备有效(→ISC模块)
   Ensure fixed room correction curve is valid for the audio device (→ ISC module)

b) 通过为麦克风位置r>0.3m创建现场补偿函数来产生模拟自由场/远场条件(→ TRF, NFS, ISC modules)
   Generate simulated far/free field condition by creating an in-situ compensation function for microphone
   position r>0.3m (→ TRF, NFS, ISC modules)

KLIPPEL Analyzer

In-situ Compensation Function
(Export to MTON)

details in KLIPPEL live #2, #4, #12
KLIPPEL Test Solution for max. SPL
IEC 60268-21

步骤1：远场/自由场测量(多音) Step 1: Far/Free Field Measurement (multi-tone)

a) 将麦克风放在评估距离(r=1m)或现场测试位置(r=0.3m)
Place microphone at evaluation distance (r=1m) or in-situ test position (r=0.3m)

b) 电压增加的整形多音激励 shaped multi-tone stimulus with increasing voltage

c) 自动搜索压缩或失真达到极限的最大输入电压$u_{test}$和$L_{test}$ (→ 新模组MTON) Automatic search for maximum input voltage $u_{test}$ and $L_{test}$ where either compression or distortion hit the limits (→ new MTON module)

$L_{test} = 74.6 \text{ dB}$
$L_{C} = 3 \text{ dB}$
$L_{MTD} = -30 \text{ dB}$
$u_{test} = 0.2 \text{ V}$
$L_{test} = 74.6 \text{ dB}$

KLIPPEL LIVE #15: Rating the maximum SPL

KLIPPEL Analyzer

细节在KLIPPEL live #5, #7, #9, #12
最大SPL的完整测试方案 Integral Test Solution for max. SPL
IEC 60268-21

步骤2：近场测量 (Chirp) STEP 2: Near Field Measurement (chirp)

a) 麦克风靠近振膜 r < 5 cm (最佳SNR) Place microphone close to the diaphragm r < 5 cm (best SNR)

b) 在 $0.1u_{test} < u < u_{test}$ 内增加电压 u 测量脉冲失真 (IDR和CID) 及谐波失真 (可选)，同时检查极限 (新模组TRF STEP) Measure Impulsive Distortion (IDR and CID) and harmonic distortion (optional) with increasing voltage u with $0.1u_{test} < u < u_{test}$ while checking the limits (new TRF STEP Module)

c) 如果 IDR和CID超出限制，创建一个更低的 $u_{test}$ 值 IF IDR and CID exceeds the limits create a lower value for $u_{test}$

KLIPPEL Analyzer

KLIPPEL LIVE #15: Rating the maximum SPL , 20
最大SPL的完整测试方案 Integral Test Solution for max. SPL
IEC 60268-21

步骤3：100小时长时测试(多音) 3 Long-term test 100 h (multi-tone)

a) 使用u_test的多音信号让DUT工作100小时(MTON → Wave Player)
   Operate the DUT for 100h with the multi-tone signal at u_test (MTON → Wave Player)

b) 检查DUT的性能并指定u_max = u_test 和 maxSPL = L_test
   Check the performance of the DUT and assign u_max = u_test and maxSPL = L_test

Wave Player
(新的KET模块针对耐久性测试进行了优化，即将推出new KET module optimized for endurance testing coming soon)

TRF Stepping
Rate maximum SPL
74.6 dB

MTON Broadband Stimulus

Check Performance

details in KLIPPEL live #5, #12
额外测试 Additional Tests

定义测试电压 $u_{test}$ for defining the test voltage $u_{test}$

测试音质 Testing audio quality

- 谐波失真 (THD、EHID、chirp激励、IEC 60268-21) \(\rightarrow\) #8
  Harmonic distortion (THD, EHID, chirp stimulus, IEC 60268-21) \(\rightarrow\) #8
- 无发热的谐波失真 (猝发激励 CEA 2010) \(\rightarrow\) #15
  Harmonic distortion without heating (burst stimulus CEA 2010) \(\rightarrow\) #15
- 互调失真 (双音信号、IEC 60268-21) \(\rightarrow\) #9
  Intermodulation distortion (two-tone signal, IEC 60268-21) \(\rightarrow\) #9
- 非相干性 (白噪或粉噪激励) \(\rightarrow\) #13
  In-coherence (white or pink noise stimulus) \(\rightarrow\) #13
- 残差 (音频信号) 和信号失真可听化 \(\rightarrow\) #13
  Residuum (audio signal) & auralization signal distortion \(\rightarrow\) #13

测试产品的可靠性和鲁棒性 Testing reliability and robustness of the product

- 破坏性测试 (短时和长时最大SPL、IEC 60268-21)
  Destructive testing (short-term and long-term maximum SPL, IEC 60268-21)
- 加速寿命测试 (关键多音激励) \(\rightarrow\) #5
  Accelerated life test (critical multi-tone stimulus) \(\rightarrow\) #5
- 环境测试 (IEC 60268-22)
  Environmental testing (IEC 60268-22)
### Comparison with Other Approaches

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>最大SPL值</strong>&lt;br&gt;Max. SPL value</td>
<td>根据特定应用额定该值&lt;br&gt;Rated value according to particular application</td>
<td>根据固定限制的两个测试计算该值&lt;br&gt;Calculated value based on two tests with fixed limits</td>
<td>单次测试的测量值&lt;br&gt;Measured value in a single test</td>
</tr>
<tr>
<td><strong>要求</strong>&lt;br&gt;Requirements</td>
<td>DUT产生最大SPL且能承受最大输入电平(需要100h测试)&lt;br&gt;DUT generates max. SPL and handles maximum input level <em>(100h test required)</em></td>
<td>DUT达到长时压缩(3dB)&lt;br&gt;和谐波失真固定限制时产生最大SPL&lt;br&gt;DUT generates max. SPL at fixed limits in <em>long-term</em> compression (3 dB) and in harmonic distortion</td>
<td>DUT达到长时压缩(2dB)&lt;br&gt;固定限制时产生最大SPL&lt;br&gt;DUT generates max. SPL at fixed limits in <em>long-term</em> compression (2 dB)</td>
</tr>
<tr>
<td><strong>激励</strong>&lt;br&gt;Stimulus</td>
<td>用户定义的宽带激励(整形的多音)&lt;br&gt;User defined broadband signal <em>(shaped multitone)</em></td>
<td>• 整形的粉噪(预热1min)&lt;br&gt;Shaped pink noise <em>(preheating 1min)</em>&lt;br&gt;• 猝发信号&lt;br&gt;Burst Signal</td>
<td>有预热(5min)的特殊M-NOISE信号(密集全频带)&lt;br&gt;Special M-NOISE signal <em>(dense full band)</em> with preheating <em>(5 min)</em></td>
</tr>
<tr>
<td><strong>音质</strong>&lt;br&gt;Audio quality</td>
<td>不包含在IEC 60268-21范围内(取决于目标应用)&lt;br&gt;not in the scope of IEC 60268-21 <em>(depends on target application)</em></td>
<td>尚未完全定义(缺少重要的物理和感知方面内容)&lt;br&gt;not completely defined <em>(important physical and perceptual aspects are missing)</em></td>
<td>尚未完全定义(缺少重要物理和感知方面内容)&lt;br&gt;not completely defined <em>(important physical and perceptual aspects are missing)</em></td>
</tr>
</tbody>
</table>
Harmonizing other Standards or Practices with IEC 60268-21

PROPERTIES OF THE AUDIO DEVICE

- Endurance (climate, load)
- Fatigue, Aging
- limitations, defects
- DSP (DRC, limiter, protection system)
- Heating and cooling
- Regular nonlinearities (transducer design)

IEC standard tests
CEA-Standard 2010-A&B
Meyer Sound (M-NOISE)
other de facto standards
Your favorite method

100h power test broadband stimulus at $u_{\text{max}}$

Test voltage $u_{\text{test}}$ (Broadband Stimulus)

Maximum test voltage $u_{\text{max}}$ (Broadband Stimulus)

MAX. SPL (Broadband Stimulus)

Performance Limits

KLIPPEL LIVE #15: Rating the maximum SPL
Tone Burst Measurement according CEA 2010-A and CEA 2034
Burst Test (CEA-2010-A)

Stimulus

Microphone Signal

Limit Check

Maximum SPL_{burst}
(last passed peak value)

Far/Free Field

Increase Voltage

PASS

FAIL

Not sensitive for impulsive distortion

Thresholds
Burst Test Results

$SPL_{\text{MAX}}$ referenced to 1m and 2.83V

<table>
<thead>
<tr>
<th>Tone Burst Center Frequency (Hz)</th>
<th>Maximum SPL</th>
<th>CEA-2010 Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>85</td>
<td>84</td>
</tr>
<tr>
<td>31.5</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>101</td>
<td>100</td>
</tr>
<tr>
<td>63</td>
<td>104</td>
<td></td>
</tr>
</tbody>
</table>

低频的房间效应必须补偿 Room effects must be compensated for low frequencies
CEA 2010A中的猝发测试
Burst Test in CEA 2010 A

优点 Benefit:
人耳对f < 200Hz低频猝发的谐波失真、脉冲失真和(调制)噪声非常灵敏
Human ear is very sensitive for harmonic distortion, impulsive distortion and (modulated) noise for low frequency bursts f < 200 Hz

问题 Problems:
• 需要远场/自由场(房间模式能引起严重误差！)  Far/free field condition required (room modes can generate a significant error !!)
• 对脉冲失真的测试不灵敏(基于能量) Test is not sensitive for impulsive distortion (energy based)
• 不良SNR(环境噪声)降低最大SPL！ Poor SNR (ambient noise) reduces max SPL!
问题：房间模式
Problem: Room Modes

问题 Problems:
- CEA 2010需要(模拟)远场/自由场条件 CEA 2010 requires (simulated) far/free field conditions
- 房间模式是窄带共振，会影响远场中测得的声压 Room modes are narrow band resonances which affect the measured sound pressure in the far field

症状 Symptoms:
- 再现猝发音信号有不对称包络(振铃) Asymmetrical envelope of the reproduced burst signal (ringing)
- 影响谐波失真 Harmonics distortion affected
- 较大的声压级SPL峰值(10dB) Larger sound pressure SPL peak value (10 dB)
问题 Problem:
房间模式会导致最大SPL值的显著误差

The room modes generate a significant error in the maximum SPL value.

用于模拟远场/自由场的复补偿滤波器可解决此问题

a complex compensation filter for simulated far/free field can solves this problem.

观看KLIPPEL live #4
See KLIPPEL live #4
**Motivation (Intention):**
- Applying burst test to other (full-band) consumer products
- Improving sensitivity for irregular distortion, rub&buzz, defects

**Solution:**
- Sensitive limits for harmonic distortion and noise

---

**Burst Response Spectrum normalized**

- **CEA 2010 LIMITS**
  - fundamental
  - 2nd
  - 3rd
  - 4th
  - 5th
  - higher order + noise
- Not sensitive for impulsive distortion

- **CEA2034 LIMIT**
  - Tighter limits

---

**CEA 2034中的猝发测试**

**Burst Test in CEA 2034**

---

**KLIPPEL LIVE #15: Rating the maximum SPL**, 31
### Results from Burst Measurement

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>Peak SPL [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>119.95</td>
</tr>
<tr>
<td>25</td>
<td>120.00</td>
</tr>
<tr>
<td>32</td>
<td>120.03</td>
</tr>
<tr>
<td>40</td>
<td>120.04</td>
</tr>
<tr>
<td>50</td>
<td>120.07</td>
</tr>
<tr>
<td>63</td>
<td>120.07</td>
</tr>
<tr>
<td>80</td>
<td>120.07</td>
</tr>
<tr>
<td>100</td>
<td>120.07</td>
</tr>
<tr>
<td>125</td>
<td>120.07</td>
</tr>
<tr>
<td>160</td>
<td>120.07</td>
</tr>
<tr>
<td>200</td>
<td>120.08</td>
</tr>
<tr>
<td>250</td>
<td>120.08</td>
</tr>
<tr>
<td>315</td>
<td>120.08</td>
</tr>
<tr>
<td>400</td>
<td>120.08</td>
</tr>
<tr>
<td>500</td>
<td>120.08</td>
</tr>
<tr>
<td>630</td>
<td>102.68</td>
</tr>
<tr>
<td>800</td>
<td>120.08</td>
</tr>
<tr>
<td>1000</td>
<td>120.07</td>
</tr>
<tr>
<td>1250</td>
<td>120.08</td>
</tr>
<tr>
<td>1600</td>
<td>120.06</td>
</tr>
<tr>
<td>2000</td>
<td>120.07</td>
</tr>
<tr>
<td>2500</td>
<td>120.01</td>
</tr>
<tr>
<td>3150</td>
<td>120.04</td>
</tr>
<tr>
<td>4000</td>
<td>120.03</td>
</tr>
<tr>
<td>5000</td>
<td>119.75</td>
</tr>
</tbody>
</table>

#### Data Post-processing

- 使用均值限制加权SPL值 Limiting the weighted SPL values using an average value
- 声压平方之和 Summing the squared pressure

### CEA2034 - Broadband Peak SPL [dB]

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>Weighed &amp; limited Maximum SPL [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>117.00</td>
</tr>
<tr>
<td>25</td>
<td>119.00</td>
</tr>
<tr>
<td>32</td>
<td>119.00</td>
</tr>
<tr>
<td>40</td>
<td>120.00</td>
</tr>
<tr>
<td>50</td>
<td>120.00</td>
</tr>
<tr>
<td>63</td>
<td>120.00</td>
</tr>
<tr>
<td>80</td>
<td>120.00</td>
</tr>
<tr>
<td>100</td>
<td>120.00</td>
</tr>
<tr>
<td>125</td>
<td>120.00</td>
</tr>
<tr>
<td>160</td>
<td>120.00</td>
</tr>
<tr>
<td>200</td>
<td>120.00</td>
</tr>
<tr>
<td>250</td>
<td>120.00</td>
</tr>
<tr>
<td>315</td>
<td>120.00</td>
</tr>
<tr>
<td>400</td>
<td>120.00</td>
</tr>
<tr>
<td>500</td>
<td>120.00</td>
</tr>
<tr>
<td>630</td>
<td>103.00</td>
</tr>
<tr>
<td>800</td>
<td>120.00</td>
</tr>
<tr>
<td>1000</td>
<td>120.00</td>
</tr>
<tr>
<td>1250</td>
<td>120.00</td>
</tr>
<tr>
<td>1600</td>
<td>119.00</td>
</tr>
<tr>
<td>2000</td>
<td>119.00</td>
</tr>
<tr>
<td>2500</td>
<td>119.00</td>
</tr>
<tr>
<td>3150</td>
<td>118.00</td>
</tr>
<tr>
<td>4000</td>
<td>117.00</td>
</tr>
<tr>
<td>5000</td>
<td>115.00</td>
</tr>
</tbody>
</table>
Maximum SPL Calculation
according CEA 2034

Broadband Peak SPL $L_{\text{peak}}$
(measured with burst stimulus)

$\text{L}_{\text{peak}} - \text{L}_{\text{con}} < 9\text{dB}$

Maximum SPL $L_{\text{max}} = L_{\text{peak}} - 9\text{dB}$
Harmonics + Noise limits Maximum SPL

Maximum Usable Continuous Output SPL $L_{\text{con}}$
(measured with noise stimulus)

$\text{L}_{\text{peak}} - \text{L}_{\text{con}} \geq 9\text{dB}$

Maximum SPL $L_{\text{max}} = L_{\text{con}}$
Long-term usable continuous (heating) limits Maximum SPL
CEA 2034中的问题
Problems in CEA 2034

- 未考虑互调失真(波动和粗糙感→ KLIPPEL live #14)
  Intermodulation distortion is not considered (fluctuation and roughness sensation → KLIPPEL live #14)
- 高猝发频率f>500Hz时，听音不再那么有意义(猝发太短<100ms) → #14
  Listening becomes less meaningful at higher burst frequencies f >500 Hz (burst too short < 100 ms) → #14
- 猝发激励太短而不能唤醒现代音频设备中的节能模式→ #7
  Burst stimulus is too short to wake up power saving mode in modern audio devices → #7
- 脉冲失真(异常音和其他缺陷)灵敏度低→ #10
  Poor sensitivity for impulsive distortion (rub&buzz and other defects) → #10
- 环境噪声(SNR较差)降低小扬声器的最大SPL
  Ambient noise (poor SNR) reduces max. SPL in small speakers
- CEA 2034提出的平均降低了所有常规失真(随机属性)的灵敏度→ #10
  Averaging proposed by CEA 2034 reduces sensitivity for all regular distortion (random properties) → #10
- 需要(模拟)远场/自由场条件→ #4 (simulated) far/free field condition required → #4
Poor Sensitivity for Impulsive Distortion: a problem in CEA 2034

Harmonic Distortion + Noise (normalized)

- 20...50 Hz
- 250...5000 Hz
- 63...200 Hz

Problems with poor SNR!

Limit required for 20 Hz tone

Order of “harmonics”

20 Hz (Fundamental) 400 Hz 2 kHz 20 kHz frequency

KLIPPEL LIVE #15: Rating the maximum SPL, 36
问题 Problems:

- 环境噪音降低最大SPL Ambient noise reduces max. SPL
- CEA 2034建议用平均来提高SNR，会降低具有随机特性的非常规失真的灵敏度
  CEA 2034 recommends averaging to improve SNR which reduces sensitivity for irregular distortion with random properties

解决SNR问题 Solution for SNR problem:

1. 根据近场(5cm) (SNR高于20dB !)的失真限制确定$u_{\text{max,burst}}(f)$
   determine $u_{\text{max,burst}}(f)$ based on distortion limits in near field (5cm) (20dB more SNR !)
2. 使用$u_{\text{max,burst}}(f)$在(模拟)远场中测量最大峰值SPL_{burst}(f)
   Measure maximum peak SPL_{burst}(f) in (simulated) far field using $u_{\text{max,burst}}(f)$
最大SPL的KLIPPEL测试方案 KLIPPEL Test Solution for maxSPL
符合CEA 2010A和CEA 2034 according to CEA 2010A and CEA 2034

0 准备(如果声学条件还不充分) 0 Preparation (if acoustical conditions are not sufficient)
a) 确保固定的修正曲线对音频设备有效(→ ISC模组) Ensure fixed room correction curve is valid for the audio device (→ ISC module)
b) 通过为麦克风位置r>0.3m创建现场补偿函数来生产模拟自由场/远场条件(→ TRF, NFS, ISC模组)
Generate simulated far/free field condition by creating an in-situ compensation function for microphone position r>0.3m (→ TRF, NFS, ISC modules)

1 远场/自由场测量(连续、多音) 1 Far/Free Field Measurement (continuous, multi-tone)
a) 放置麦克风到评估距离(r=1m)或者现场测试距离(r=0.3m)
Place microphone at evaluation distance (r=1m) or in-situ test position (r=0.3m)
b) 增加整形多音激励的电压 shaped multi-tone stimulus with increasing voltage
c) 自动搜索压缩或失真达到极限的最大测试电压$u_{con}$和SPL$_{con}$ (→新模组MTON)
Automatic search for maximum test voltage $u_{con}$ and SPL$_{con}$ where either compression or distortion hit the limits (→ new MTON module)

2 近场测量(猝发) 2 Near Field Measurement (burst)
a) 放置麦克风靠近振膜$r<5cm$(最佳SNR) Place microphone close to the diaphragm $r < 5 $ cm (best SNR)
b) 自动搜索规范化谐波失真超过极限的最大测试电压$u_{burst}(f)$ (→新模组TBM)
Automatic search for maximum test voltage $u_{burst}(f)$ where normalized harmonic distortion exceeds the limits (→ new TBM module)

3 远场/自由场测量(猝发) 3 Far/Free Field Measurement (burst)
a) 放置麦克风到评估距离(r=1m)或者现场测试距离(r=0.3m) Place microphone at evaluation distance (r=1m) or in-situ test position (r=0.3m)
b) 在归一化谐波失真超过极限的最大测试电压$u_{burst}(f)$下测量最大SPL (→新模组TBM) Measure maximum SPL at maximum test voltage $u_{burst}(f)$ where normalized harmonic distortion exceeds the limits (→ new TBM module)

4 指定最大SPL 4 Assignment of maxSPL
a) 基于SPL$_{con}$和SPL$_{burst}$计算最大SPL Calculate maxSPL based on SPL$_{con}$ and SPL$_{burst}$
b) 执行100h测试以符合IEC 60268-21(可选但强烈推荐) Perform 100h test to comply with IEC 60268-21 (optional but strongly recommended)
最后：什么是重要的？
At the end: What is important?

IEC 60268-21的讯息 Message of IEC 60268-21:
• 使用IEC 60268-21提供的自由度 Use the freedom provided by IEC 60268-21
• 明确定义和记录测试条件 Clearly define and document the test conditions
• 考虑可靠性和耐久性并用$u_{\text{max}}$处的100h功率测试检查 Consider reliability and endurance and check it with a 100 h power test at $u_{\text{max}}$
• 把最大SPL值连带记录的测量条件提供给同事、供应商和客户 (标准简化工作量！) Provide maxSPL value together with documented measurement conditions to your coworkers, suppliers and customers (standard simplifies the effort!)

然后 THEN

以下方面maxSPL将是一个有意义的数值 MaxSPL becomes a meaningful number for
• 校准有源系统的输入 → #5 Calibrating the input of active systems → #5
• 音频产品的基准测试 → #12 Benchmarking of audio products → #12
• 制作终端用户眼里的好产品 → #14 Making better products as seen by the end user → #14
Discussion
结束 Conclusions

• 基于输出的测量可以确保对音频设备进行全面评估
  OUTPUT based measurements can ensure comprehensive evaluation of audio devices
• DSP算法、无线传输、智能放大器需要现代测量技术
  DSP algorithms, wireless transmission, smart amplifiers need modern measurement techniques
• IEC标准60268-21是一个很好的基础，已经可以服务于您的应用
  IEC Standard 60268-21 is a good basis and is ready for your application
• 向IEC或AES标准委员会提供任何反馈(错误、新想法)
  Provide any feedback (errors, new ideas) to IEC or AES standard committees
• 感知建模和可听化技术可以进一步缩小聆听和测量之间的差距(未来标准项目？)
  Perceptual modeling and auralization techniques can further reduce the gap between listening and measurement (future standard project ?)
KLIPPEL LIVE “符合IEC 60268-21音响系统设备的声学测量”？
KLIPPEL LIVE “Acoustical Measurement of Sound System Equipment according IEC 60268-21”？

1. 在www.klippel.net.cn免费访问录制的网络研讨会
   Free access to the recorded webinars on www.klippel.net.cn

2. 联系 rnd-support@klippel.de 或者 china@klippel.de，
   Contact rnd-support@klippel.de if you
   • 需要更多详细信息 need more detailed information,
   • 发现错误，有些建议或新想法 found errors, have some suggestions or new ideas,
   • 需要软件和模板以及免费demo授权进行实际评估 need software and templates for practical evaluation with free demo license,
   • 其他 other things
展望 OUTLOOK


将讨论 will address the points:

• 考虑基本物理关系 Considering fundamental physical relationships
• 利用扬声器建模能力(集总、模态、有限元、面向系统等) Exploiting the power of loudspeaker modeling (lumped, modal, finite element, system oriented…)
• 识别模型参数 Identification of free model parameters
• 优化设计和产品开发 Optimal design and product development
• DSP开发的结论 Consequences for DSP development
• 以及更多 and much more