Exercises for **Digital Audio Signal Processing**, 2nd Edition
Prof. Dr.-Ing. Udo Zölzer
Department of Signal Processing and Communications
Helmut-Schmidt-University Hamburg, Germany

Chapter N°7: **Dynamic Range Control**

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1. Low-pass Filtering for Envelope Detection

Generally, envelope computation is performed by low-pass filtering the input signal's absolute value or its square.

1. Sketch the block diagram of a recursive first-order low-pass $H(z) = \frac{\lambda}{1-(1-\lambda)z^{-1}}$.
2. Sketch its step response. What characteristic measure of the envelope detector can be derived from the step response and how ?
3. Typically, the low-pass filter is modified to use a non-constant filter coefficient λ. How does λ depend on the signal? Sketch the response to a rect-signal of the low-pass filter thus modified.

2. Discrete-Time Specialties of Envelope Detection

Taking absolute value or squaring are non-linear operations. Hence care must be taken when using them in discrete-time systems as they introduce harmonics the frequency of which may violate the Nyquist bound. This can lead to unexpected results, as a simple example illustrates. Consider the input signal $x(n) = \sin\left(\frac{\pi}{2}n + \varphi\right)$, $\varphi \in [0, 2\pi]$.

1. Sketch $x(n)$, $|x(n)|$ and $x^2(n)$ for different values of φ.
2. Determine the value of the envelope after perfect low-pass filtering, i.e. averaging, $|x(n)|$. Note: As the input signal is periodical, it is sufficient to consider one period, e.g.
$$\bar{x} = \frac{1}{4}\sum_{n=0}^{3}|x(n)|.$$
3. Similarly, determine the value of the envelope after averaging $x^2(n)$.

3. Dynamic Range Processors

Sketch the characteristic curves mapping input level to output level and input level to gain for and describe briefly the application of:

1. limiter
2. compressor
3. expander and
4. noise gate.