# Noise Equivalent Bandwidth (NEB) for Second-Order ADPLL System

This document explains how to compute the noise equivalent bandwidth (NEB) for a second-order low-pass system, such as those used in analog and digital phase-locked loops (ADPLLs).

## System Transfer Function

For a second-order low-pass system with damping factor ζ and natural frequency ωₙ (in rad/s), the transfer function is given by:

H(s) = (2ζωₙs + ωₙ²) / (s² + 2ζωₙs + ωₙ²)

## Definition of Noise Equivalent Bandwidth

The NEB is defined as the bandwidth of an ideal rectangular filter that would pass the same total power (noise energy) as the actual filter. Mathematically, this is:

NEB = (1 / |H(0)|²) × ∫₀^∞ |H(jω)|² dω

For this second-order system, assuming the DC gain is 1 (|H(0)| = 1), the integral simplifies and results in the closed-form solution:

NEB = (π · ωₙ) / (2ζ)

## Conversion to Frequency in Hertz

Since ωₙ is in radians per second, and fₙ (the natural frequency) is in Hertz, we use the relation:

ωₙ = 2π · fₙ

Substituting this into the NEB equation gives:

NEB\_Hz = (π · 2π · fₙ) / (2ζ · 2π) = fₙ / (2ζ)

## Final Formula

NEB\_Hz = fₙ / (2ζ)

## Example

If the natural frequency is fₙ = 1 Hz and damping ζ = 1.0:

NEB\_Hz = 1 / (2 × 1) = 0.5 Hz

This result provides an intuitive understanding of how damping controls noise spreading in a second-order system.

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