SignalForge Noise Analysis & Filter Design Report

Source File: mixed_300_600.wav

Sampling Rate: 48000.0 Hz

User Specifications

Metric	Specification
Tonal Suppression	>= 10 dB
IIR Notch Count	<= 4 count

This table is rendered from design_result.json (verify output). Undefined specifications are shown as N/A.

Performance & Compliance Summary

Metric	Specification	Measured	Margin	Pass?
Tonal Suppression	>= 10 dB	12.8 dB	2.85 dB	PASS
IIR Notch Count	<= 4 count	1 count	3 count	PASS

All defined user specifications are satisfied by the current filter design.

Executive Summary

- This report analyzes **mixed_300_600.wav**.
- Sampling rate: **48000.0 Hz**.
- This report was generated strictly under the user-specified constraints: **min_prominence=6.0 dB, max_notches=4**.
- Tonal components were detected near **298.8, 597.7, 1160.2, 1429.7, 1933.6, 2466.8, 3867.2, 4921.9, 5080.1, 5343.8, 5777.3, 6252.0, 6732.4, 6966.8, 7306.6, 7675.8, 9052.7, 10095.7, 10353.5, 11074.2, 11560.5, 12357.4, 12919.9, 13587.9, 14267.6, 14789.1, 14935.5, 15363.3, 15837.9, 16054.7, 16628.9, 17332.0, 17783.2, 18246.1, 18785.2, 19160.2, 19716.8, 20015.6, 20267.6, 20865.2, 21503.9, 21709.0, 21837.9, 22089.8, 22400.4, 22494.1, 22863.3, 23085.9, 23361.3, 23841.8 Hz**.
- Note: detection may identify multiple candidates; notch placement is constrained by user settings (e.g., max notch count, prominence thresholds, and protected bands).
- The filter pipeline includes **1** IIR notch filter(s) at 597.7 Hz.
- A FIR low-pass filter is applied with cutoff **10800.00 Hz** and **101** taps (approx **2.104 ms** latency).
- **All user specifications are satisfied.**

System Health Check

Status	Comment
Info	No obvious full-scale clipping observed.
Info	DC offset is within normal range.
Info	Signal duration >= 3.000 s (sufficient).

These checks provide a quick sanity review of the input signal and analysis conditions, including clipping, DC offset, and duration relative to the sampling rate.

Measurement Notes

Tonal Suppression Measurement:
- Suppression is computed from the Welch PSD of the input and filtered signals at the selected tonal frequency.
- Suppression (dB) = 10*log10(PSD_before(f0) / PSD_after(f0)).

SNR Measurement:
- SNR is estimated from PSD statistics, optionally excluding narrow bands around notch frequencies.
- total_power = sum(PSD), noise_power ~= median(PSD)*N_bins, signal_power = total_power - noise_power.
- SNR(dB) = 10*log10(signal_power / noise_power). If signal_power <= 0 under this estimator, SNR is reported as N/A.

- Note: For tone-dominant signals or near numerical-noise-floor inputs, broadband SNR may be non-representative; interpret SNR together with tonal suppression and the before/after PSD.

Applicability Note:
- For tone-dominant signals, tonal suppression is the primary performance indicator; broadband SNR metrics may be less representative and are provided for reference only.

FIR Metrics:
- Passband ripple is measured from the magnitude response in a passband region excluding the transition band near cutoff.
- Stopband attenuation is measured from the stopband magnitude response (robust percentile-based estimate).

User Specification Interpretation

General Principle
- All outcomes reported here are produced under the user-specified constraints configured in the SignalForge UI. Detection results may include multiple tonal candidates; the final filter design applies only a constrained subset according to notch budget, thresholds, and protected-band rules.

Main Tone Protection
- Main Tone Frequency defines a protected signal component. No notch filtering is applied within the specified tolerance range.

Tonal Suppression Target

- Required Suppression specifies a verification target evaluated after filter design. It does not guarantee exact attenuation under all conditions.

SNR Target
- Output SNR is used for post-design evaluation only. The filter design process does not explicitly optimize SNR.

Bandwidth Constraint
- Maximum Bandwidth defines the frequency range to preserve. Frequencies above this limit may be attenuated by the FIR stage.

Filter Design Preferences
- Design preferences influence filter selection but do not override protection, stability, or verification rules.

Performance Gap Analysis

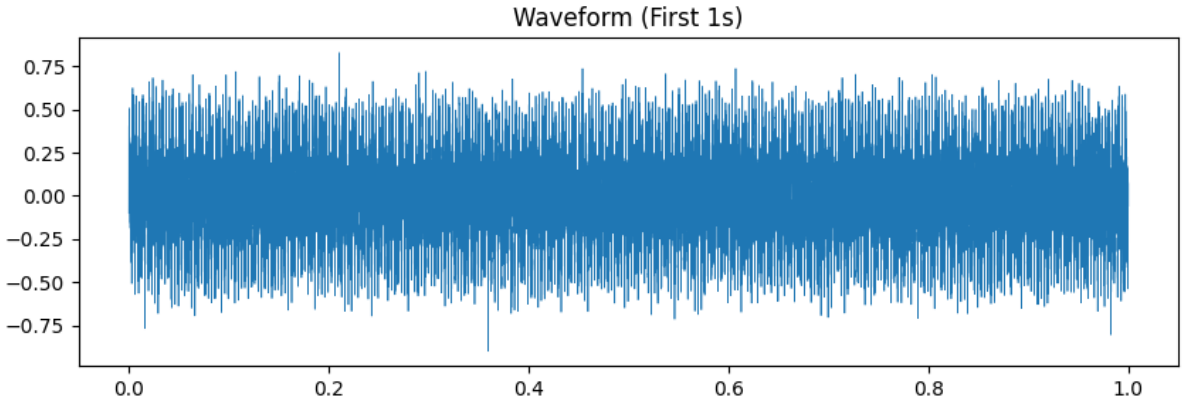
This section provides an engineering interpretation of why certain metrics may not fully meet the requested specifications, based on tonal behavior, filter alignment, and residual noise characteristics.

Engineering Recommendations

- The current filter design meets all user specifications; no corrective actions are required.

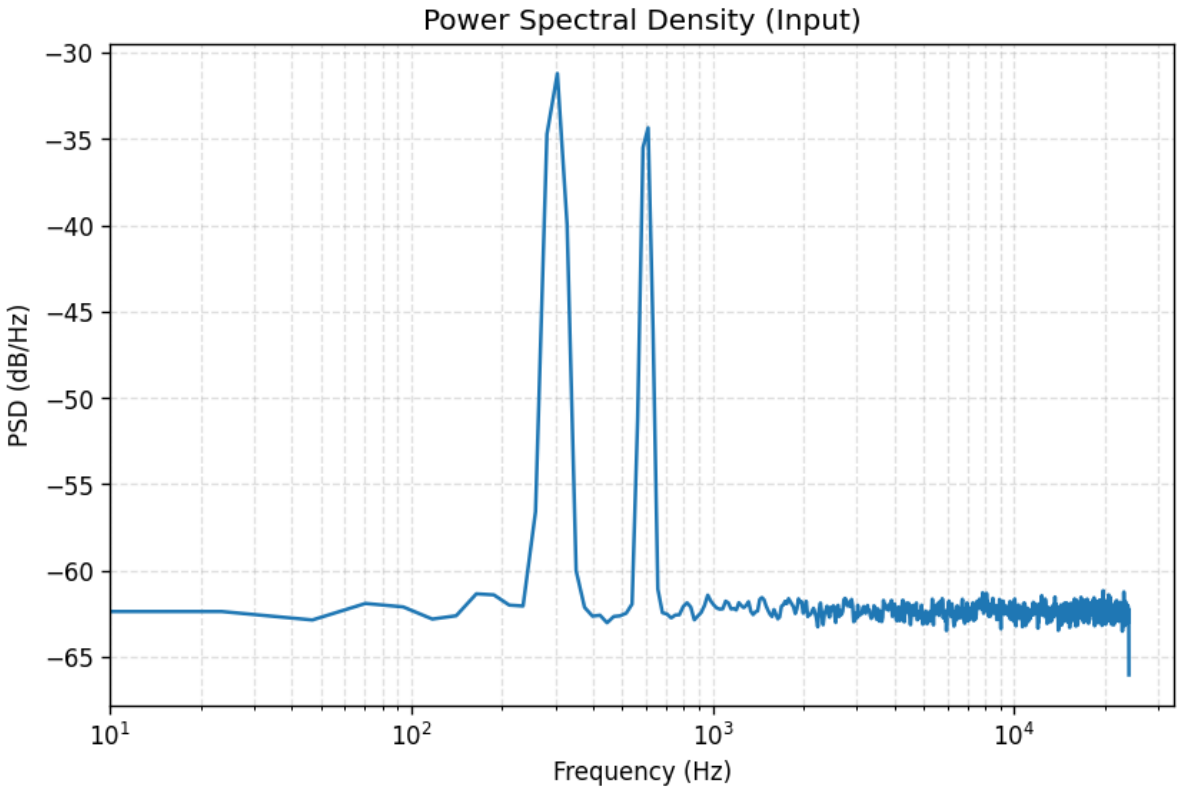
These recommendations provide practical options for further optimizing the filter design with respect to tonal rejection, SNR, and implementation constraints.

Input Signal Waveform



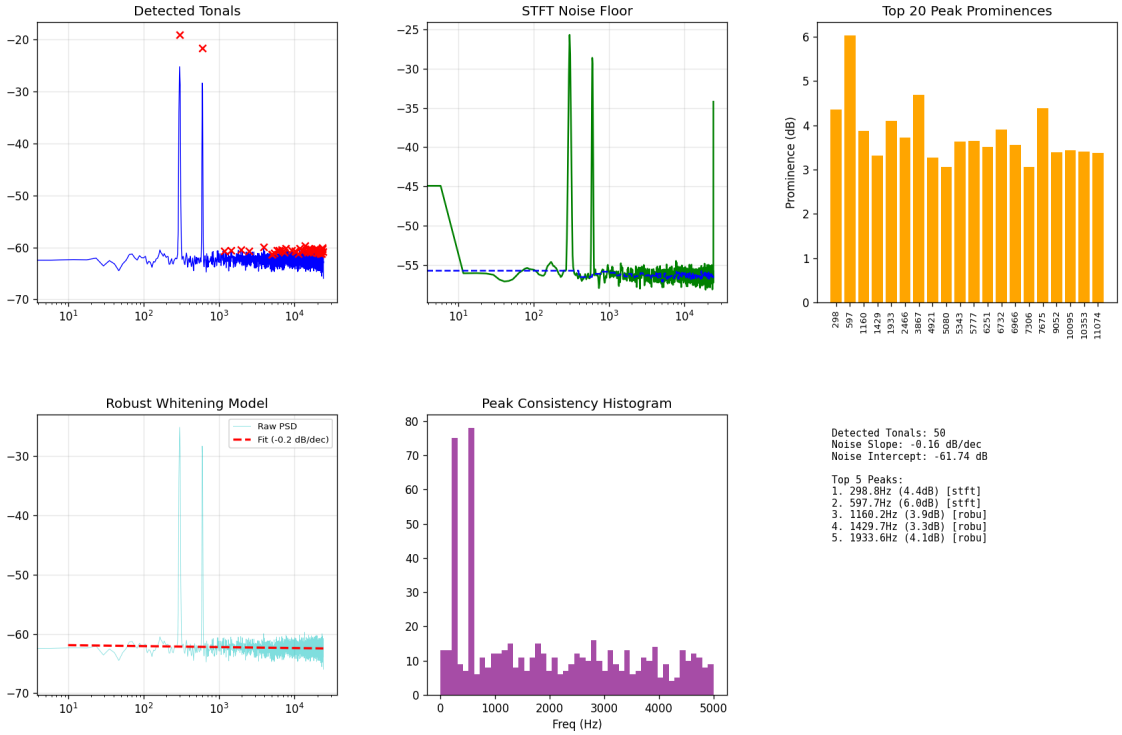
Time-domain representation of the input signal.

Power Spectral Density (Input)



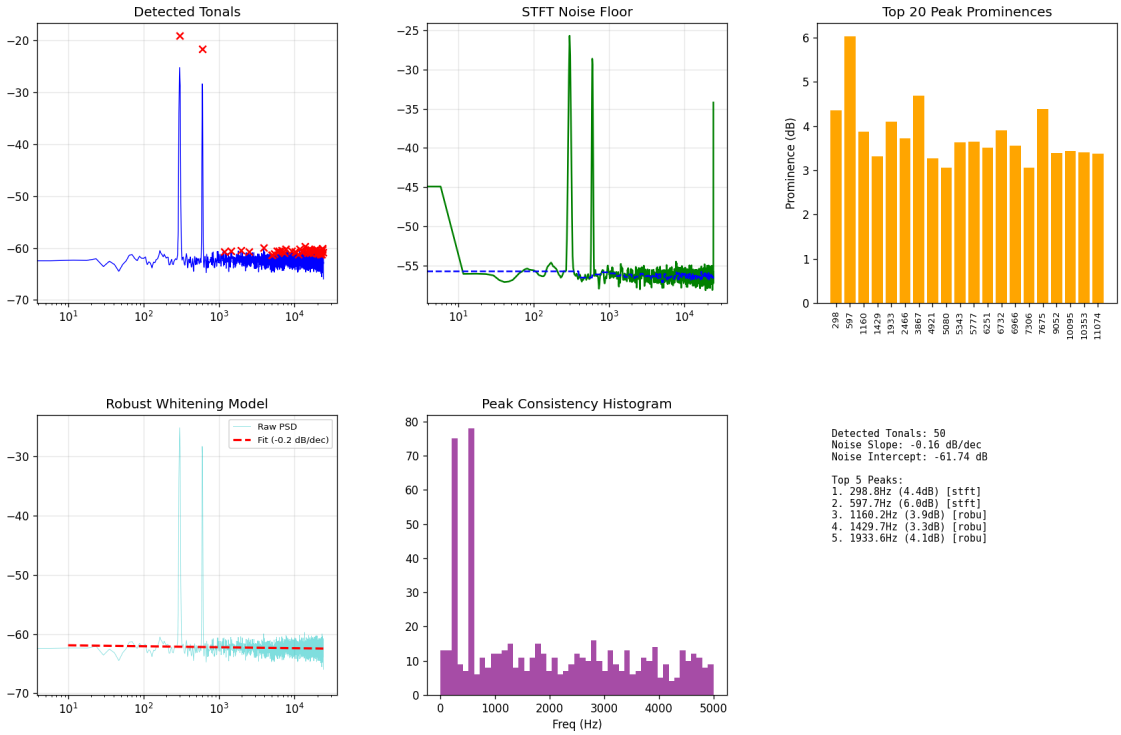
The input spectrum shows broadband noise and tonal components.

Tonal Detection Debug (Overview)



Detailed breakdown of tonal detection showing thresholds and candidate evaluations.

Tonal Detection Debug Analysis



Detailed breakdown of tonal detection showing thresholds, noise floors, and candidate evaluations.

Detection Summary:

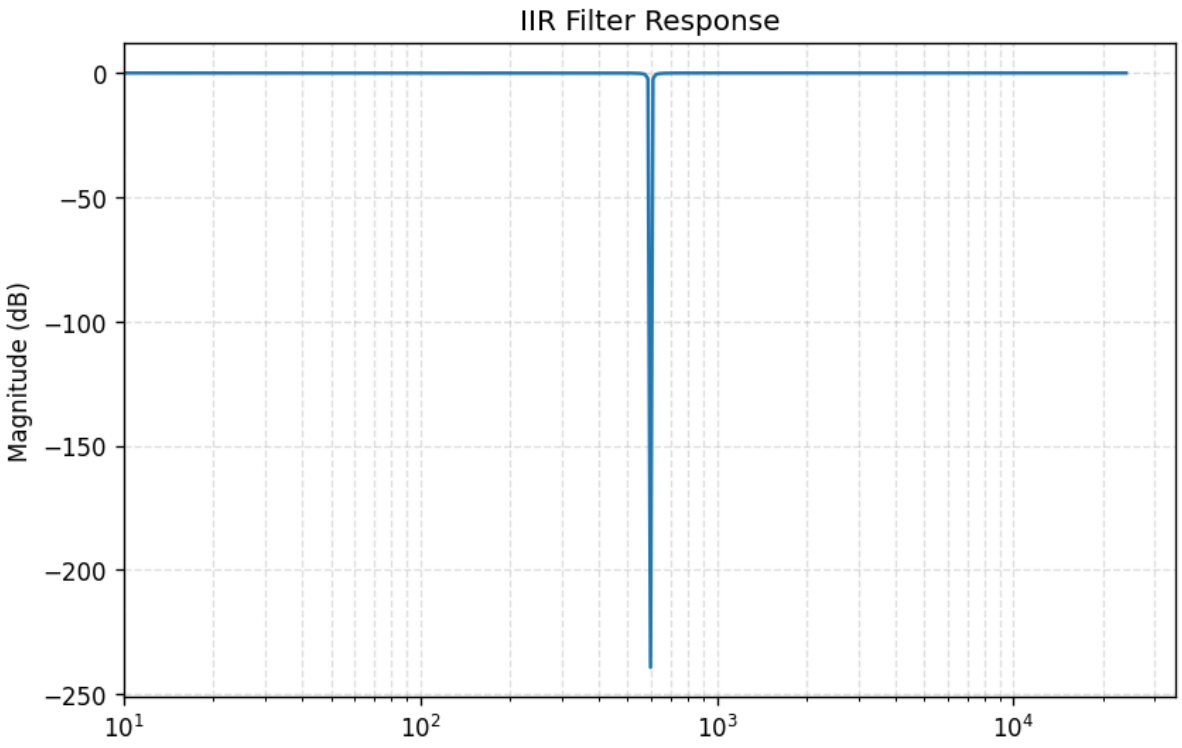
Detected 50 tonal component(s):

#	Frequency (Hz)	Prominence (dB)	Source	Notch Recommended?
1	298.8	4.4	stft_voting	No (below 5 dB threshold)
2	597.7	6.0	stft_voting	Yes
3	1160.2	3.9	robust_whitening	No (below 5 dB threshold)
4	1429.7	3.3	robust_whitening	No (below 5 dB threshold)
5	1933.6	4.1	robust_whitening	No (below 5 dB threshold)
6	2466.8	3.7	robust_whitening	No (below 5 dB threshold)
7	3867.2	4.7	robust_whitening	No (below 5 dB threshold)
8	4921.9	3.3	robust_whitening	No (below 5 dB threshold)
9	5080.1	3.1	robust_whitening	No (below 5 dB threshold)
10	5343.8	3.6	robust_whitening	No (below 5 dB threshold)
11	5777.3	3.7	robust_whitening	No (below 5 dB threshold)

12	6252.0	3.5	robust_whitening	No (below 5 dB threshold)
13	6732.4	3.9	robust_whitening	No (below 5 dB threshold)
14	6966.8	3.6	robust_whitening	No (below 5 dB threshold)
15	7306.6	3.1	robust_whitening	No (below 5 dB threshold)
16	7675.8	4.4	robust_whitening	No (below 5 dB threshold)
17	9052.7	3.4	robust_whitening	No (below 5 dB threshold)
18	10095.7	3.4	robust_whitening	No (below 5 dB threshold)
19	10353.5	3.4	robust_whitening	No (below 5 dB threshold)
20	11074.2	3.4	robust_whitening	No (below 5 dB threshold)
21	11560.5	3.9	robust_whitening	No (below 5 dB threshold)
22	12357.4	3.4	robust_whitening	No (below 5 dB threshold)
23	12919.9	3.2	robust_whitening	No (below 5 dB threshold)
24	13587.9	5.2	robust_whitening	Yes
25	14267.6	3.7	robust_whitening	No (below 5 dB threshold)
26	14789.1	3.4	robust_whitening	No (below 5 dB threshold)
27	14935.5	3.2	robust_whitening	No (below 5 dB threshold)
28	15363.3	4.4	robust_whitening	No (below 5 dB threshold)
29	15837.9	3.5	robust_whitening	No (below 5 dB threshold)
30	16054.7	3.7	robust_whitening	No (below 5 dB threshold)
31	16628.9	4.2	robust_whitening	No (below 5 dB threshold)
32	17332.0	3.4	robust_whitening	No (below 5 dB threshold)
33	17783.2	3.1	robust_whitening	No (below 5 dB threshold)
34	18246.1	3.5	robust_whitening	No (below 5 dB threshold)
35	18785.2	3.8	robust_whitening	No (below 5 dB threshold)
36	19160.2	4.4	robust_whitening	No (below 5 dB threshold)
37	19716.8	4.3	robust_whitening	No (below 5 dB threshold)
38	20015.6	3.1	robust_whitening	No (below 5 dB threshold)
39	20267.6	3.4	robust_whitening	No (below 5 dB threshold)
40	20865.2	3.7	robust_whitening	No (below 5 dB threshold)
41	21503.9	3.8	robust_whitening	No (below 5 dB threshold)
42	21709.0	3.2	robust_whitening	No (below 5 dB threshold)
43	21837.9	3.7	robust_whitening	No (below 5 dB threshold)
44	22089.8	3.1	robust_whitening	No (below 5 dB threshold)
45	22400.4	3.1	robust_whitening	No (below 5 dB threshold)
46	22494.1	4.3	robust_whitening	No (below 5 dB threshold)

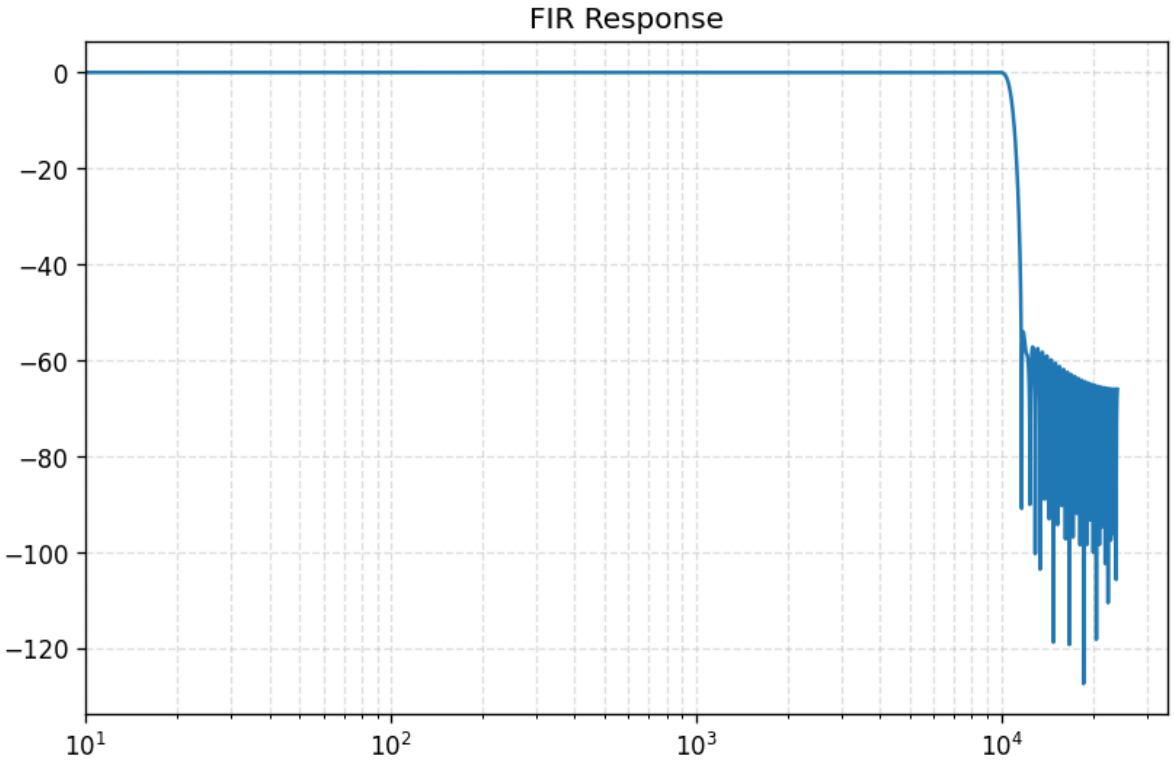
47	22863.3	3.2	robust_whitening	No (below 5 dB threshold)
48	23085.9	5.5	robust_whitening	Yes
49	23361.3	4.4	robust_whitening	No (below 5 dB threshold)
50	23841.8	3.7	robust_whitening	No (below 5 dB threshold)

IIR Notch Cascade Response



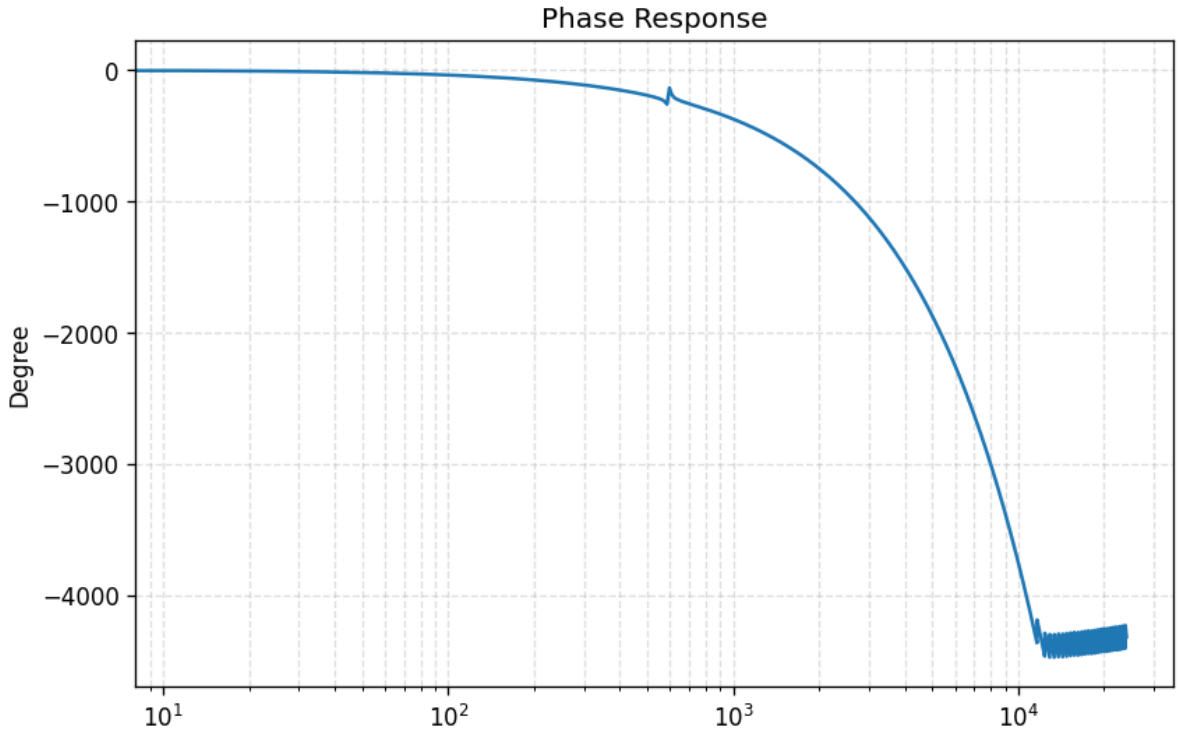
Each notch suppresses a narrow-band interference frequency.

FIR Low-pass Response



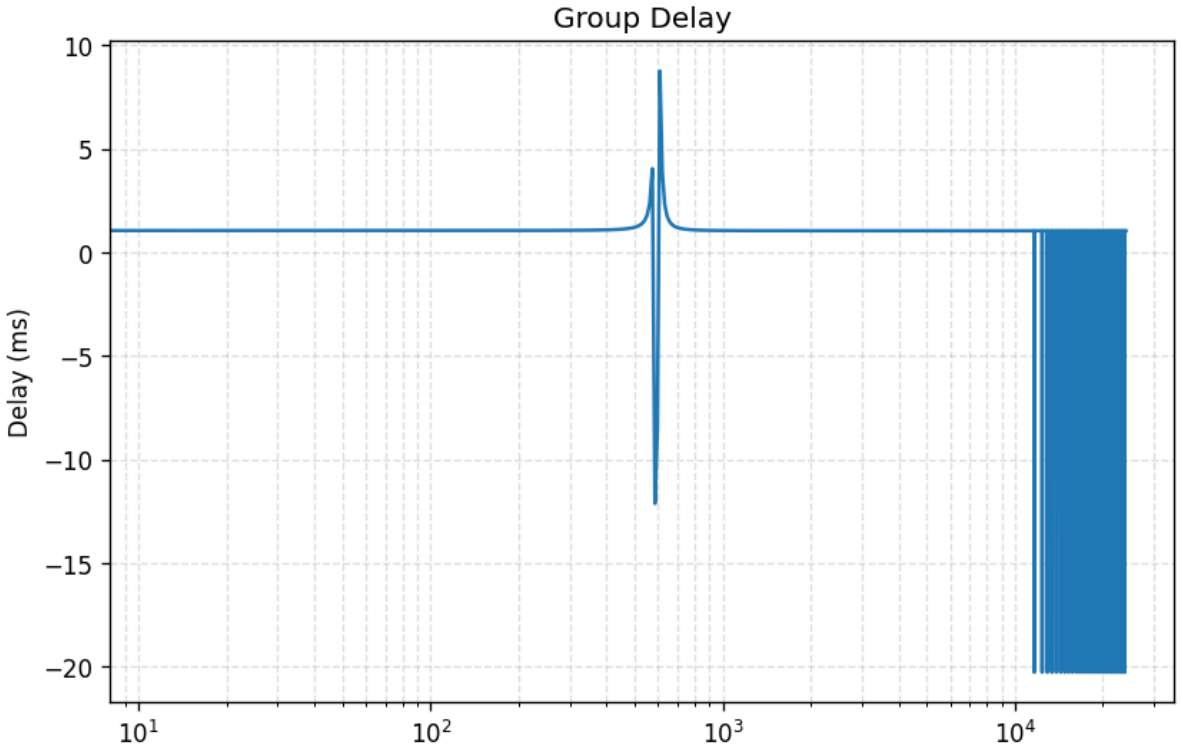
The FIR stage removes high-frequency noise beyond the cutoff.

Phase Response (Pipeline)



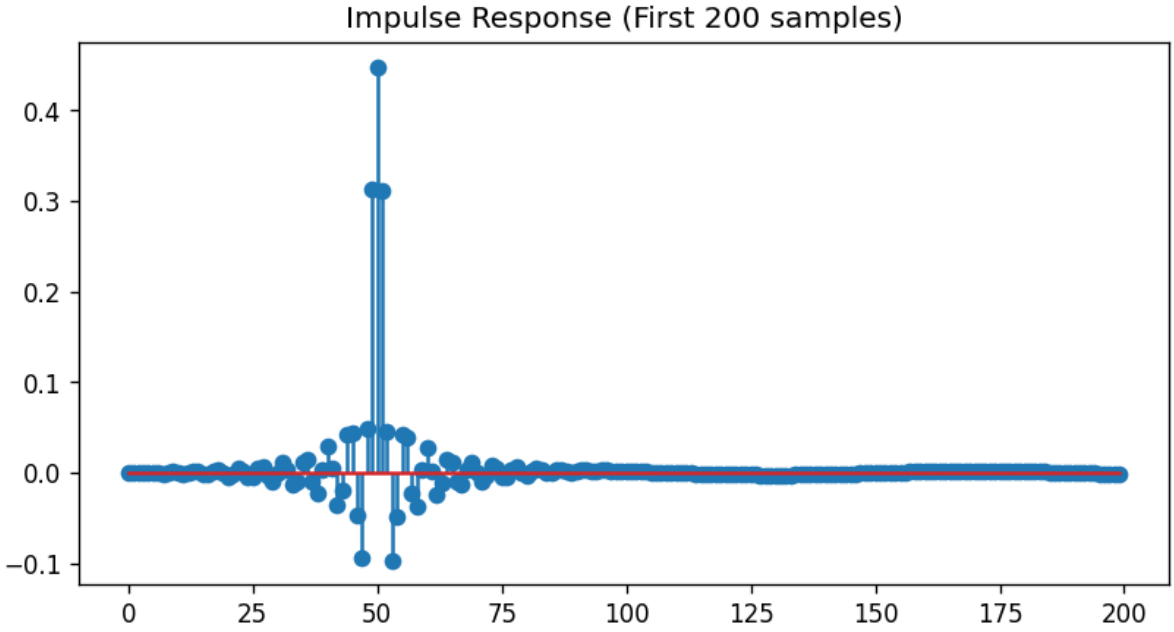
Phase remains approximately linear across most of the passband.

Group Delay (Pipeline)



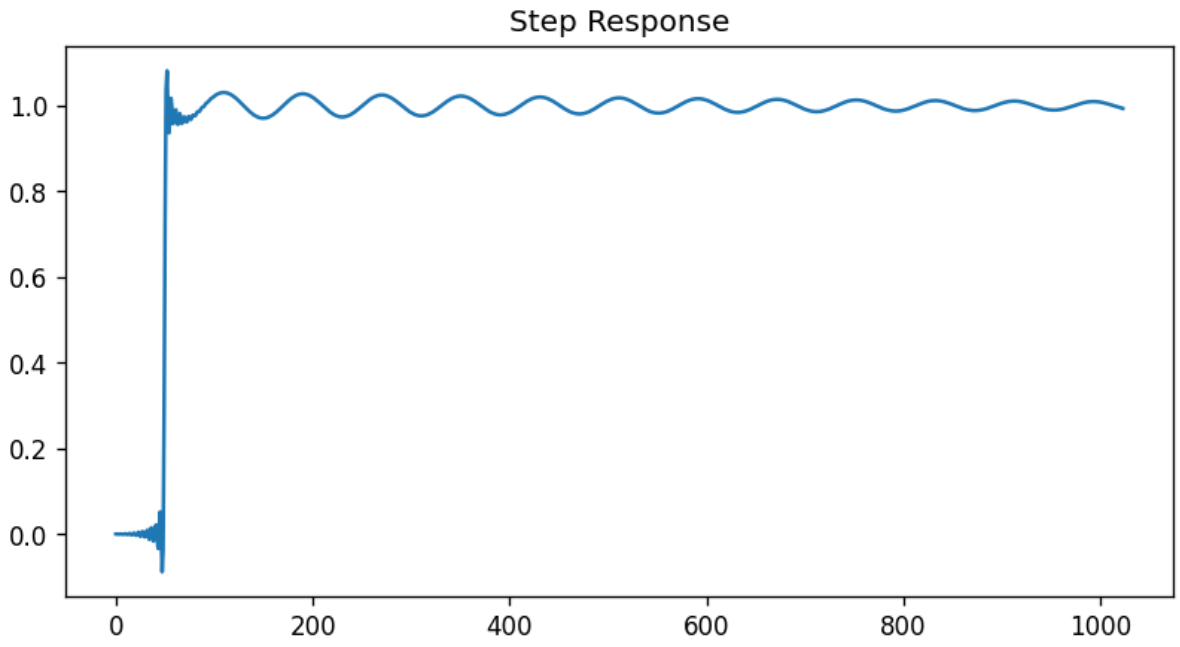
Group delay spikes indicate the frequency of notch filters.

Impulse Response (Pipeline)



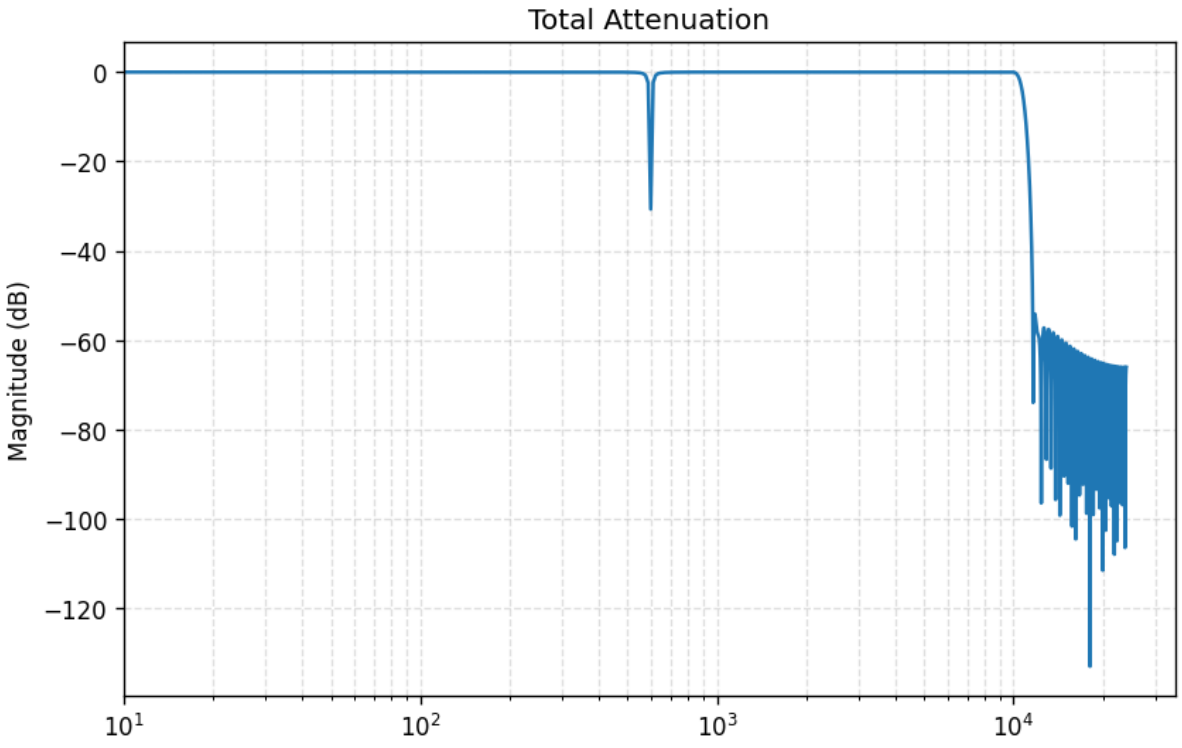
Impulse response reveals filter stability and temporal spread.

Step Response (Pipeline)



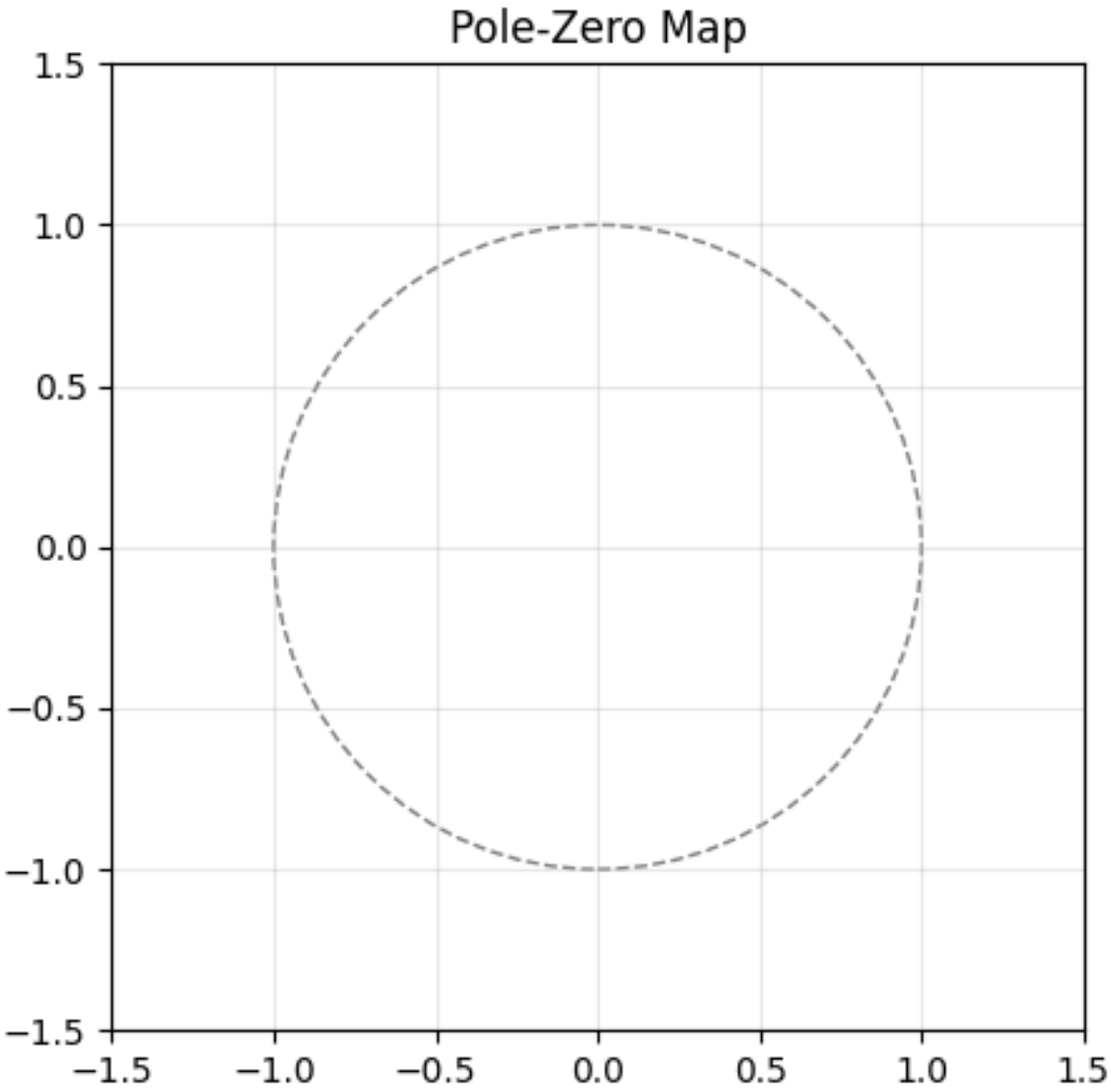
Step response highlights settling behavior and overshoot control.

Cumulative Attenuation Mask



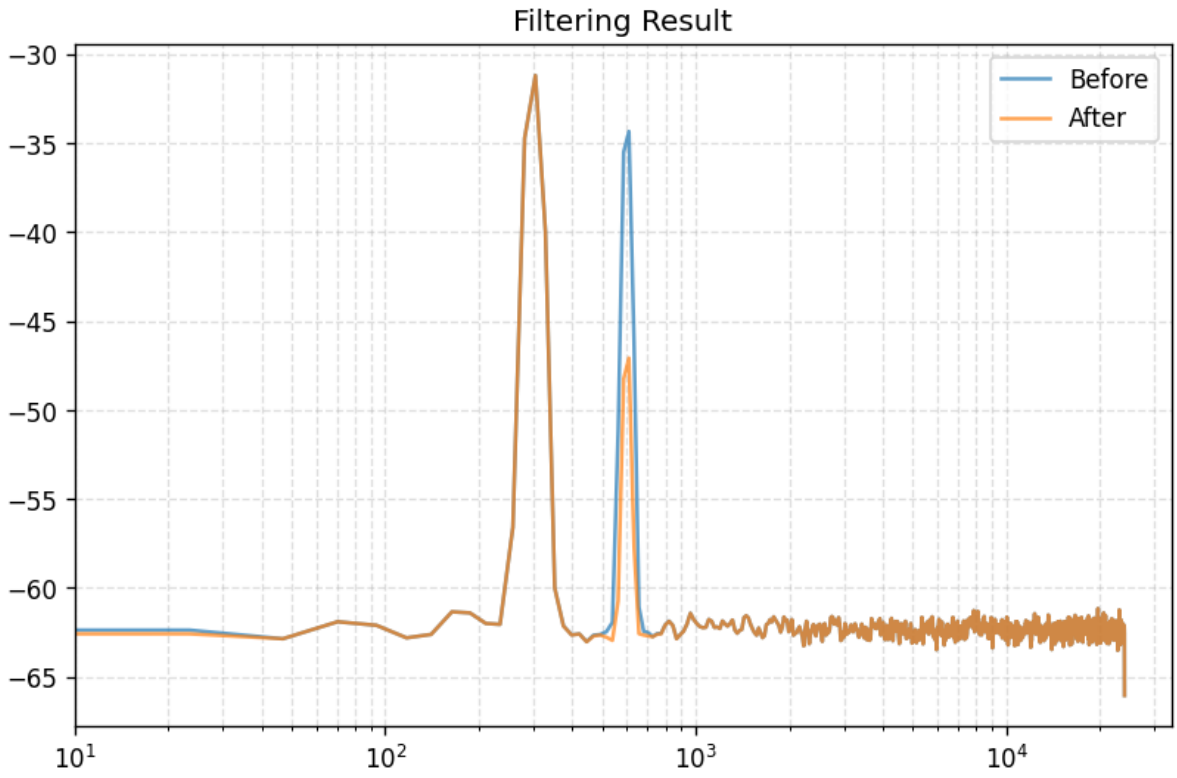
Shows total attenuation of the complete filter pipeline.

Pole-Zero Plot (Overall Pipeline)



Poles and zeros indicate stability and notch sharpness.

PSD Before / After Filtering



Illustrates the spectral changes before and after applying the designed filter pipeline.

Filter Design Summary

Parameter	Value
Source File	mixed_300_600.wav
Sampling Rate (Hz)	48000.0
FIR Cutoff (Hz)	10800.00
FIR Tap Count	101
IIR Notches	597.66 Hz (Q=30.0)

This summary captures the key parameters of the automatically designed filter pipeline, including FIR low-pass characteristics and IIR notch frequencies with their Q-factors.

IIR Notch Detail Table

#	Center (Hz)	Q	Approx BW (Hz)
1	597.66	30.0	19.922

Each notch section is implemented as a biquad (second-order IIR) with a pair of complex-conjugate zeros on the unit circle and poles slightly inside the unit circle to control bandwidth and stability.

Implementation Notes

Pipeline Notes:
- The filter cascade is stable and suitable for real-time use.
- IIR notch sections introduce negligible additional latency.
- FIR stage length is **101** taps, giving approximately **2.104 ms** of group delay at the center of the passband.
- The exported C header and runtime implementation can be integrated into embedded systems, DSPs, or microcontrollers without modification.