Measuring Loudness

EECS 4462 - Digital Audio

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YORK UNIVERSITÉ UNIVERSITY

Measuring loudness

- How to compute a measure of perceived loudness for a digital audio signal?
- The largest absolute value for the samples is a very poor measure
  - The whole distribution of sample values affects the perceived loudness
  - The frequency content of the signal also affects the perceived loudness

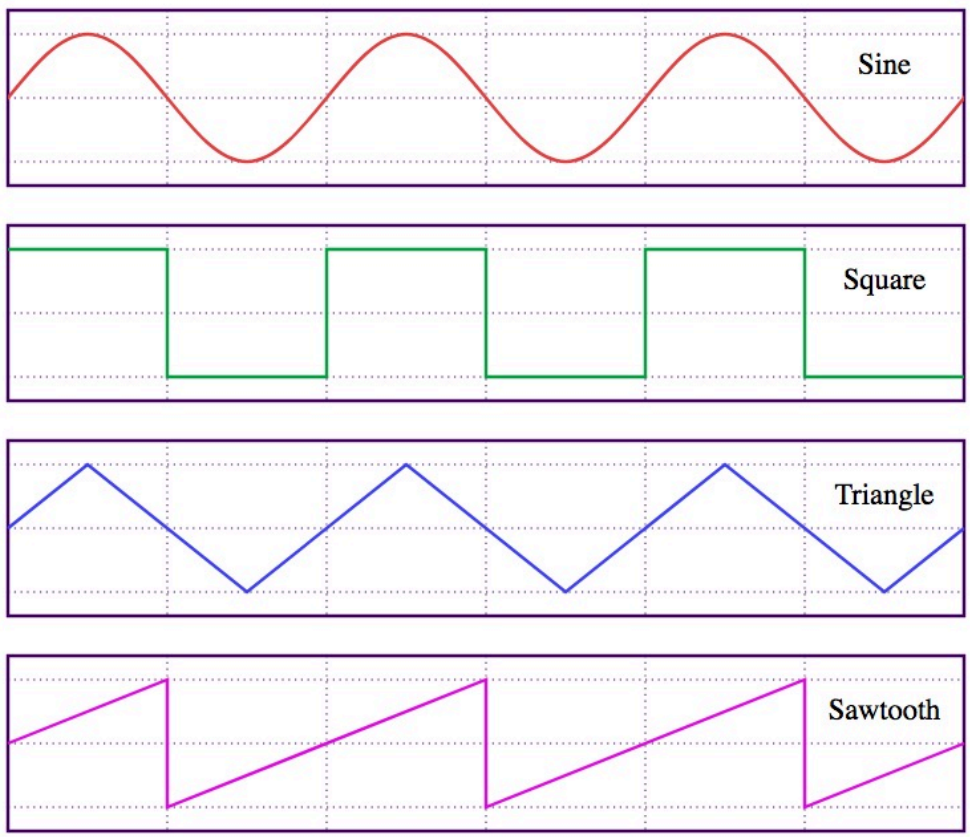
A first approach: RMS

- Averages sample values over a set of n samples
  - RMS = Root Mean Square

$$x_{\text{rms}} = \sqrt{\frac{1}{n}\left(x_1^2 + x_2^2 + \cdots + x_n^2\right)}$$

- Computed every *h* samples (*h* can be as low as 1) for a block of *n* samples
  - *n* is chosen so that computation spans a significant amount of time, such as half a second

RMS values of standard signals



$\frac{A_1}{\sqrt{2}}$

A_1

$\frac{A_1}{\sqrt{3}}$

$\frac{A_1}{\sqrt{3}}$

Audacity demo

A_1 is max amplitude

https://en.wikipedia.org/wiki/Root_mean_square

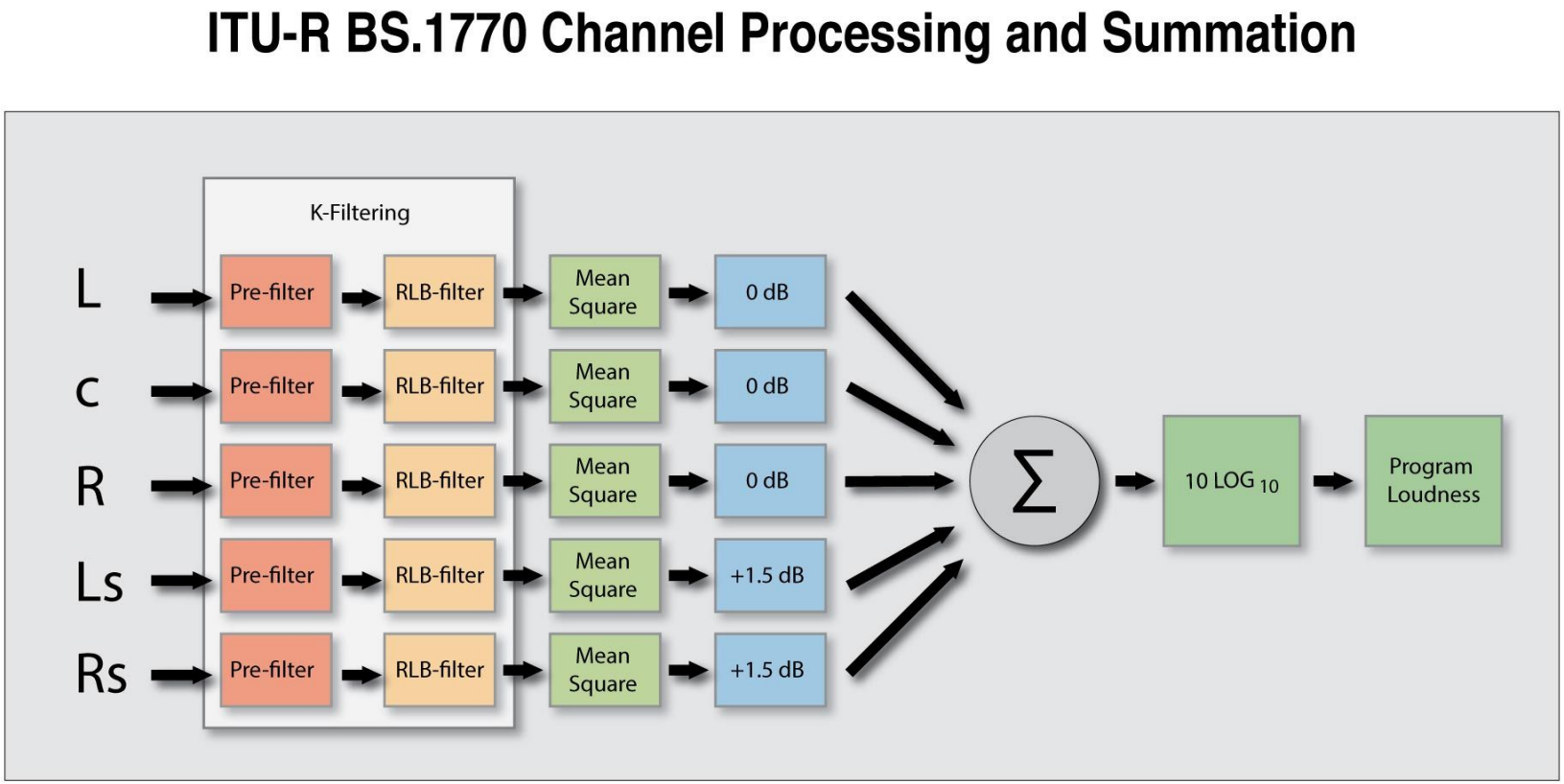
Weighting filters

- In order to compensate for the different response of the human ear to different frequencies a weighting filter (similar to dBA for sound measurement) must be applied
- The ITU-R BS.1770 recommendation requires:
  - A pre-filter raising the levels above 2kHz by 4dB to compensate for the effect of the human head
  - A Revised Low frequency B-weighting filter (RLB) to high pass low frequencies
  - The combination of these two filters is referred to as a k-weighting filter (see next slide)
  - RMS is calculated after the k-weighting filter is applied
  - Rear channels are also raised by 1.5dB

K-Weighting filter

https://ask.audio/articles/demystifying-the-confusion-around-loudness-metering-levels

Total loudness



https://ask.audio/articles/demystifying-the-confusion-around-loudness-metering-levels

EBU R-128

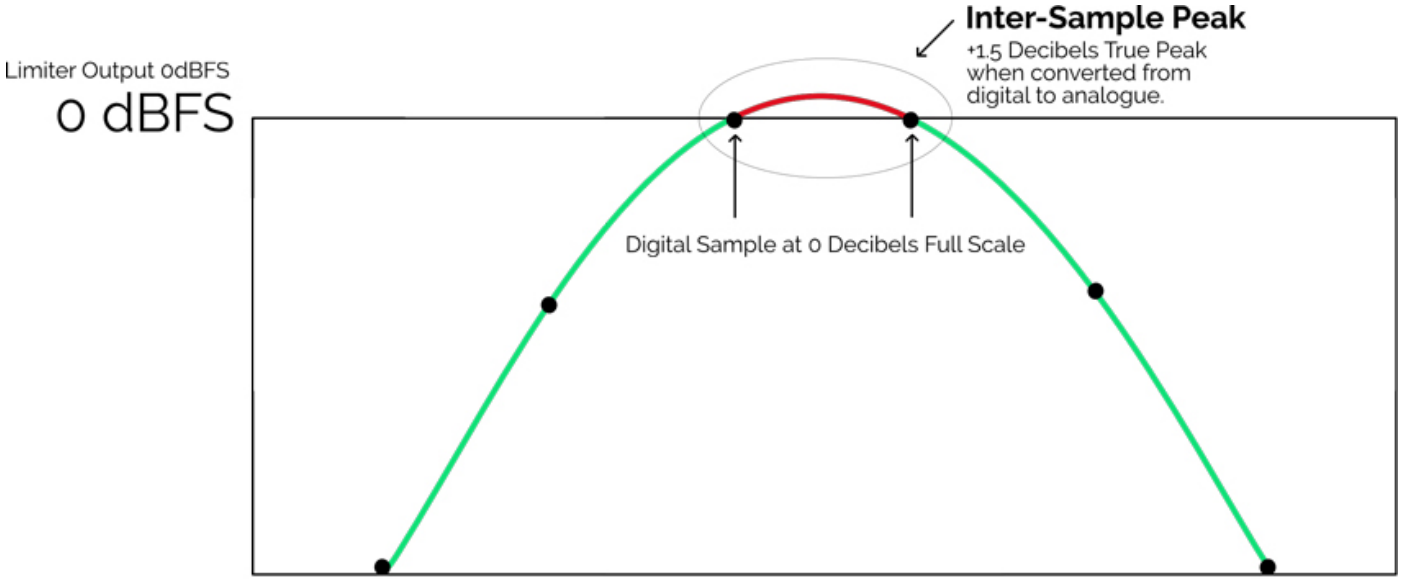
- A European Union standard that accepted the ITU-R BS.1770 recommendation
- Measures loudness in Loudness Units (LU)
  - 1 LU = 1 dB
  - LUFS = LUs referenced to digital Full Scale
    - Sometimes written as LKFS
- Added a gating function that halts computation if the level is less than 10 LU below the target, so that long sections of silence do not bias the calculation
- Canada has not adopted such a standard yet

Types of loudness in EBU R-128

- **Momentary Loudness** measures the loudness of the past 400 Milliseconds.
- **Short Term Loudness** measures the loudness of the past 3 Seconds.
- **Integrated Loudness** indicates how loud a broadcast is on average, and is measured over the entire duration of material (also called Programme Loudness).
- **Loudness Range** quantifies, in LU, the distribution of short term loudness within a broadcast.
  - The top 5% and the lowest 10% of the total loudness range is being excluded

EBU-R 128 target levels

- Broadcasting must be at -23 LUFS integrated loudness
- Short term loudness cannot be more than -18 LUFS
- Maximum true peak level must be -1dBTP
- True peaks are possible inter-sample peaks



https://www.pro-tools-expert.com/home-page/2016/9/7/video-true-peak-metering

Conclusion

- Youtube normalizes all audio to -14 LUFS
- iTunes (Soundcheck) uses -16 LUFS
- Logic demo
- https://www.youtube.com/watch?v=iuEtQqC-Sqo&t=15m35s