CTS-Prep Workshop 2
Loi de Ohm, Impédence et Décibels
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Goals

• Review Ohm’s Law
  – Calculate V, I, R and P
  – Understand Bus Power in AV systems

• Calculate Speaker Systems Impedance (Z)

• Understand Impedance matching with amplifiers

• Review the concept of decibel

• Understand decibel calculations

• Review Speaker configurations
Circuits have:
- Source
- Load
- Conductor
Ohm’s Law  \( V = I \times R \)

- **V** (voltage) - volts
- **I** (current) - amperes
- **R** (resistance) - ohms
Introduction to Ohm’s Law

• Expresses the relationships between Voltage (V), Current (I) and Resistance (R) in an electrical circuit
  - \( V = I \times R \)

• Helps calculate the Power (P) in a circuit
  - \( P = I \times V \)
  - \( P = \frac{V^2}{R} \)
  - \( P = I^2 \times R \)

• If you know any 2 values, you can find the third one.
Current and Voltage

• Expressed in amps by the symbol “I”
  - The flow of electrons in a circuit
  - In a DC circuit the flow is in one direction back to source
  - In an AC circuit the flow reverses periodically.
• I=V/R

• The force that causes the electrons to flow.
  - Expressed in Volts or V (or E)
  - Mic level .002V
  - Line level 0.316V (consumer) or 1.23V(pro)
  - Loudspeaker level up to 100V
• V=I * R
Current and Resistance

• The opposition to the flow of electrons
  - Expressed in ohms (Ω) and by the symbol R
  - Applies to DC (e.g. battery)

• \( R = \frac{V}{I} \)
Calculate the current in a circuit where the voltage is 2V and resistance is 8 ohms.

- \( I = \frac{2}{8} \)
- \( I = 0.25 \text{ A} \)

Calculate the voltage in a circuit where the current is 4 amps and resistance is 25 ohms.

- \( V = 4 \times 25 \)
- \( V = 100 \text{V} \)
BUS Powered solutions

• An electrical connection between a host and a set of devices attached to and dependent upon the host is called a Bus

• When the connexion also carries power, we refer to it as Bus Power.

• Ohm’s Law defines the relationship between V, I and R as $V = I \times R$ and it is critical to the operation of the bus
BUS Powered solutions

• Due to the resistance of the cable, some of the voltage is lost in the transmission

• 5 meters of AWG 28 copper wire will add 1.1 ohms of resistance, for various types of connectors this means:
  – USB 5V @ 200 mA, .22 V or 4.4%
  – Display port 3.3 V @ 300 mA, .33 V or 6.6%
  – HDMI 5V @ 50 mA, .06 V or 1.2% (for a 15 meter HDMI cable it would be 3.6%), if it supplies more current, say 150 mA, the
BUS Powered solutions

• Why does it matter?
  – Every time a source is connected to a sink, the source sends 5V to the sink and expects them back in the Hot Plug Detect Pin, to confirm that a sink has been connected.
  – This then triggers EDID and HDCP.
  – If the HPD does not happen, the signal will not be displayed
**BUS Powered solutions**

- With HDMI, manufacturers are asking for more power from the source for equalizer chips, media converters and downstream devices.
- The 5V/55 mA of the specification may not be enough for the system to function.
- A voltage inserter at the source, disables pin 18 and replaces the power with a transformer at 1000 mA or a USB connection at 500(USB2.0)/900
Loudspeaker Impedance

• Like resistance, but applied to Alternating Current (AC).
• (Audio signals, radio signals, the power from the wall outlet)
• Expressed in ohms and with the symbol Z
• Important for loudspeakers and power amps
Wiring Loudspeakers

• Loudspeakers have a nominal impedance
• Impedance is the opposition to alternating current flow
• A common loudspeaker has an impedance of 4, 8 or 16 Ohms
Wiring Loudspeakers

- Impedance (Z) is Resistance (R) to AC signals

- Series
  \[ Z_{\text{total}} = Z_1 + Z_2 + \ldots + Z_i \]

- Parallel Different Z’s
  \[ Z_T = \frac{1}{\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \ldots + \frac{1}{Z_N}} \]

- Parallel Same Z all speakers
  \[ Z_{\text{total}} = \frac{Z_1}{N} \]
Series Impedance Example

Calculate the impedance of the following loudspeaker circuit. First, identify what type of circuit you're dealing with, then calculate the impedance from the corresponding formula.

8 ohm + 8 ohm + 8 ohm = 24 ohm
Parallel Impedance Example

Calculate the impedance of the following loudspeaker circuit. First, identify what type of circuit you're dealing with, then calculate the impedance from the corresponding formula.

1.33 ohms. $Z_T = \frac{4}{3}$
Loudspeakers Wired in a Series Parallel Circuit
Power Amplifier Ratings

Amplifiers have an output impedance they are expecting to have connected to their output terminals.

<table>
<thead>
<tr>
<th>Output Power (per channel, RMS watts, both channels driven)</th>
<th>2 ohms, 1 kHz, 1% THD +/- 1 dB</th>
<th>350</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 ohms, 1 kHz, 1% THD</td>
<td>270</td>
<td></td>
</tr>
<tr>
<td>4 ohms, 20 Hz-20 kHz, 0.1% THD</td>
<td>225</td>
<td></td>
</tr>
<tr>
<td>8 ohms, 1 kHz, 1% THD</td>
<td>170</td>
<td></td>
</tr>
<tr>
<td>8 ohms, 20 Hz-20 kHz, 0.1% THD</td>
<td>150</td>
<td></td>
</tr>
</tbody>
</table>

*Dual mode (with both channels driven):*
- 240 watts into 4 ohms.
- 220 watts into 8 ohms.
- 225 watts with 70 volt output.
Power Amplifier Ratings

• Matching this output impedance with the loudspeaker load maximizes energy transfer from amplifier to loudspeaker to acoustic energy

• What happens if we don’t calculate the expected load and match that with the power amplifiers capabilities?
Power Amplifier Ratings

• Ratings
  – 16 ohm, 8 ohm, 4 ohm, 2 ohm
  – These type of systems are considered to be Direct-Coupled
Constant Voltage

A transformer added to a loudspeaker will increase the impedance of that loudspeaker to the amp.
Constant Voltage
Example: A PA amplifier is rated at 120 W @ 100 V, therefore you could connect:

- 20 x 5 W (100 V) ceiling speaker for a total of 100 W
- 40 x 2.5 W (100 V) ceiling speakers for a total of 100 W
- 10 x 5 W (100 V) ceiling speakers and 20 x 2.5 W (100 V) ceiling speakers for a total of 100 W
- Any combination of speakers that add up to no more than 120 W, but it is recommended not to exceed 80% of the amplifier rating, thus 96 W
Decibels

- **Decibel**
  - Use it because we hear logarithmically
  - It is always a ratio of two values
  - For acoustics, the formulas are:
    - $dB = 10 \times \log \left( \frac{P_2}{P_1} \right)$ for power
    - $dB = 20 \times \log \left( \frac{D_1}{D_2} \right)$ for distance
  - Replacing a 250 W amp with a 500 W amp, is a change of 3dB in sound level
    - $10 \times \log \left( \frac{500}{250} \right) = 10 \times \log 2 = 10 \times 0.3 = 3dB$
  - Doubling the distance to a listener, is a change of -6dB in sound level
    - $20 \times \log 2 = 20 \times 0.3$
  - It can be referenced to Sound Pressure Level (SPL), typically the threshold of hearing
• Some values to remember:
  – 1 dB is the smallest perceptible change in sound (most people will not notice it)
  – A “just” noticeable change requires 3 dB
  – 10 dB is twice or half the perceived volume (uses log2)
  – Conversation = background noise of 35 dB + 25 dBmin signal to noise ratio (to hear over the background) = 60 dB
  – Beyond 194 dB is called a shock wave (NASA rocket launch)
  – Loudest sound recorded 172 dB, Karakatoa eruption
Logarithms

A logarithm is the exponent of base 10 that equals the value of a number.
Introduction to the Decibel

• 1/10 of a Bel (dB)
• Describes a base 10 logarithmic relationship of a power ratio between two numbers
• Logarithmic scale used to describe ratios with a very large range of values
Why Use Decibels?

• Describes a base 10 logarithmic relationship of a power ratio between two numbers
• Comparing two powers
  \[ \text{dB} = 10 \times \log \left( \frac{P_1}{P_2} \right) \]
• Comparing two distances, voltages, etc.
  \[ \text{dB} = 20 \times \log \left( \frac{D_1}{D_2} \right) \]
  \[ \text{dB} = 20 \times \log \left( \frac{V_1}{V_2} \right) \]
Calculating Decibel Changes

• By itself, a decibel doesn't measure anything
• It is a ratio: compares two numbers (number A to number B)
• It must have a reference
• If a reference is divided by itself for example
  • 0.775V/0.775V
  • The answer is 1
• And the log10 of 1 is 0 hence zero reference
Reference Level

• Zero Reference Sound Pressure Level
• 0 dB SPL = 0.00002 Pascals (threshold of hearing) at 1 kHz

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Decibel Abbreviation</th>
<th>Reference Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound pressure</td>
<td>0 dB SPL</td>
<td>0.00002 Pa at 1 kHz</td>
</tr>
<tr>
<td>Voltage (consumer electronics)</td>
<td>0 dBV</td>
<td>1 V</td>
</tr>
<tr>
<td>Voltage (pro AV equipment)</td>
<td>0 dBu</td>
<td>0.775 V</td>
</tr>
<tr>
<td>Power</td>
<td>0 dBW</td>
<td>1 W</td>
</tr>
<tr>
<td>Power</td>
<td>0 dBm</td>
<td>0.001 W, or 1 mW</td>
</tr>
</tbody>
</table>
Zero References: Voltage

• 0 dBu
• Reference: 0.775 Vrms
• Microphone level: -50 dBu / 0.002 V
• Pro Audio line level: +4 dBu / 1.23 V
• 0 dBV
• Reference: 1 Vrms
• Consumer line level: -10 dBV / 0.316 V
Commit to Memory

- **Sound Pressure**
  - 0 dB SPL to 140 dB SPL

- **Microphone Level**
  - Microphones: -60 to -50 dBu

- **Line Level**
  - Pro Audio: 0 dBu (0.775 V) to +4 dBu (1.23 V)
  - Consumer: -10 dBV (0.316 V)
Example of 10 Log Decibel Calculations

10 Log:

• An audio amplifier is delivering 15 watts, and its output is decreased to 5 watts.

  What is the change in decibels?

\[ 10 \log\left(\frac{5}{15}\right) = -4.8 \text{dB} \]
Example of 20 Log Decibel Calculations

20 Log:

• Assume a loudspeaker is generating 80 dB SPL at a distance of 22 feet (7m) away from the source outdoors.

  What would the level be at 88 feet (27m) away?

\[ 20 \times \log(22/7) = 12\text{dB} \]

Farther away, loss of dB: \[ 80\text{dB} - 12\text{dB} = 68\text{dB} \]
Power Decibels Exercise

\[ dB = 10 \times \log \left( \frac{P_1}{P_2} \right) \]

- \( P_1 \) is the power change (to) value
- \( P_2 \) is the power reference (from) value

**How many dB do we gain if we replace a 250w amp with a 500w amp?**

\[ dB = 10 \times \log \left( \frac{500}{250} \right) \]
\[ dB = 10 \times \log(2) \]
\[ dB = 3 \]
10 and 20 Log Practice Problems

Q: An existing audio amplifier is rated at 20 watts of output power. If the power is replaced by an amplifier rated at 8 watts, what is the expected change in decibels? Round your answer to the nearest decibel.

Hints

Power is calculated using the 10 log formula:

\[ \text{dB} = 10 \times \log \left( \frac{P_1}{P_r} \right) \]

Your reference value, \( P_r \), is the first value you measured. 20 goes on the bottom. 8 on the top.

Since power is reduced, you'd expect a loss. This will be a negative number.

\[
\begin{align*}
\text{dB} &= 10 \times \log \left( \frac{8}{20} \right) \\
\text{dB} &= 10 \times \log (0.4) \\
\text{dB} &= 10 \times (-0.39794) \\
\text{dB} &= -3.9794
\end{align*}
\]

The expected change is around -4 dB.

\[
\begin{align*}
\text{dB} &= 10 \times \log \left( \frac{20}{8} \right) \\
\text{dB} &= 10 \times \log (2.5) \\
\text{dB} &= +3.9794
\end{align*}
\]
Q:
A listener in a meeting room is 10 feet (3,048 mm) from a loudspeaker. If the listener moves to a new distance of 25 feet (7,620 mm) away, what is the expected change in decibels? Round your answer to the nearest decibel.

Hints
Use the 20 Log formula to calculate decibel changes in distance:
\[ dB = 20 \times \log \left( \frac{D_1}{D_2} \right) \]

\( D_1 \) should be your starting point: 120 inches (3084 mm).

The listener is moving farther away from the loudspeaker, so you’d expect the answer to be negative, a loss.

\[ dB = 20 \times \log \left( \frac{10}{25} \right) \]
\[ dB = 20 \times \log (0.4) \]
\[ dB = 20 \times (-0.39794) \]
\[ dB = -7.9588 \]

The expected change is around -8 dB.

\[ dB = 20 \times \log \left( \frac{25}{10} \right) \]
\[ dB = +8 \text{ dB} \]
What is the decibel change from a microphone signal of 0.004 volts to a line level signal of 0.775 volts? Round your answer to the nearest decibel.

Hints

Use the 20 log formula to solve for decibel changes in voltage:

\[ dB = 20 \times \log \left( \frac{V_1}{V_r} \right) \]

Voltage is increasing, so you'd expect a gain, a positive number.

\( V_r \) should be your starting point, 0.004 volts.

\[ dB = 20 \times \log \left( \frac{0.775}{0.004} \right) \]

\[ dB = 20 \times \log (193.75) \]

\[ dB = 20 \times (2.2872417) \]

\[ dB = 45.744834 \]

The expected change is around 46 dB.
10 and 20 Log Practice Problems

• A loudspeaker is rated at 91dB@ 1W@1M. How loud will it play, if measured at 1 meter at 75 watts?

• $10 \times \log \left( \frac{P_1}{P_2} \right) = 10 \times \log \left( \frac{75}{1} \right) = 18.8$ dB

• $91$ dB + $18.8$ dB = $109.8$ dB
A speaker is rated at 88dB@1W@1m. Using a 150 watt amplifier, what will the sound pressure level be at 6 meters?

10 * log (P1/P2) = 10 * log (150/1) = 21.76 dB
20 * log (D1/D2) = 20 * log (1/6) = -15.5 dB

21.76 dB – 15.5 dB = 6.2 dB
88 dB + 6.2 dB = 94.2 dB
Introduction to Loudspeaker Directivity
50% Overlap (center-to-center)

• Pros
  – Excellent coverage at most frequencies (1.2 dB variation)

• Cons
  – Costly
  – Maybe coverage is better than required
  – Negative interaction from nearby loudspeakers
  – Adds too much acoustical energy to space
Edge-To-Edge

• Pros
  – Acceptable coverage at main speech frequencies (5.4 dB variation)
  – Inexpensive
  – Minimum interaction of loudspeakers with each other and room

• Cons
  – May have uneven frequency response
  – May have some low spots in corners
Partial Coverage at 2 kHz

- Advantages
- Good coverage
- About a +/- 2.6 variation in coverage
- Good "middle-of-the-road" design

- Disadvantages
- Some interaction between loudspeakers
- Some acoustical energy introduced

\[ D = r \times \sqrt{2} \]
Question?

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