

SOUND SYSTEM

DESIGN, SOURCES, SCENE

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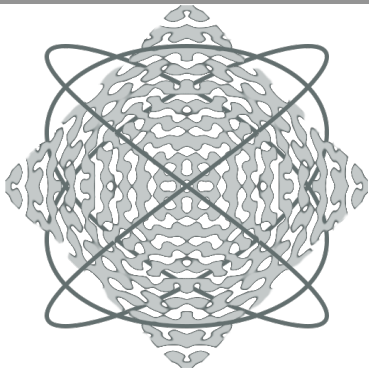
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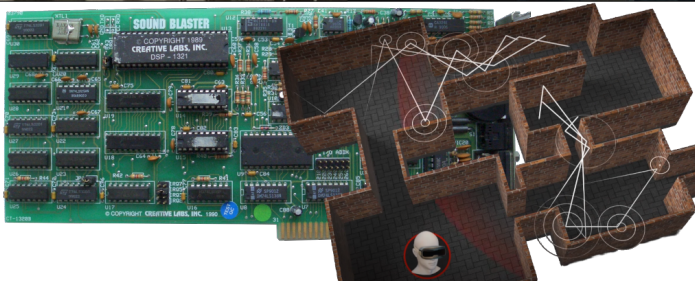
GAME MEDIA STUDIO



INTRODUCTION

SOUND IN GAMES

- User Communication [2]
- Theme, Mood, Emotion [6]
- Movie × Game: Interaction
- Essential Part of Games [3]
 - ▶ User Interface
 - ▶ Interactive Sounds
 - ▶ Communication
 - ▶ World Immersion
- Long History
- → Audio System



SOUND THEORY

PHYSICS OF SOUND

■ Compression Wave

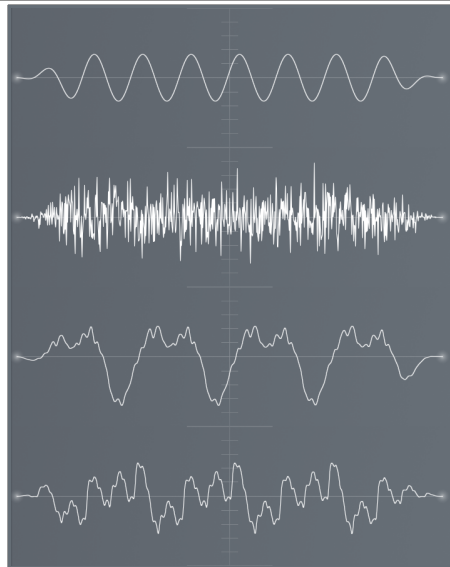
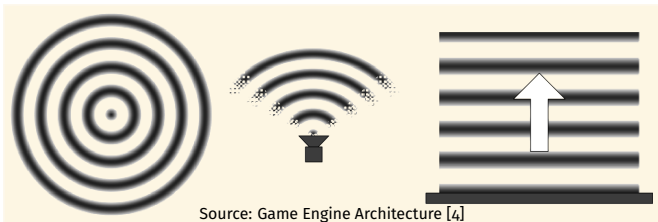
$$p(t) = p_a(t) + p_s(t) [Pa]$$

■ Change in Time \rightarrow Signal

■ Sound Sources

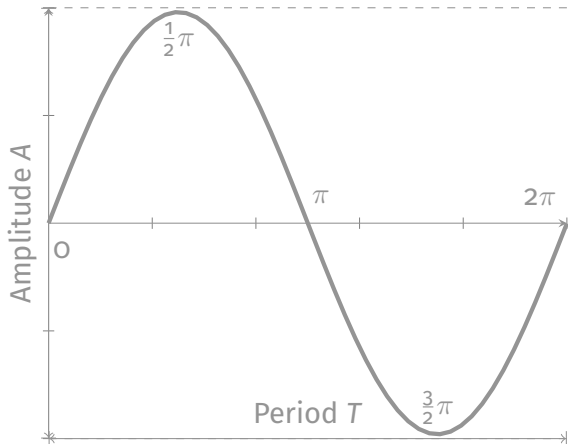
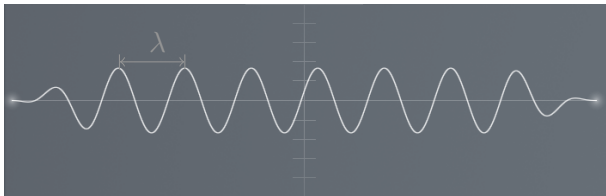
■ Propagation in Medium

- ▶ Wave Properties: Reflect, Refract, Diffract
- ▶ Absorption & Falloff: $p \propto \frac{1}{r}$ $I \propto \frac{1}{r^2}$



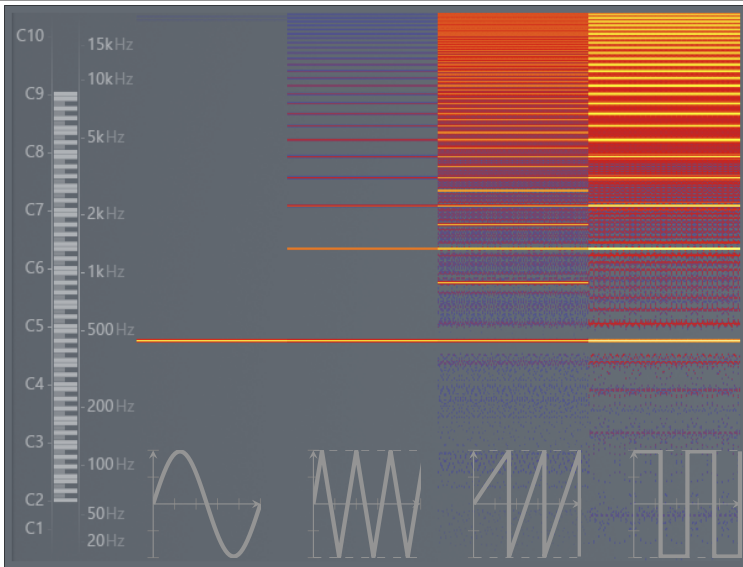
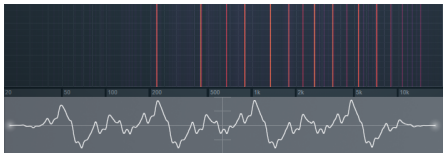
SOUND WAVE ATTRIBUTES

- Periodic Nature
- Period T [s]
- Frequency f [Hz]
- Phase ϕ [rad]
- Speed v [ms^{-1}]
- Wavelength λ [m]



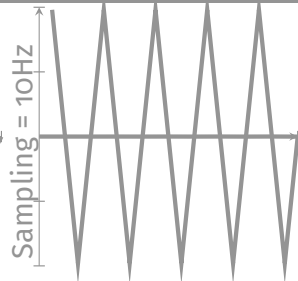
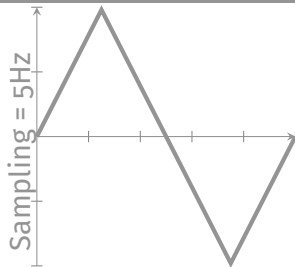
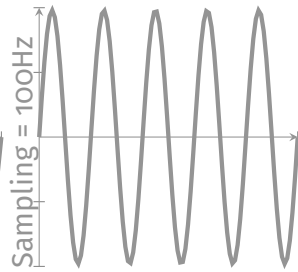
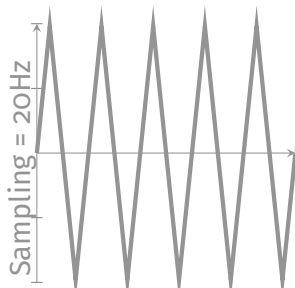
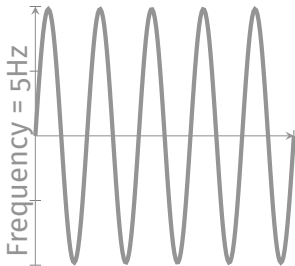
SOUND SPECTRUM

- Signal = Sinusoid Sum
- The Spectrum
- Fourier Transform
time \leftrightarrow *frequency*
- Wave Shapes
 - ▶ Sine
 - ▶ Triangle
 - ▶ Sawtooth
 - ▶ Square



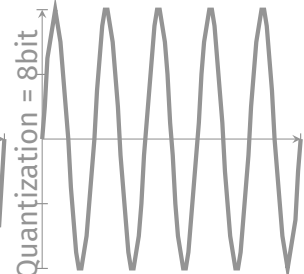
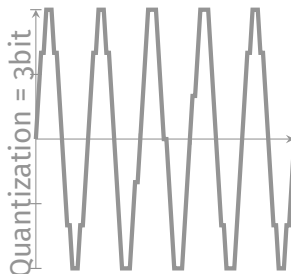
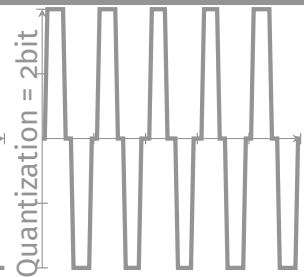
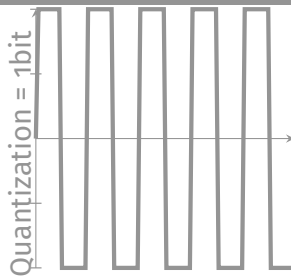
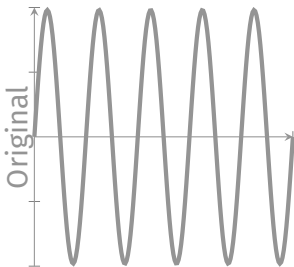
SAMPLING

- Analog → Digital
- AD & DA Converters
- Sampling Frequency
Nyquist–Shannon Theorem
- Quantization



SAMPLING

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PERCEPTION OF SOUND

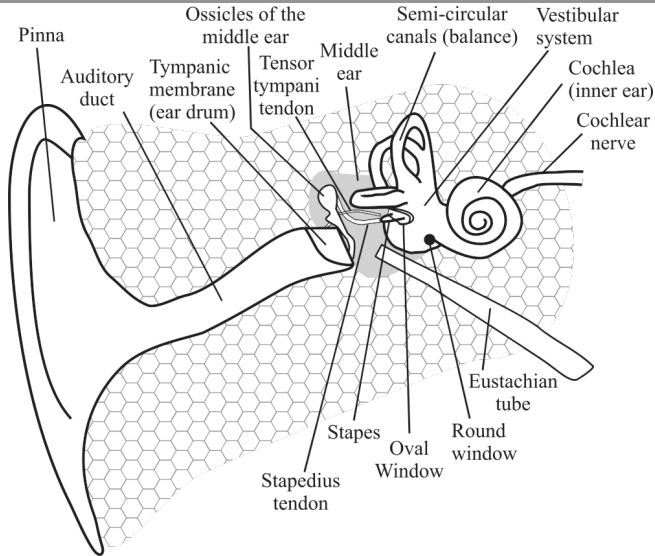
■ Ear Construction [1]

- ▶ External Ear
- ▶ Middle Ear
- ▶ Internal Ear
- ▶ Neural Encoding

■ Sound Loudness [4]

- ▶ Sound Pressure
- ▶ Wide Dynamic Range
- ▶ Logarithmic → decibels [dB]
- ▶ Sound Pressure Level (SPL)

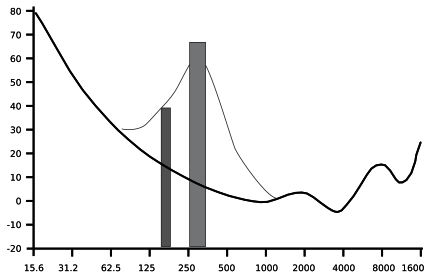
$$L_p = 10 \log_{10} \left(\frac{p_{rms}^2}{p_{ref}^2} \right)$$



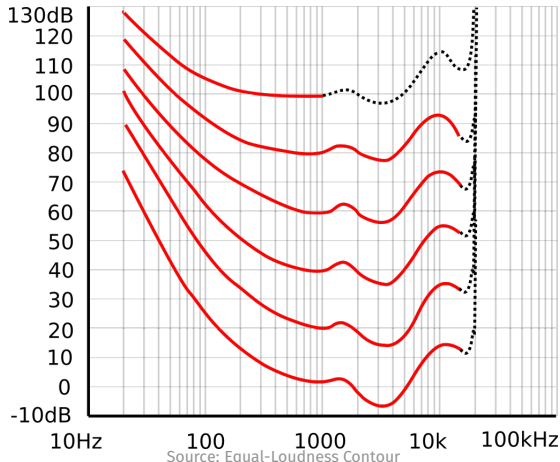
Source: Engineering Noise Control [1]

PSYCHOLOGY AND ACOUSTICS

- Signal Processing → Perception
- Limits of Hearing : 20 Hz–20 kHz
- Psychoacoustics
 - ▶ Fletcher-Munson Curve [5]
 - ▶ Auditory Masking ⇔ [1]
- Gestalt Psychology



Source: Psychoacoustics



Source: Equal-Loudness Contour

SOUND DESIGN

HISTORICAL DEVELOPMENT: 8-BIT

- Arcade Machines [2]
 - ▶ Specialized Hardware
 - ▶ Digital Recording \rightsquigarrow DAC
 - ▶ Sound Synthesis \rightsquigarrow PSG
- Home Consoles [2]
 - ▶ Shared I/O Chip
 - ▶ Programmable Sound
 - ▶ Looping Tracks
- Personal Computers [2]
 - ▶ The Beeper
 - ▶ Programming & Memory



HISTORICAL DEVELOPMENT: 16-BIT

■ Programmable Sound Generator

- ▶ Voice Channels
- ▶ Envelope & ADSR

■ Subtractive Synthesis 1

■ Frequency Modulation Synthesis [2]

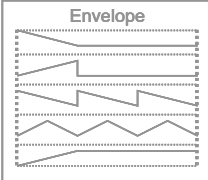
- ▶ Frequency Modulation (I) (II)
- ▶ Synthesizer (I) (II)

■ Table-Based Synthesis

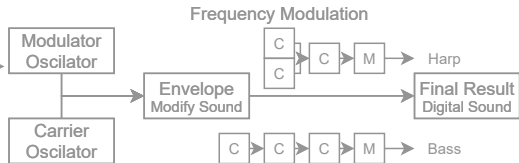
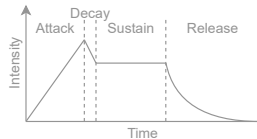
- ▶ WaveTable
- ▶ Granular

Programmable Sound Generator

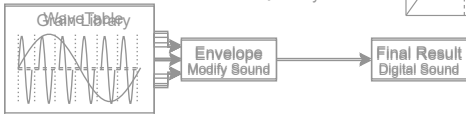
Channel	Frequency	Volume
A	440 0.75	0.75
B	292 0.50	0.50
C	X X 0.00	0.00
...		
Noise	X X 0.00	0.00



The envelope diagram shows four distinct curves: Channel A has a long attack and sustain; Channel B has a shorter attack and sustain; Channel C has a very short attack and sustain; Noise has a very short attack and sustain.

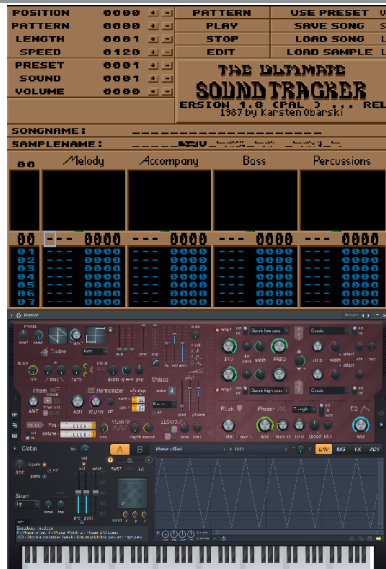


WaveTable Synthesis



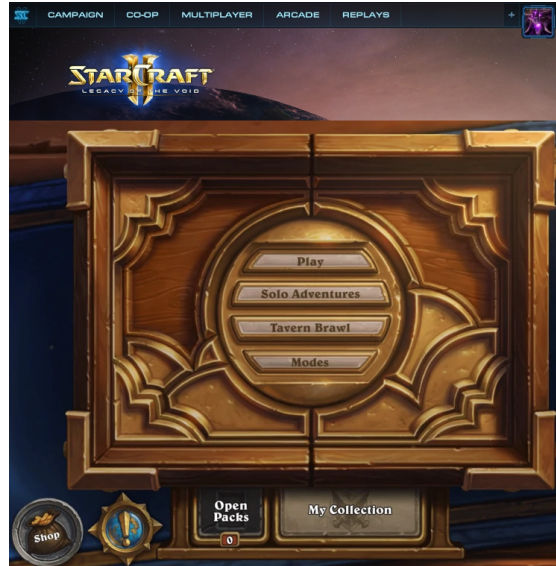
HISTORICAL DEVELOPMENT: SEQUENCING

- “Programmer-Composer”
- Sequencer → Synthesizer
- MIDI
 - ▶ Standard Format
 - ▶ Command Interface
 - ▶ Hardware Dependant Sound
- iMUSE [2] (I)
- Music Tracker (I)
- Digital Audio Workstation



DIGITAL SOUND DESIGN

- DAW → Samples & Synthesis
- Magic of Sound Design (I)
- Diegetic vs Nondiegetic [2]
- Music Track
- Sound Effects Library
- User Interface (I)
 - ▶ Digital
 - ▶ Mechanical



PHYSICAL SOUND DESIGN

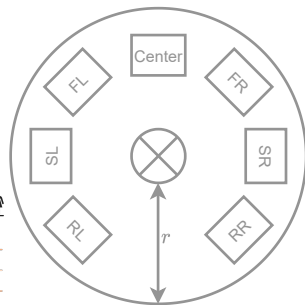
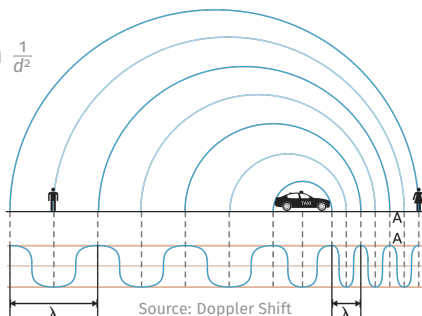
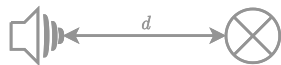
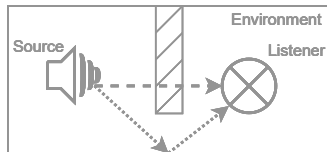
- Physical × Synthesis
- Recording + Touch Up
- Sound Effects
- Music & Voice
- Foley (I) (II)



IMPLEMENTATION

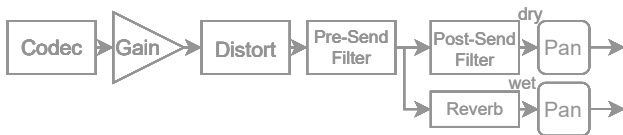
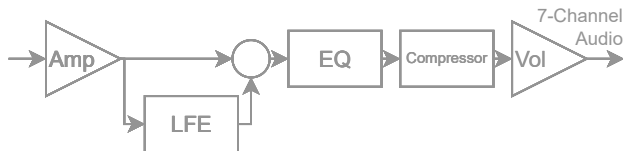
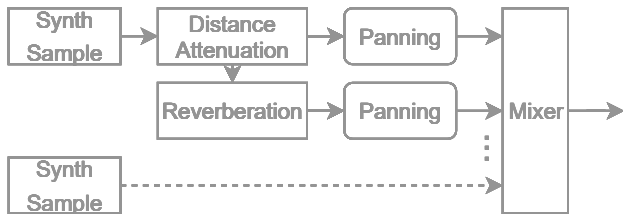
RENDERING THE AUDIO

- Direct Playback?
- Modeling the World [4]
 - ▶ Environment
 - ▶ Sound Sources
 - ▶ Listeners
- Sound Synthesis & Triggers
- Occlusion → Indirect
- Spatialization
 - ▶ Distance Attenuation $\frac{1}{d^2}$
 - ▶ Volume Panning
- Acoustic Modeling
- Doppler Shift
- Real-Time Tricks



AUDIO ENGINE ARCHITECTURE

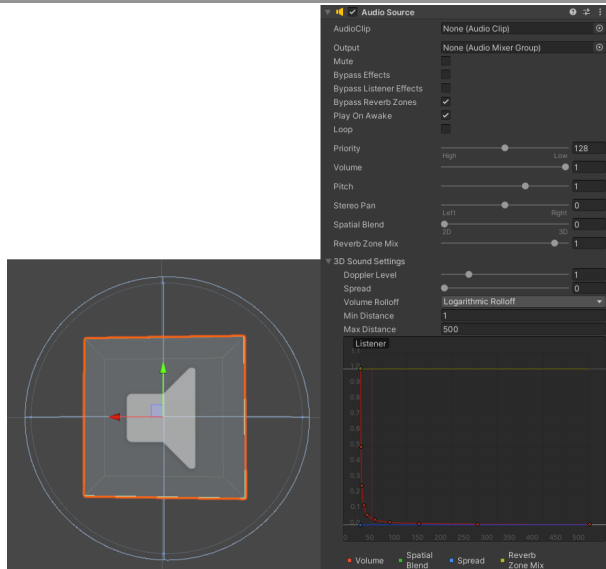
- Audio Processing Pipeline
- Sound Voices
 - Degree of Polyphony
 - 2D × 3D
- Voice Pipeline
- The Master Mixer
 - Mixing Voices
 - Depth & Rate Conversion
- Output Bus
- Audio Engines:
 - System Audio
 - FMOD
 - Wwise



AUDIO IN UNITY

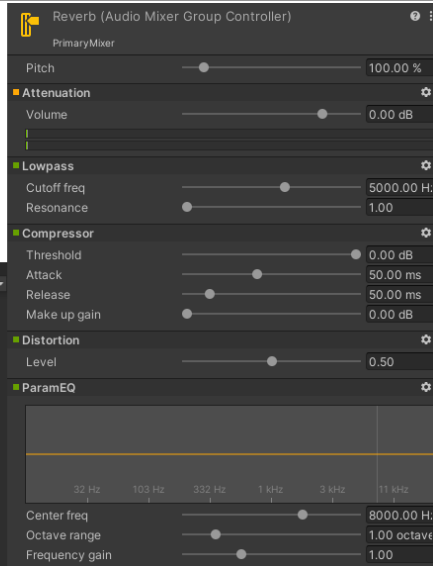
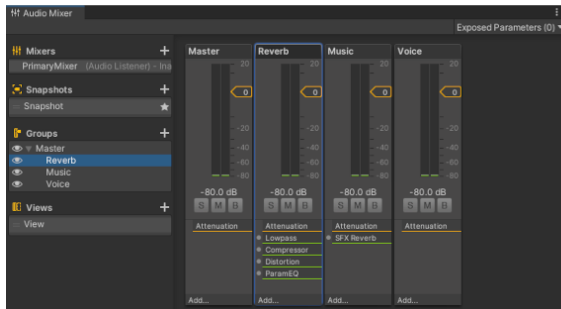
AUDIO OVERVIEW

- Hierarchy Integration
- Audio Source & Listener
- 2D and Full 3D
- Audio Asset Support
- Profiler Section
- Tracker Modules



AUDIO MIXING

- Spatial Blending & Distance
- Equalizer → Groups
- Filters, Parametric Equalizer
- Effects: Reverb, Echo, ...



ADDITIONAL RESOURCES

- [YouTube] Trackers: the sound of 16-bit
- [YouTube] Augmented Second - An Analysis of the Arabic Interval
- [YouTube] Signal Processing for Sound Design
- [YouTube] Magic of Making Sounds
- [Software] Sonic Pi



Source: Toxic Biohazard Synthesizer

Thanks For
Your Attention!

AudioSurf

REFERENCES I

- [1] DAVID BIES. **ENGINEERING NOISE CONTROL**. London: CRC Press, 2017. ISBN: 9781498724050.
- [2] KAREN COLLINS. **GAME SOUND: AN INTRODUCTION TO THE HISTORY, THEORY, AND PRACTICE OF VIDEO GAME MUSIC AND SOUND DESIGN**. Mit Press, 2008.
- [3] JAIME CROSS. **GAME AUDIO AND THE 50% FALLACY**.
<https://speedyjx.com/2015/06/04/game-audio-and-the-50-fallacy/>. 2015.
- [4] JASON GREGORY. **GAME ENGINE ARCHITECTURE, SECOND EDITION**. 3rd. USA: A. K. Peters, Ltd., CRC Press, 2018. ISBN: 1351974288.
- [5] JARED H. **FLETCHER MUNSON CURVE: THE EQUAL LOUDNESS CONTOUR OF HUMAN HEARING**.
<https://ledgernote.com/columns/mixing-mastering/fletcher-munson-curve/>. 2021.
- [6] DAVID SONNENSCHNEIN. **SOUND DESIGN: THE EXPRESSIVE POWER OF MUSIC, VOICE, AND SOUND EFFECTS IN CINEMA**. Michael Wiese Productions Studio City, 2001.