Using Basic Signal Filters

Optimizing signal quality using common filter methods

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Signal noise has many causes and can be difficult to diagnose. In some applications it may be preferable to identify and mitigate the root causes; see *Epsilon TechNote-Resolution and Noise* for more detail on this. In other applications this may be difficult, and it may be more practical to filter the noise.

Low-pass filtering of a signal can often be an effective and expedient way to improve signal quality in many situations, regardless the cause of elevated noise. Filtering is most effective when the noise is at a higher bandwidth (frequency) than the test.

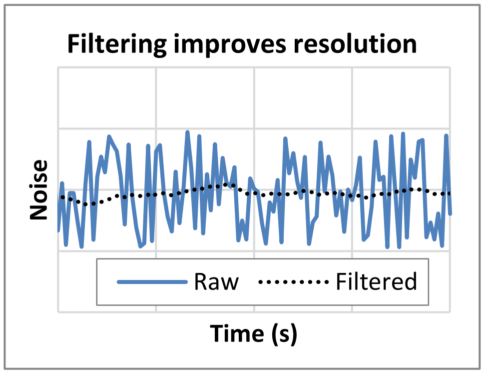
Filtering: in instrument, in software, and post-process

Epsilon's capacitive and non-contact Epsilon ONE systems include configurable built-in filters. Filtering on-board the instrument is often a convenient method, where possible. Most testing systems software include provision for signal filtering by various means; filtering in the control system software can be especially beneficial in high-frequency fatigue testing, where it may beneficial to apply similar filters across multiple channels.

Where options for filtering in the instrument or in software are limited, post-process filtering can be implemented in a spreadsheet with *moving average* or *exponential* filters. The latter (exponential) are more easily tuned. Post-process filtering is most effective when more data rows per second are recorded.

Filtering random vs repeating noise

When filtering random noise with no discernable frequency content, signal quality will tend to improve as the filter becomes more aggressive. When a simple moving-average is used, a 10-pt moving average will typically improve resolution by ~2x, etc.



When filtering repeating noise with a distinct characteristic frequency. Select a filter with a cutoff frequency *below* the frequency of concern. For example, to mitigate a 120 Hz signal caused by vibration or electrical sources by ~90%, a filter at <15 Hz might be suitable.

The attenuation (effectiveness in reducing noise), roll-off (tendency to reject noise without reducing the desired signal) and phase lag (induced delay) of a low-pass filter are all characteristics of the filter which between the methods and should be considered. It is a broad topic and a complete understanding goes well beyond the scope of this introductory technical note. *Learn more*

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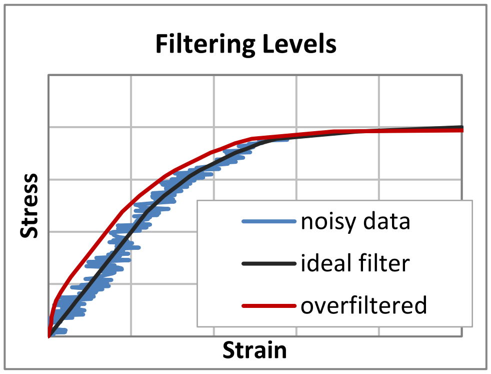
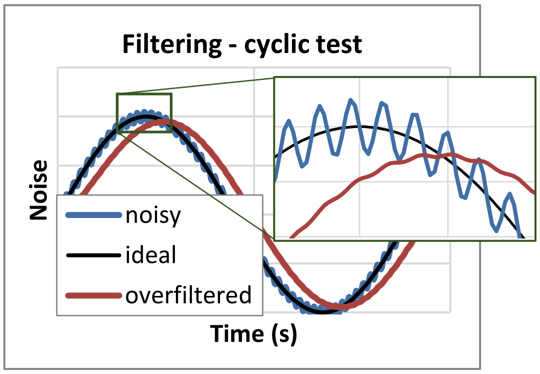


Filtering in quasi-static and low-frequency testing

For quasi-static (slow) monotonic (*e.g. tensile*) and low-frequency testing, it is often possible to use an aggressive filter to improve measurement resolution.

- Over-filtering can cause lag at the beginning of the test, and looping in strain-control testing.
- 1-100 Hz is a typical filter cutoff.

Filtering in cyclic, higher-frequency testing



Cyclic testing is more likely exhibit 'sinusoidal' noise caused by small-amplitude vibrations. Over-filtering can cause reduction in signal amplitude as well as phase lag (example at right).

- Select a filter frequency well *above* the frequency of the *test* to avoid reducing this signal amplitude
- Select a filter frequency well *below* the frequency of the *noise* to effectively reduce the noise.
- *Filtering is most effective when the noise is at a much higher bandwidth (frequency) than the test. Reduce the test frequency if necessary.*
- Filtering all channels (load, elongation, etc) similarly using controller firmware will mitigate relative phase lag, can affect some tests. See Epsilon TechNote – Regression Bias for more on this advanced topic.

Strain control

Strain-controlled testing adds some challenges with filter design. The effects of strain-control feedback can be difficult to discern from the underlying signal, and phase lag due to signal filters can increase strain-control instability and make tuning more difficult with some test frame controllers.

It may be necessary to use a less aggressive filter in a strain-controlled test than in a displacement-controlled test.

Another solution to this problem, where more aggressive filtering is desired but strain-control problems are present, is to apply the signal filter *downstream* from the control loop feedback to avoid lag effects on control.

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