21M.380 · Music and Technology
Recording Techniques & Audio Production

Mastering techniques

Session 25 · Monday, December 5, 2016

# 1 Student presentation (PA1)

- [redacted]

# 2 Preview of remaining semester

- Command-line sound editing on Wed, 12/7
- Don't miss class on Mon, 12/12, you would most likely regret it. ☺
- 5.1 surround sound workshop on Wed, 12/14

# 3 Why master?

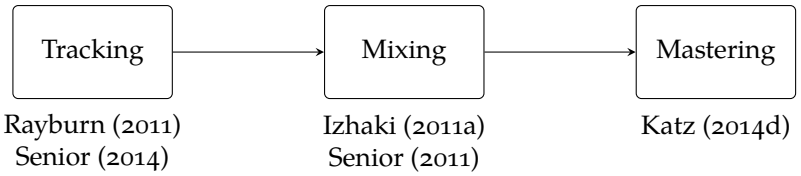


Figure 1. The music production process (after Eargle 2003a, p. 326)

- Often performed by specialized engineer not involved in mixing
- Idea: Unbiased & very expert pair of ears optimizes end result
- Unites focus on very small details with concern for 'big picture'

## 3.1 Improving the overall sound

- E.g., increase impact, punch, brilliance, etc.
- Primarily defines mastering as an art form (discussed in depth later)
- But mastering also includes other, more mundane aspects.

### 3.2 Assembling a coherent album

- Provide coherence between songs on an album (Eargle 2003b, p. 333)
- Track listing: Defining the album sequence (Katz 2014g; RNZ 2015)
- Deciding on length of silence between tracks (Katz 2007c)
  - Considerations: genre, listening environment, playback device
  - Listen & stop with eyes closed to find 'correct' position
- Separate problem: *Where* to put track marker in break between 2 tracks?
- Balancing the perceived loudness of all tracks on an album

### 3.3 Preparation for end-user distribution

- Preparation of files & tapes (cf., Katz 2014e)
- Delivery of media to client & pressing plant
- *Always* listen through your final master in full before you sign it off!
- Anecdote: Gerd Kühr – *Revue instrumental et électronique* (Kühr 2007)
  - Automation envelope mishap in final chord at 31'46"
  - Detected during final listening session (3 am)
  - Another 31'46" of rendering, another 31'46" of proof-listening

## 4 History of mastering (record cutting)

Dates back to creation of metal *masters* used to press vinyl records

### 4.1 Process

- Dorsey (2013): Good general overview
- Eargle (1996): More technical detail
- *Lathe* (turntable with cutting head) cuts *lacquer* (aluminum disc topped with acetate plastic layer)
- Cutting head receives L/R signals and *mechanically* M/S-encodes them[1]
  - Lateral cutting head movement corresponds to sum signal $M = L + R$
  - Vertical movement corresponds to difference signal $S = L - R$
- One can listen to the sounds cut onto a lacquer, but:
  - Softness of acetate plastic layer optimized for cutting, not playback
  - Repeated playback will wear out HF content of groove
- Instead, multi-step process yields vinyl disc for end user (cf., figure 2)

[1] The animations by Sourisseau (1997) illustrate this process very comprehensively.

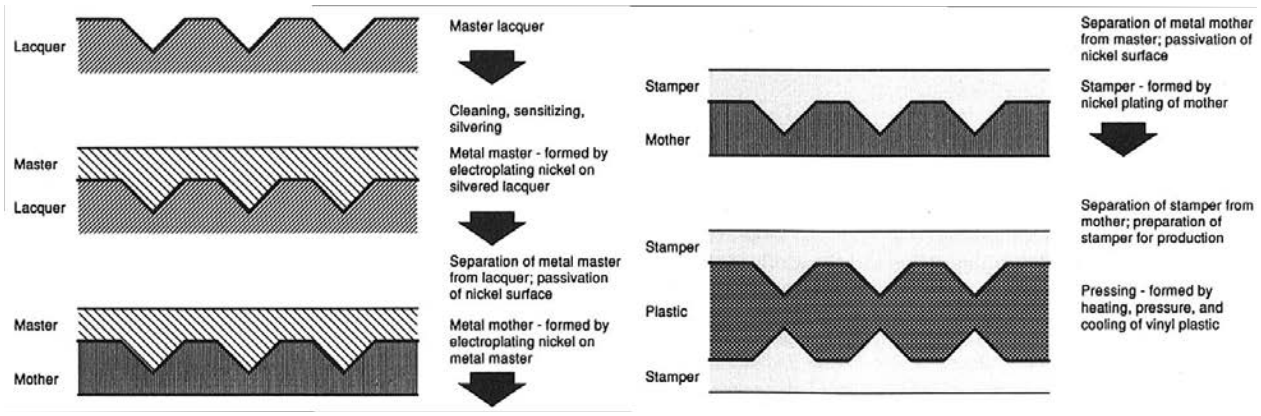


FIGURE 2. Record replication process (Eargle 1996, p. 488. © . All rights reserved. This content is excluded from our Creative Commons license. For more information, see http://ocw.mit.edu/help/faq-fair-use/)

1. Silver layer deposited on lacquer to make it conductive
2. Electroplated to create metal *master* (negative)
3. From that make a metal *mother* (positive)
4. From that make a *stamp* (negative)
5. From that press actual vinyl records

### 4.2 Bass requires space

- Record grooves do *not* represent $A(t)$ as in DAW waveform!
  - Reason: Stylus *velocity* (not elongation) constant across freq. range
  - Implication: Greater stylus excursion per waveform period $T$ for LF
  - So low frequencies occupy more groove width than high ones![2]
- Interesting: Requires aesthetic compromises *inherent to medium*:
  - Record with more bass has to be quieter or shorter
  - Wider stereo image → needle more likely pops out of groove
- Particularly relevant in electronic dance music (EDM):
  - Genre-specific emphasis on bass
  - Groove stability crucial (subwoofer meets Technics SL-1210 turntable)
  - But still need to fit all the music onto the vinyl!

[2] This was the reason for the introduction of RIAA pre-emphasis and de-emphasis, the need for which was recognized already in 1926 (Rumsey and McCormick 2009, p. 595)

## 5 Mastering engineer's toolkit

Typically increased focus on very high quality hardware & software!

- Excellent pair of studio monitors
- But also alternative (and often cheap) 'real-world' playback systems
- A/D and D/A converters

- Sample rate converters
- EQs
- Dynamics processors (more focus on limiters & expanders)
- Signal meters
- Noise reduction
- Stereo enhancers, exciters, tube emulators, etc.

# 6 Processing chain

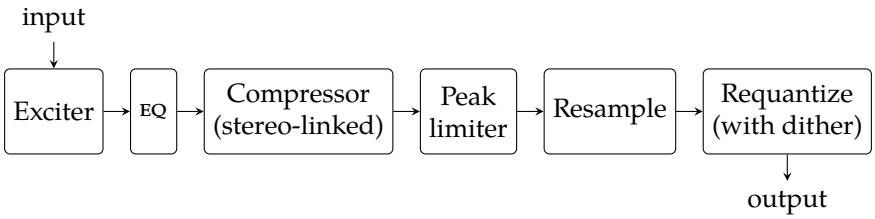


FIGURE 3. Typical mastering chain

- Dedicated plugins, e.g.: Izotope's *Ozone* suite (cf., Ariza 2012a, pp. 261 f.)
- But not unusual to use analog devices plus high-quality ADC/DAC!
- Selection and order of processors *really* depends on circumstances!
- Figure 3: Example of a typical mastering chain
  - Includes some guidelines re. order (e.g., excite early, requantize last)
  - See Katz (2014a, p. 131) & Ariza (2012a, pp. 257 f.) for details
- Rules of 👍:
  - *Less is more!* Applies to number of processors & intensity of use
  - Link L & R channels of stereo input to ensure identical FX parameters

## 6.1 Exciter

- Put early in the signal chain (Ariza 2012a, p. 257)
- Originally analog hardware. Pioneer: Aphex Aural Exciter (1975)
- Today often DSP-based (might model tube saturation etc.)
- No coherent definition, but usually some combination of:
  - Dynamic EQing depending on input signal
  - Subtle overdrive to add favorable harmonic distortion
  - Synthesis of higher harmonics (or sub-bass)
  - Phase manipulation
- (Dis)advantages (Ariza 2012a, p. 262):
  - In right doses can add warmth and presence to dry and cold mixes
  - Excessive use might make mix too bright or edgy

## 6.2 EQ

- Goal: Improve spectral balance (but inevitably affects level balance!)
- Linear-phase EQs more relevant than elsewhere (cf., Katz 2017)
- Katz (2014b) discusses mastering-specific EQing techniques
- Recommendations by Ariza (2012a, p. 261):
  - *Less is more!* $\pm 3$ dB may be sufficient
  - Confirm by ear over long listening periods & by A/B comparisons
- Common applications (Ariza 2012a, p. 261):
  - Focusing middle range: Use parametric EQ to boost or cut
  - Controlling bass: Boost 80 Hz to 120 Hz; cut $<$ 60 Hz
  - Boosting 'air' or 'sparkle': Seductive, but danger of long-term fatigue
  - DC offset removal: high-pass at $<$ 20 Hz
- EQ $\rightarrow$ compressor is perhaps the more common order in mastering:
  - Preferable with *multiband* compressors (Ariza 2012a, p. 257)
  - But compressor might undo EQ effect if some emphasized frequency range causes it to overreact (Katz 2014a, p. 131)
  - In that case, consider reverse order (compressor $\rightarrow$ EQ)
  - Senior (2011, p. 180): General advice on order of EQ & compression

## 6.3 Stereo compressor

- An essential mastering tool (Eargle 2003b, p. 333)
  - Closes the circle: We start & end with compression
  - But more subtly applied in mastering than in stem preparation
- May increase punch… or flatten sound and take life out of it
- Rules of 👍 (Ariza 2012a, p. 259):
  - Low ratios
  - Low tresholds
  - Long attacks, short releases
- Music mastering compression recipe (Katz 2014c, pp. 84, 93)
  - Attack time: 30 ms to 300 ms (average: 100 ms)
  - Release time: 50 ms to 500 ms (average: 150 ms to 250 ms)
  - Ratio: 1.5:1 to 2:1. Threshold: −20 dB to −10 dB
  - More subtle: Ratio: 1.01:1 to 1.1:1. Threshold: −40 dB to −30 dB
  - "Delicate painting": Ratio: 1.01:1. Threshold: −3 dB

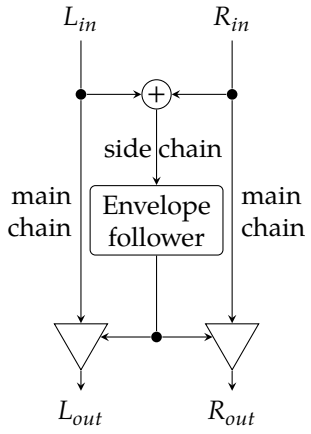


FIGURE 4. Stereo compressor

- Multiband compressors frequently used (Ariza 2012a, pp. 260 f.):
  - Blessing and curse: Allows to change mix balance after the fact
  - Potential tendency to overcompress (use with care!)
- Remember to *link stereo channels* (cf., figure 4)!

## 6.4 Stereo enhancer (M/S processing)

- Note: Not shown in signal chain of figure 3
- Goal: Improve spatial balance
- We previously discussed stereo enhancing mono signals ('fake' stereo)
- In mastering, however, we typically have a signal that is already stereo
- Tricky: How to adjust width of a stereo signal *after* the mix?
- Answer: M/S-based processing (cf., figure 5). Build your own in a DAW:
  1. Encode L/R stereo mix to M/S
  2. Adjust S/M ratio (e.g., increase to widen image)
  3. Optional: Compress, EQ, reverberate M/S signal (Katz 2014a, pp. 135 ff.)
  4. Decode to L/R again
- Works best with coincident stereo recordings (why?)

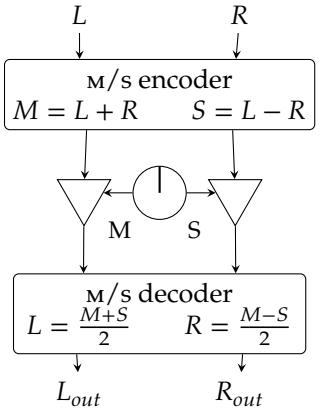


Figure 5. M/S-based stereo enhancer (cf., Senior 2011, pp. 262 ff. Katz 2007a, pp. 210 ff.)

## 6.5 Peak limiter

- Put late in the signal chain (last step before resampling & requantizing)
- Ariza (2012a, p. 258) provides suggestions for parameter settings

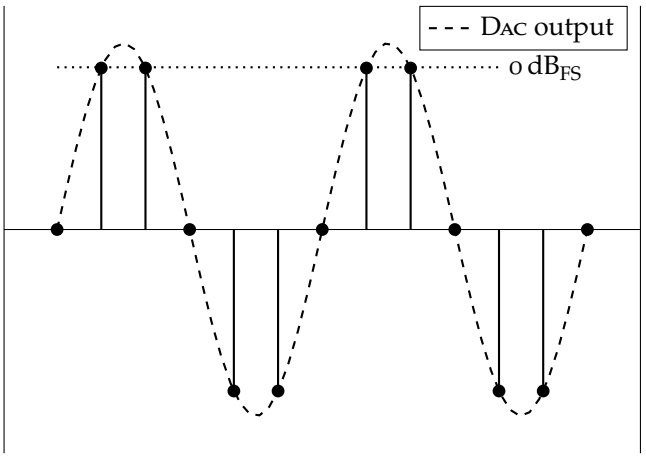


Figure 6. Inter-sample peaks in D/A conversion

- Rule of 👌: Don't limit all the way up to 0 $dB_{FS}$!
  - Reason: *Inter-sample peaks* (cf., figure 6)
  - Clipping behavior can vary among different DACS
  - Limit to, say, −0.2 $dB_{FS}$ (Ariza 2012a, p. 258)
- Peak limiting frequently (mis)used as a means of maximizing loudness
  - Evidence shows: Louder media (radio stations, CDS) are preferred
  - But no predictable relation to perceived loudness ☹
  - Resulted in *loudness war* (Katz 2014h)
- However, excessive limiting can make a mix sound very flat!
  - Katz (2007b, pp. 213 f.) suggests guidelines for compromises
  - Consider *loudness normalization* as an alternative

## 6.6 Loudness normalization (LUFS, EBU R128, CALM Act)

- Holistic, modern approach towards loudness management
- Let's use it to end the *loudness war* (Katz 2014h)!
- Legislation for broadcasting exists in US (CALM Act, ATSC A/85) & EU
- Recommendations: ITU-R BS.1770-4 (ITU 2015); EBU R128 (Camerer 2011)
- New measure: LUFS ("loudness unit with regards to full scale")
  - Models perceived loudness (cf., Hollerweger and Holzmann 2012)
  - Nice: Predict how loud production will be compared to others ☺
- Requires dedicated loudness meters (Katz 2014i)
  - Robin Gareus' excellent LV2 meter plugins (not just LUFS)
    Debian/Ubuntu: `sudo apt-get install x42-plugins`
  - *Hindenburg* audio editor comes with integrated LUFS metering
- Requires calibrated monitoring (Katz 2014j)
- Which LUFS value should I use?
  - EBU R128 recommends −23 LUFS for broadcasting
  - Higher targets may be required for other applications
    (web audio, portable music players, etc.)
  - No definite standards yet (for guidelines, see Hollerweger 2013)

### 6.7 Resampling

- Different interpolation algorithms (e.g., sinc, ZOH, linear)
- Significant differences in sound quality!
- Smith (2017) describes theory & implementation in depth
- High-quality FLOSS converter: `sndfile-resample`
  Debian/Ubuntu: `sudo apt-get install samplerate-programs`

### 6.8 Requantizing (with dither & noise shaping)

- *Requantizing*… fancy term for 'changing the bit depth'
- May be required in order to match target medium (e.g., CD: 16 bit)
- Should always happen last!
- Remember to dither & noise-shape when moving to a lower bit depth!
- FLOSS converter: `sndfile-convert`
  Debian/Ubuntu: `sudo apt-get install sndfile-programs`

## 7 Mastering workflows

- Idealized goal: Mastering happens *after* mixing stage is completed
  "When the mix is done, it should be done!" (Katz 2014a, p. 133)
- Motivations:
  - Breaking down complex process into manageable entities
  - Allowing everyone to focus on what they are best at
  - Retaining sanity (don't tweak the mix forever)

### 7.1 Mastering from stereo mix

- Traditional approach
- Mastering engineer receives *only* stereo mix from mixing engineer
- No possibility to 're-open' the mix (can also be a blessing)
- Re-submission of mix requested only in case of significant problems

### 7.2 Mastering from stems

- Becoming more common, due to ease of rendering in DAW environments
- Mastering engineer receives from mixing studio
  1. Stereo mix
  2. Set of stems which yields same mix when played together[3]

[3] Usually instrumental stems are submitted, i.e., one stem per instrument (rather than per microphone). Note that even a center-panned mono signal (e.g., bass) might be deliberately provided as a stereo stem (in this case with identical L/R signals), to avoid ambiguities with regards to the intended panning. The idea is that if all stems play at 0 dB, the result should perfectly match the submitted stereo mix.

- Mastering process focuses on stereo mix as usual
- But possibility to 're-open' mix if need be (Izhaki 2011b, p. 53)
- See also Katz (2014a, pp. 133 f.)

### 7.3 Surround mastering

- Special requirements for mastering in 5.1 surround
- Workflows & best practices still under much development
- Consult Katz (2007d, 2014f) to learn more about state of the art

## 8 DAW workflow suggestion[4]

[4] Ariza 2012b, pp. 252 ff.

1. Mix from 16 or 24 bit sources without FX on master output track[5]
2. Render stereo mix from DAW in 24 bit *without* dither
3. Create a new 24 bit DAW session for mastering
   (a) Add stereo mix to new input track
   (b) Add mastering processing chain to input track with stereo mix
   (c) Duplicate *clean* input track (for quick A/B comparisons)
4. Render to final master. Depending on bit depth of target medium:
   - Render to 24 bit *without* dither & noisehaping, or:
   - Render to 16 bit *with* dither & noisehaping

[5] Note that DAWS use higher bit depths (32 or 64) internally to provide headroom for digital signal processing purposes.

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