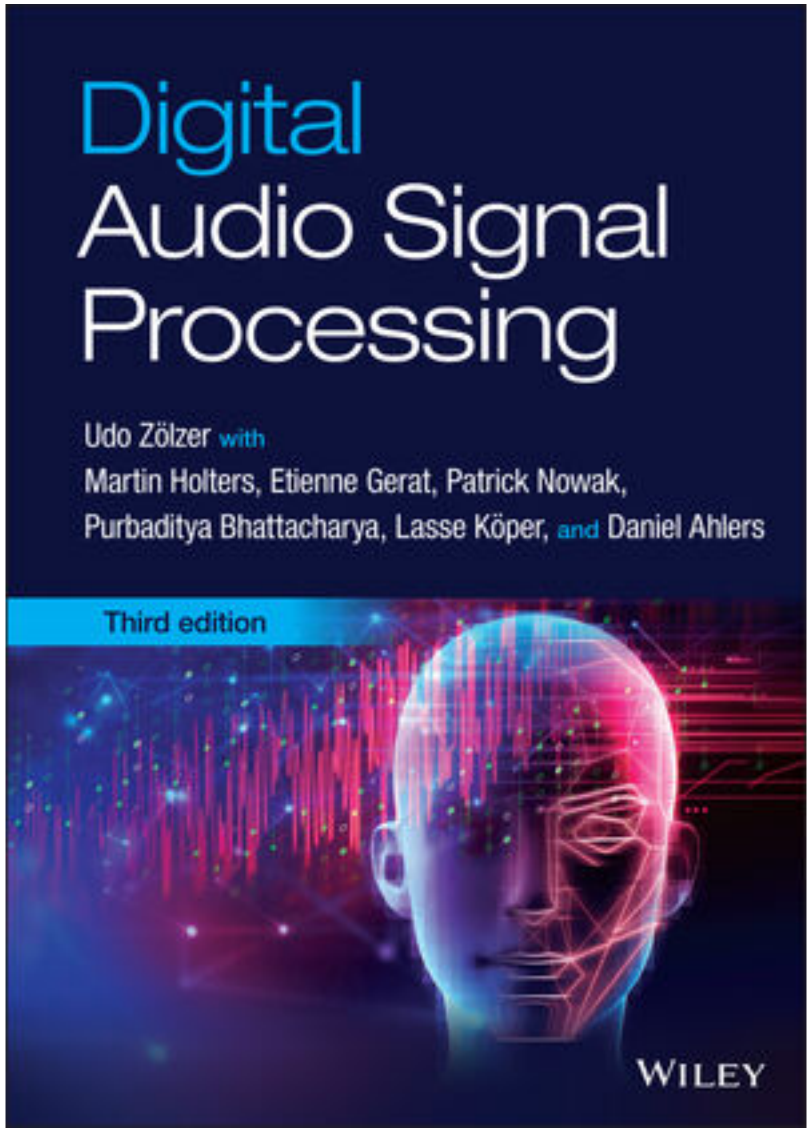


Lecture by Udo Zölzer

- Introduction
- Quantization
- Sampling Rate Conversion
- AD/DA Conversion
- Equalizers
- Room Simulation
- **Dynamic Range Control**
- Audio Coding
- Nonlinear Processing
- Machine Learning for Audio

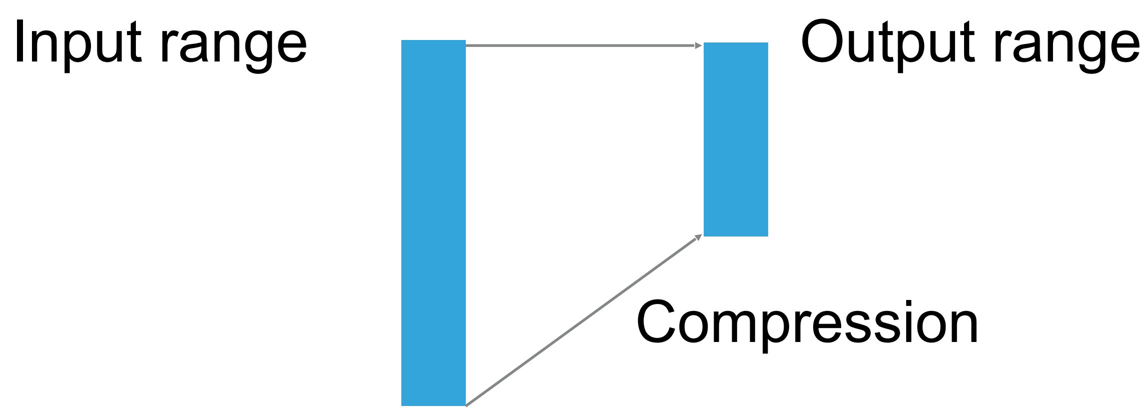
DYNAMIC RANGE CONTROL

OUTLINE

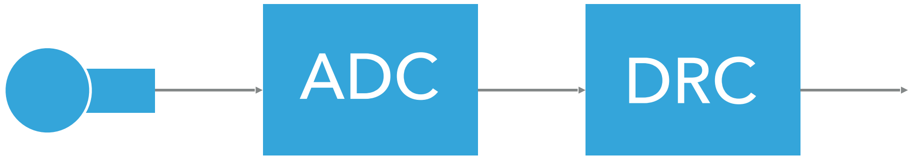
- Basics
- Static curve
- Dynamic behavior
- Realization aspects

APPLICATIONS

- Fitting the dynamic range of the audio signal to the application

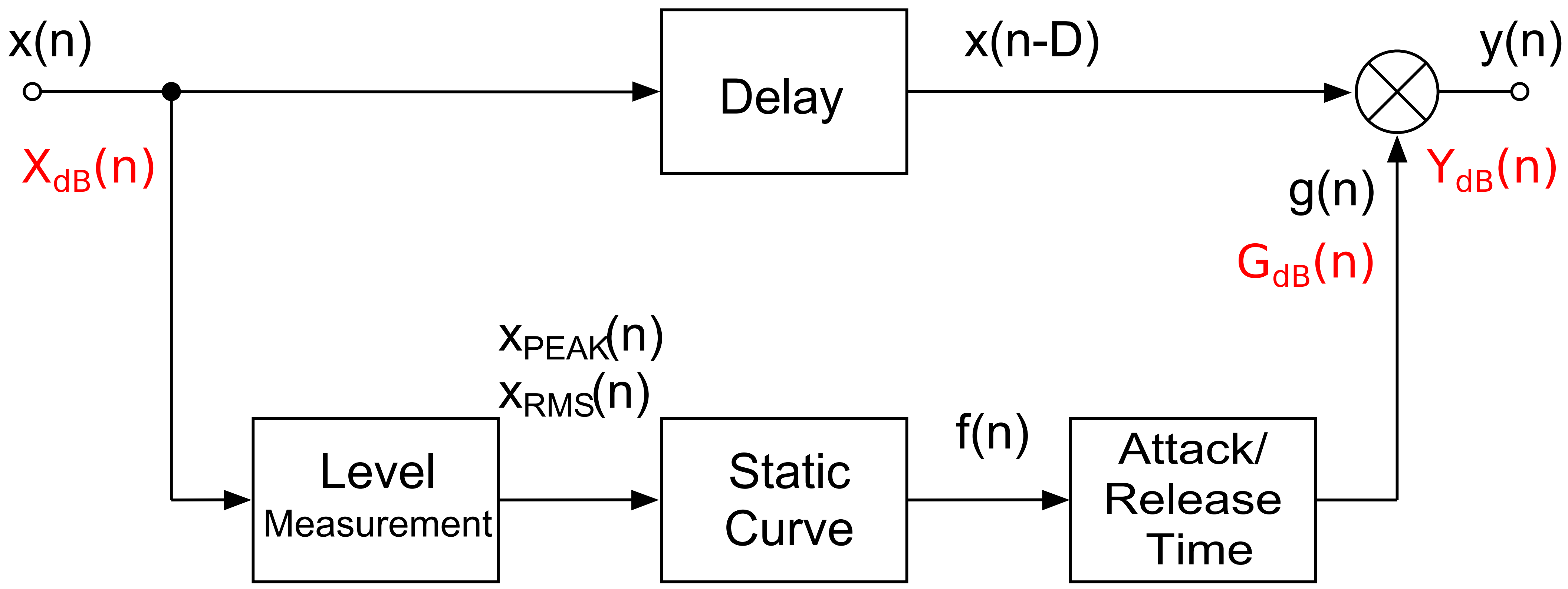


- Microphone processing



- Car entertainment (automatic volume control)

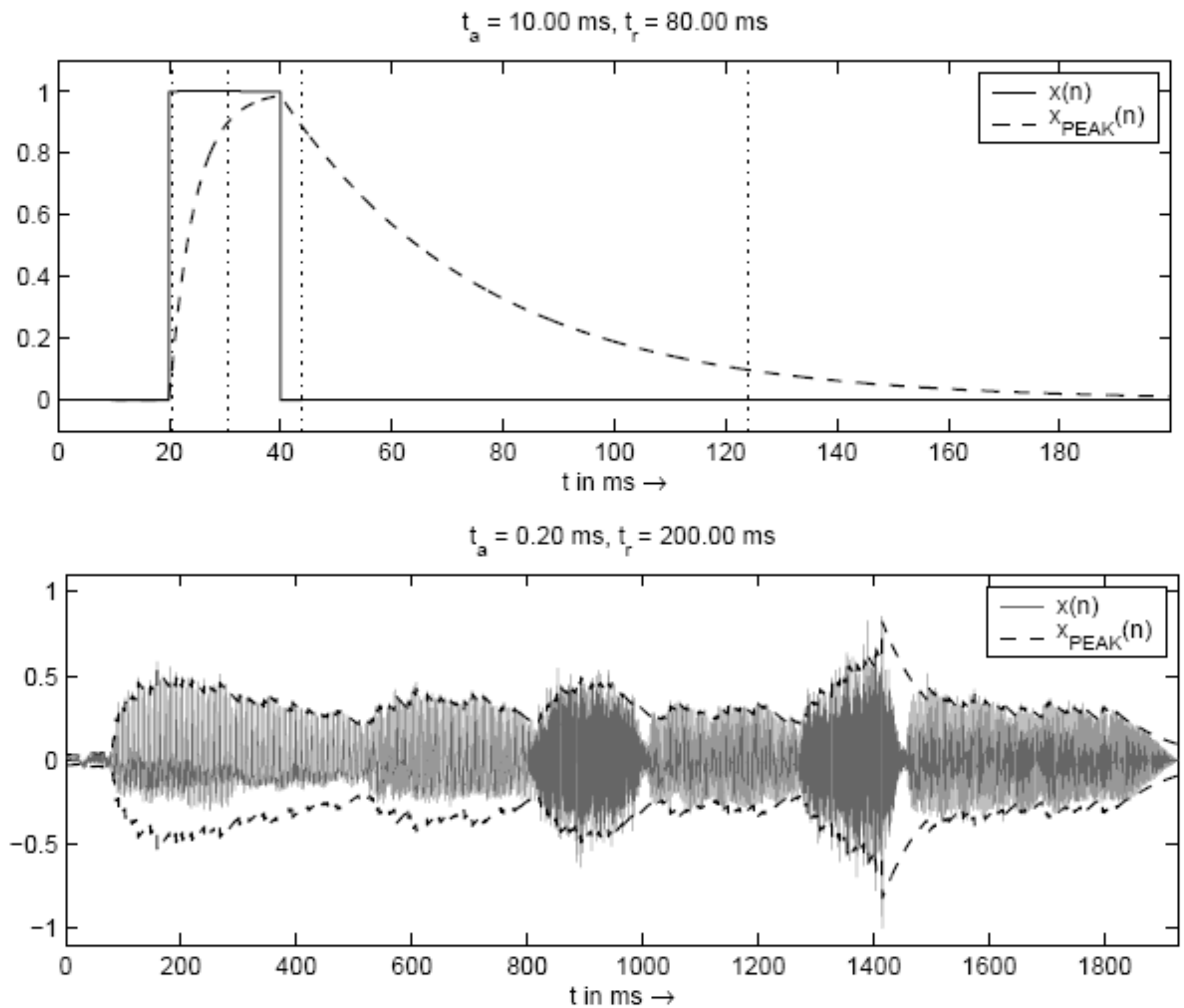
FUNCTIONAL UNITS



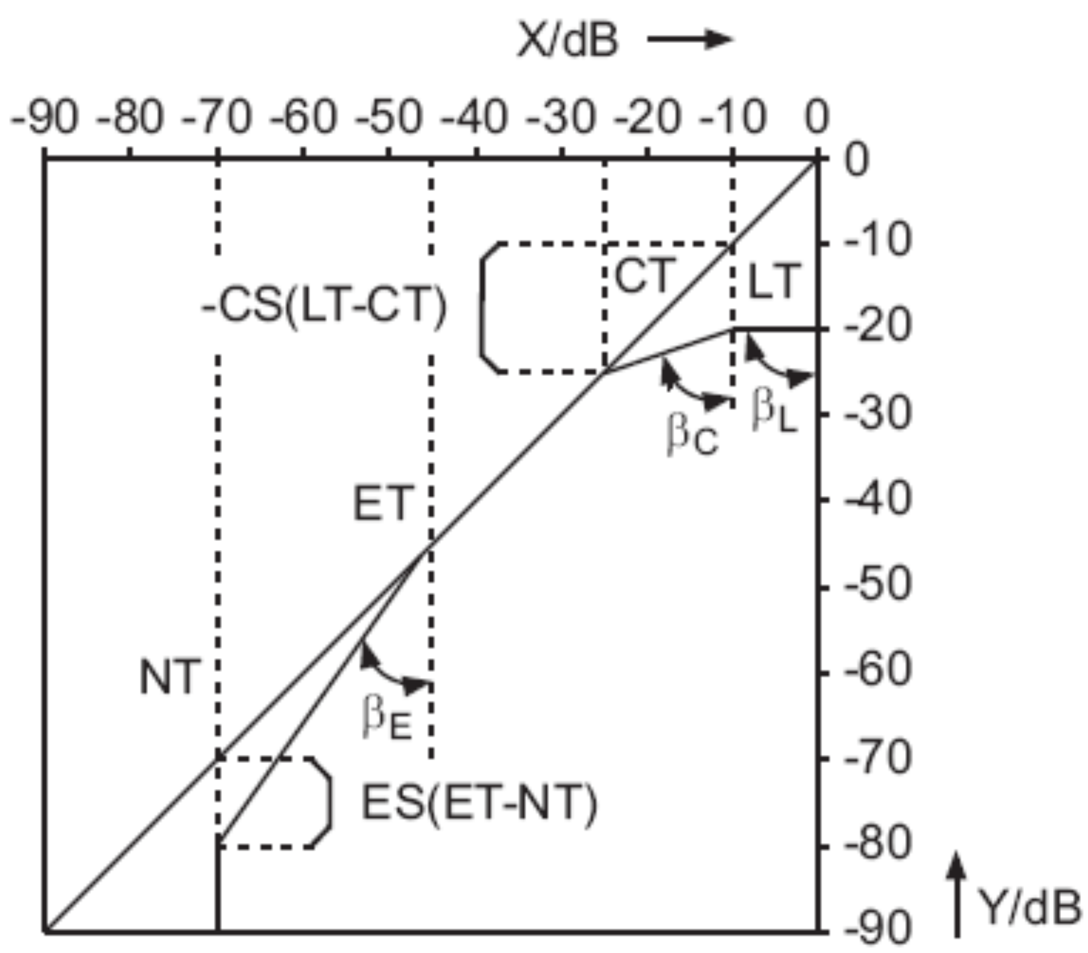
$$y(n) = g(n) \cdot x(n-D) \Rightarrow Y(e^{j\Omega}) = G(e^{j\Omega}) * X(e^{j\Omega})e^{-jD\Omega}$$

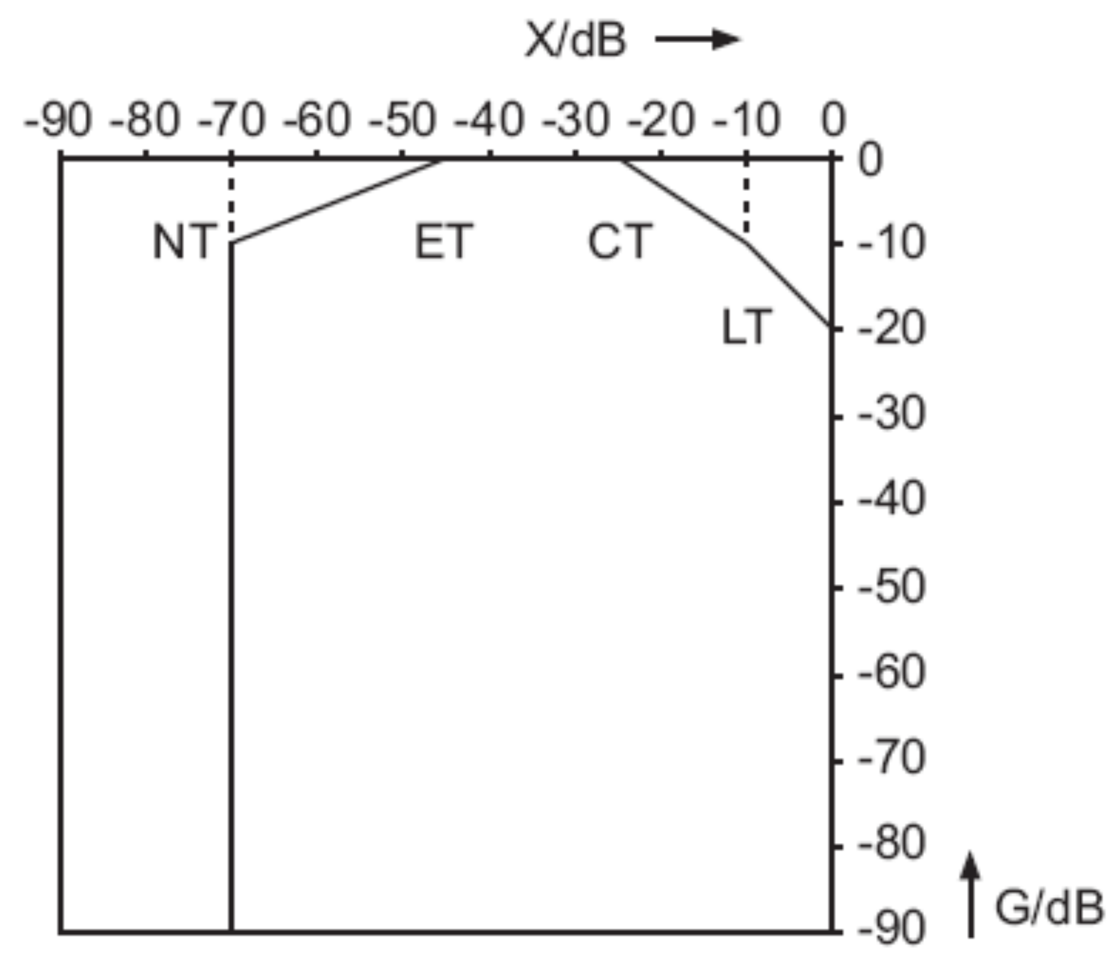
$$Y_{\mathrm{dB}}(n) = G_{\mathrm{dB}}(n) + X_{\mathrm{dB}}(n)$$

ATTACK AND RELEASE TIMES



STATIC CURVE





$$Y_{\mathrm{dB}}(n) = X_{\mathrm{dB}}(n) + G_{\mathrm{dB}}(n)$$

PEAK LEVEL MEASUREMENT

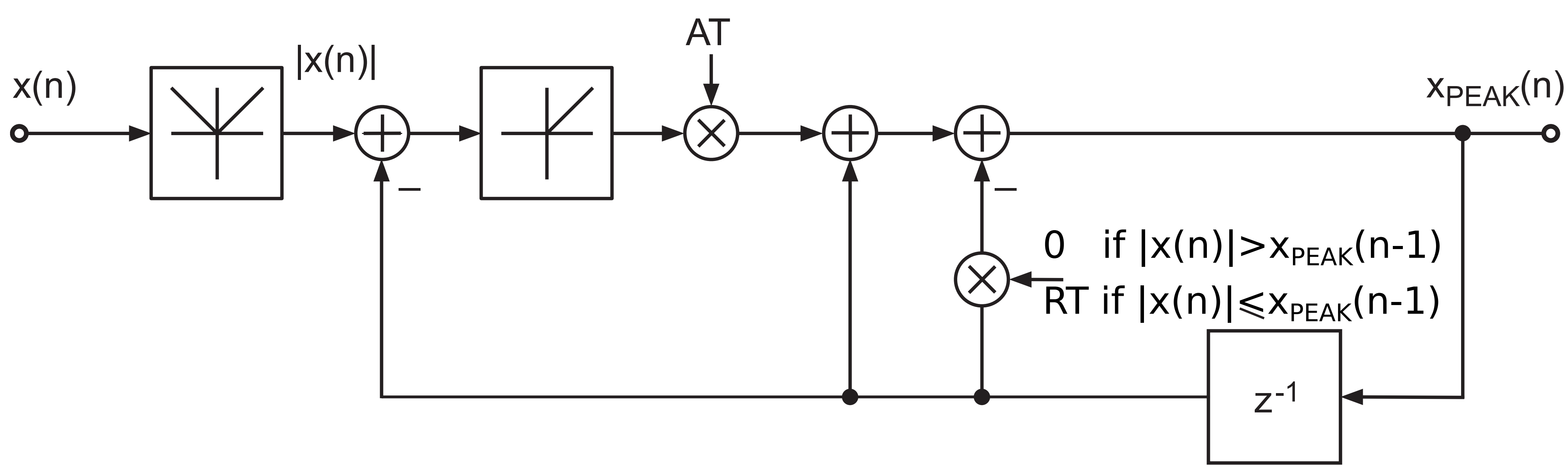
Attack operation

$$x_{\mathrm{PEAK}}(n) = (1 - \mathrm{AT}) \cdot x_{\mathrm{PEAK}}(n-1) + \mathrm{AT} \cdot |x(n)| \qquad H(z) = \frac{\mathrm{AT}}{1 - (1 - \mathrm{AT})z^{-1}}.$$

Release operation

$$x_{\mathrm{PEAK}}(n) = (1 - \mathrm{RT}) \cdot x_{\mathrm{PEAK}}(n-1) \qquad H(z) = \frac{1}{1 - (1 - \mathrm{RT})z^{-1}}$$

AT attack time, RT release time



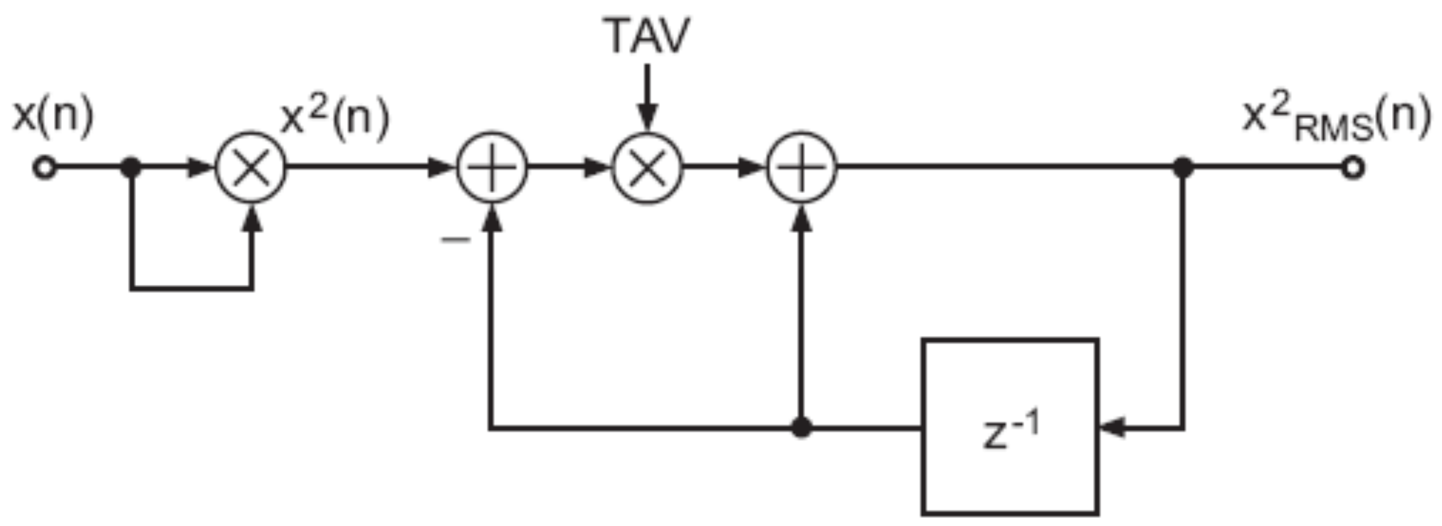
RMS LEVEL MEASUREMENT

$$x_{\mathrm{RMS}}(n) = \sqrt{\frac{1}{N}\sum_{i=0}^{N-1} x^2(n-i)}$$

$$x^2_{\mathrm{RMS}}(n) = (1-\mathrm{TAV}) \cdot x^2_{\mathrm{RMS}}(n-1) + \mathrm{TAV} \cdot x^2(n)$$

$$H(z) = \frac{\mathrm{TAV}}{1-(1-\mathrm{TAV})z^{-1}}.$$

TAV averaging time



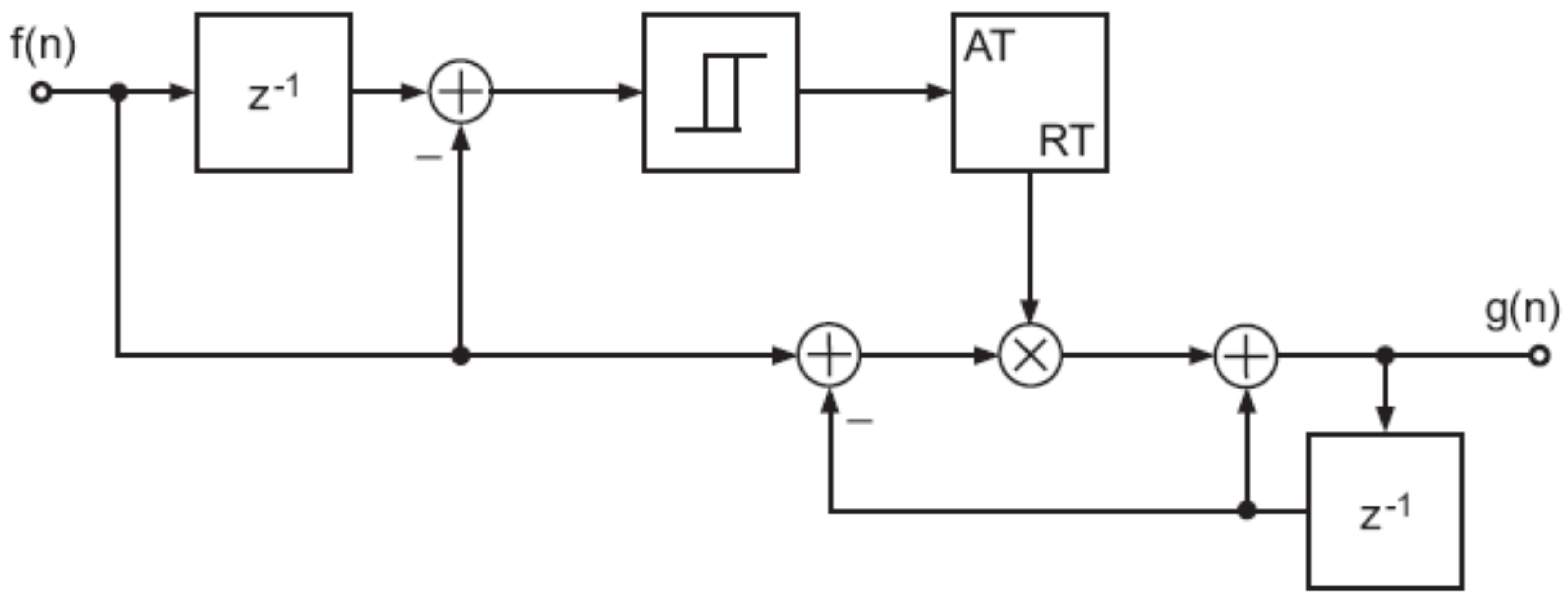
ATTACK/RELEASE TIME – GAIN FACTOR SMOOTHING

$$g(n) = (1-k)\cdot g(n-1) + k \cdot f(n)$$

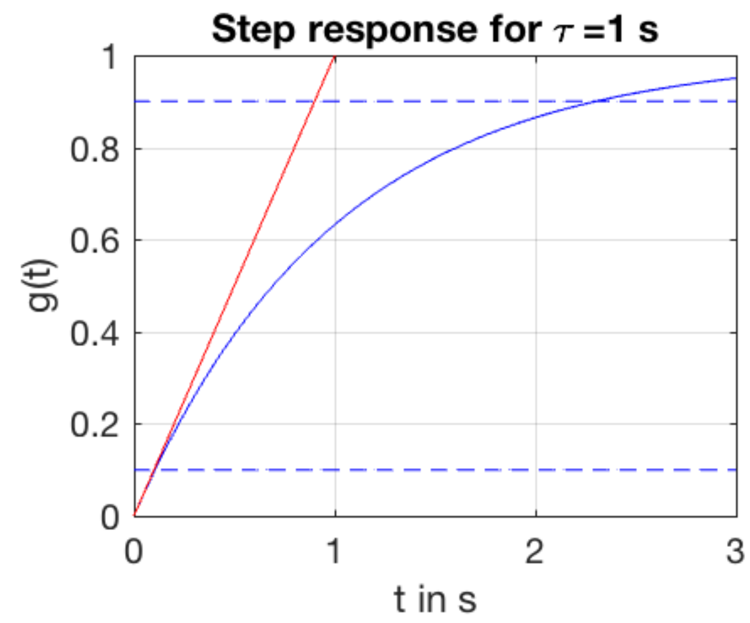
$$H(z) = \frac{k}{1-(1-k)z^{-1}}.$$

f(n) < f(n-1) -> RT

f(n) >= f(n-1) -> AT



TIME CONSTANTS – 1



Step response

$$\begin{aligned} g(t) &= \epsilon(t) - e^{-t/\tau} \cdot \epsilon(t) \quad \text{with time constant} \quad \tau \\ g(nT_S) &= \epsilon(nT_S) - e^{-nT_S/\tau} \cdot \epsilon(nT_S) \\ &= \epsilon(nT_S) - z_\infty^n \cdot \epsilon(nT_S) \quad \text{with} \quad z_\infty = e^{-T_S/\tau} \end{aligned}$$

Z-Transform of step response

$$\begin{aligned} G(z) &= \frac{z}{z-1} - \frac{1}{1 - z_\infty z^{-1}} \\ &= \frac{1 - z_\infty}{(z-1)(1 - z_\infty z^{-1})} \end{aligned}$$

TIME CONSTANTS – 2

Attack time in sec $t_a = t_{90} - t_{10}$

$$\begin{aligned} 0.1 &= 1 - e^{-t_{10}/\tau} \\ 0.9 &= 1 - e^{-t_{90}/\tau} \end{aligned}$$

$$\begin{aligned} 0.9/0.1 &= e^{(t_{90}-t_{10})/\tau} \\ \ln(0.9/0.1) &= (t_{90} - t_{10})/\tau \\ t_a &= t_{90} - t_{10} = 2.2\tau. \end{aligned}$$

$$\begin{aligned} \Rightarrow \quad \tau &= \frac{t_a}{2.2} \\ z_\infty &= e^{-T_S/\tau} = e^{-2.2 \cdot T_S/t_a} \end{aligned}$$

Z-Transform of impulse response derived form Z-Transform of step response $H(z) = \frac{z-1}{z} G(z).$

$$\Rightarrow \quad H(z) = \frac{1 - z_\infty}{1 - z_\infty z^{-1}} \cdot z^{-1} = \frac{k}{1 - (1-k)z^{-1}} \cdot z^{-1}$$

STEREO PROCESSING