Measurement Resolution and Signal Noise

Interpreting and optimizing signal quality

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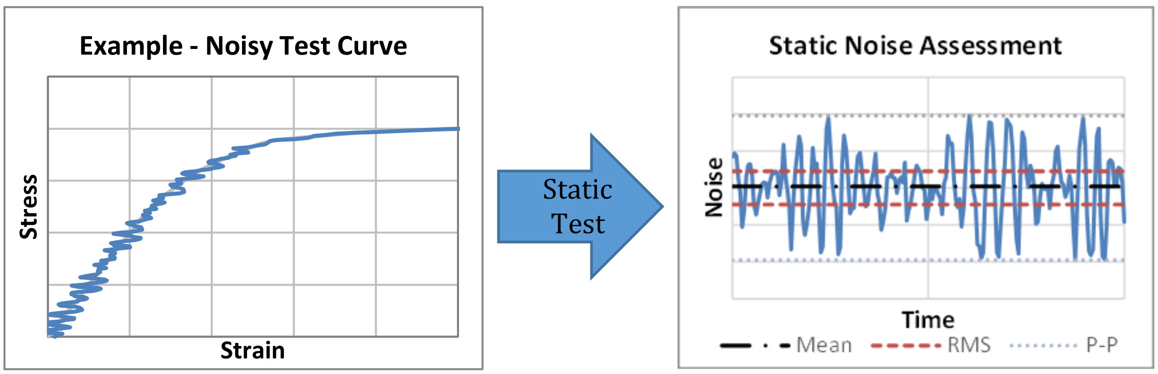
Signal noise has many causes and can be difficult to diagnose without high quality, well-formatted data. This technical note covers some of the most common problems and their mitigation.

In this note, noise will sometimes be presented against time for clarity. Noise *can* be extracted from a test curve using a high-pass filter, *but it is often advisable to use static (zero displacement) tests when assessing noise. Plotting signal (noise) against time enables quantitative assessment and diagnosis.*



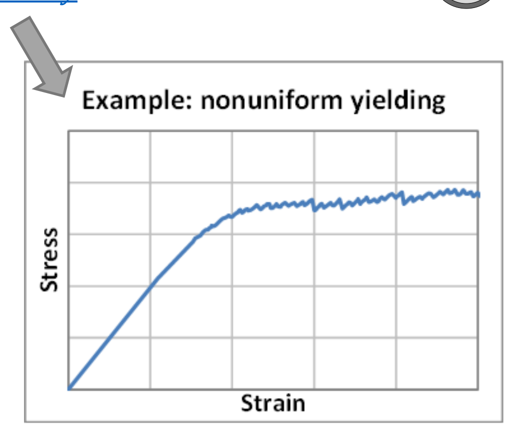
Measurement and analysis

- Common causes of signal noise cover frequencies up to 200 Hz. Data should be sampled at 500-1000 Hz to avoid aliasing which make the results uninterpretable.
- It is often impossible to diagnose noise problems from images of graphs. High quality data in spreadsheet format with meaningful column labels allows the frequency content of the noise to be interpreted – a critical metric. > *Download an example data file here* <
- Noise / resolution are often reported in terms of P-P or RMS. P-P values are about 3x larger.
- Some causes of 'noise', especially if it occurs only during a certain part of a test, are really issues of *nonlinearity*. See related *Epsilon TechNote – Test Curve Nonlinearity* for more on these issues.

Common problems

Some of the common causes of poor resolution are listed below, which may be present in combination:

- Test Design & DAQ configuration
- Thermomechanical / thermo-optical noise
- Vibration / strain control / mounting / hydraulic noise
- Electrical mains interference (60 / 120 Hz), ground loops, & cable damage



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Diagnosing common problems

Is there a problem with the extensometer? Usually not.

Most noise/resolution problems with strain data reflect issues with usage and test design* or data interpretation and do not indicate problems with the extensometer. The intrinsic electrical resolution of strain-gaged extensometers is extremely good, and resolution is usually limited by the data acquisition system (DAQ) itself – therefore resolution values are often not listed for strain-gaged extensometers**.

> *A typical DAQ will achieve effective resolution of 1/20,000 to 1/100,000 of the range of the extensometer (10-50 PPM, e.g., 0.001%ε to 0.005%ε for an extensometer with a range of 100%ε). A first step in assessing measurement resolution is to compare the indicated resolution to this range †. Some users may be attempting to resolve small measurements beyond the expected performance of their system.*

** Usage and test design problems may offer room for improvement of overall system performance – see below.*

*** Capacitive and optical extensometers typically have higher noise than strain-gaged devices, and may have options for filtering – check the specifications of the instrument to see if your results are in the expected range.*

† Low quality or inappropriately configured DAQ systems often exhibit lower performance and may not achieve the nominal resolution of the DAQ. This problem is more common in R&D settings.

Making comparisons between different extensometers and applications

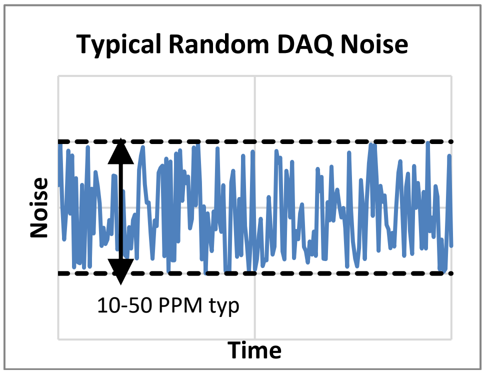
A common difficulty when making resolution comparisons between extensometers is that they are often not compared on an equal basis. Basic resolution, in units of *strain:*

- … is inversely proportional to gauge length
- … is proportional to *extensometer's* full-scale range
- … is more significant as the *test's* full-scale is reduced

> *Strain noise will be larger as the gauge length and test range are reduced. Is your test method appropriate? Is the extensometer range suitable?*

For cyclic applications, the dynamic range of the extensometer or COD is a consideration as well and will vary between devices. Ask Epsilon engineering staff about model selection for your application.

Characteristics of typical basic DAQ performance for strain-gaged extensometers



High-frequency / random measurement noise with no visible characteristic frequency, with a constant amplitude over time, which is not related to test temperature, vibration, or test control mode, is usually an indication of the basic measurement resolution of the data acquisition system (DAQ). 10-50 PPM of the range of the extensometer is typical.

The following pages cover causes that can cause increased noise levels beyond this typical level.

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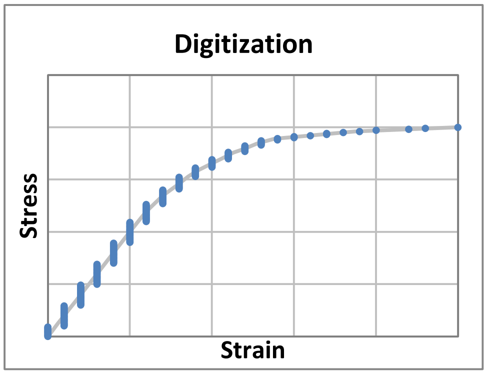
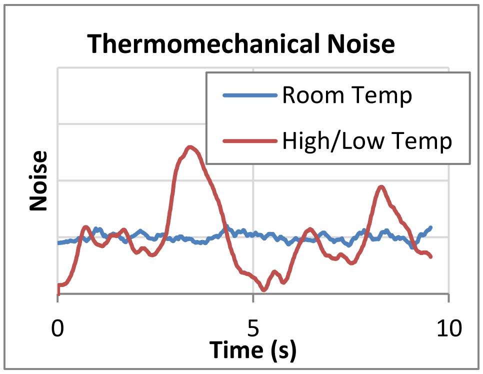
Digitization / Discretization



Digitization (discretization) results in "stair-steps" in the test data. This problem generally occurs due to rounding in the user's software or test method; mechanical extensometers* themselves are analog devices, not digital.

**Non-contact systems have selectable range; output can become visibly discretized if the selected range is considerably greater than the measurement range.*

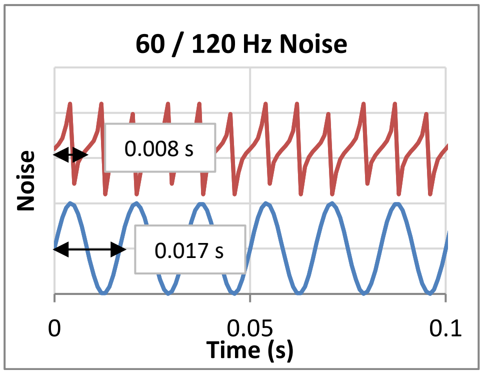
Elevated / Cryogenic Temperature



Thermomechanical noise corresponding to elevated temperature or cryogenic tests is wandering noise with a characteristic time interval of ~0.1 to 10 seconds *and amplitude that correlates to the test temperature*. See www.epsilontech.com/tech-notes for help mitigating thermomechanical noise. (Epsilon TechNote-High Temp Thermomechanical Noise & Epsilon TechNote – Cryogenic Thermomechanical Noise).

Elevated noise during high temp testing which is characteristically *sinusoidal* and present when the heater / chamber is operating, but does *not* increase in proportion to the test temperature, may be simply a problem of vibration caused by environmental chamber fans or electrical interference from a heating element.

Electrical Interference & EMI



Consistent, repeating noise with a characteristic frequency of 60 or 120 Hz (0.008s or 0.017s period) is often caused by electrical supply mains and could indicate a grounding / shielding problem if the amplitude is significantly larger than expected. Check for wiring errors and ground loops, and try different grounding schemes, especially with high-level (10V output) devices.

Electrical interference can also be present due to "through-the-air" sources by way of EMI (electromagnetic interference). These sources are often very steady, consisting noise sources that may be at a typical 60/120 Hz mains frequency, although higher-frequency EMI sources are not uncommon. Some common sources of EMI include:

- Inductive heating systems
- Nearby hydraulic pumps and other heavy equipment
- Signal cables wrapped/bundled with power cables

i EMI and electrical noise sources can be difficult to distinguish from other sources in test data, but tend to be quite consistent and steady, and unaffected by physical manipulation of the extensometer. Isolate the root cause by trial and error.

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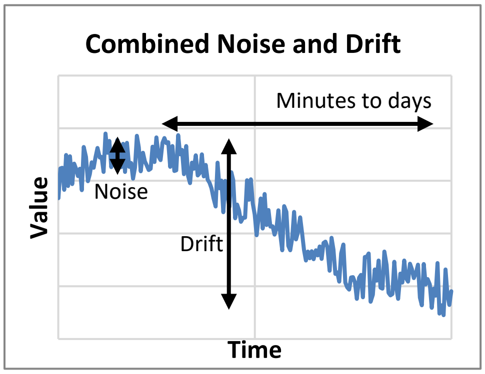
Drift

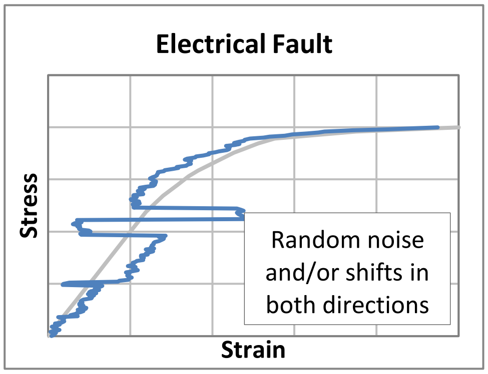


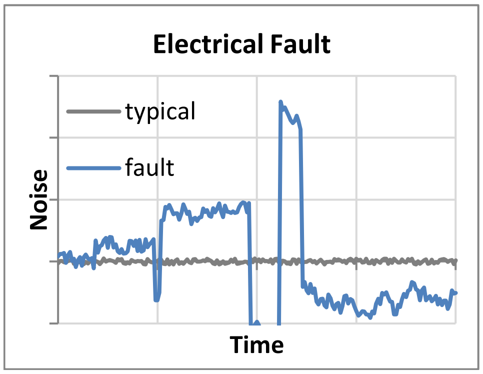
Slowly varying readings with a long characteristic time period (minutes to days) are referred to as *drift* and are often correlated to changes in temperature. Drift can sometimes be much larger in amplitude than noise.

See *www.epsilontech.com/tech-notes* for technical notes on the topic of drift, which is not covered here. (*Epsilon TechNote – Understanding Thermal Drift* and other topics)

Electrical Faults

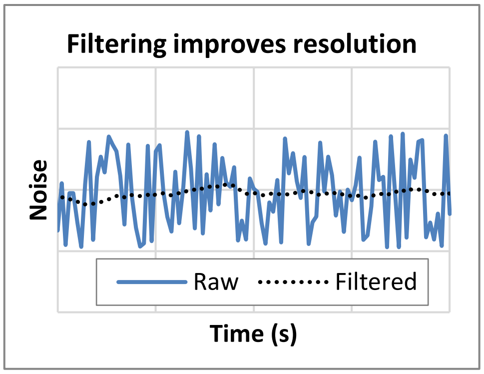
Impending extensometer failure is often characterized by greatly increased random noise and/or very large to off-scale random shifts in strain in both directions. The noise is typically wandering and random, and may be intermittent or highly variable between tests. Electrical faults are most often caused by physical damage to the signal cables; moving the cables can cause significant changes in the noise level. As a rule this is the only type of elevated noise which is indicative of extensometer damage / problems.





Filtering

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.



- Simple moving-average filters are usually sufficient. A 10-pt moving average will typically improve resolution by ~2x.
- Epsilon's capacitive and non-contact Epsilon ONE systems include configurable built-in filters.
- Most testing systems include provision for signal filtering.
- Overly aggressive filtering will cause signal lag (time delay).

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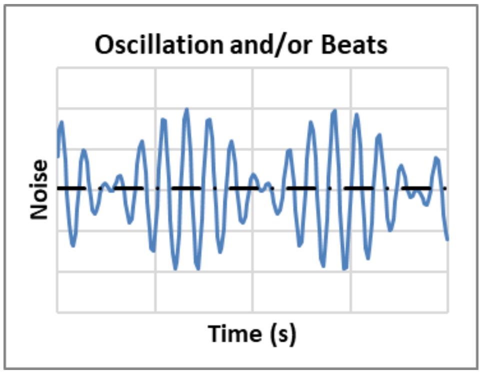
Strain control and vibration problems



A variety of common causes can result in oscillating, sinusoidal noise, potentially much greater than the typical range. Mechanical vibration, hydraulic noise, and strain control feedback are common causes. Beats (as at left) may or may not be present.

<u>Identifying the root cause is the first step and can be challenging.</u>

Strain control feedback can greatly increase signal noise; eliminate this problem from consideration first by repeating the test in displacement control to see if it persists.

- Vibration problems can sometimes be traced to specific impact events that typically "decay" over time.
- Overly compliant mounting systems for externally-mounted systems can increase vibration sensitivity.
- High-speed loading and high cyclic test frequencies can increase vibration problems.
- Dynamic range (vibration sensitivity) varies between models and configurations. Ask Epsilon for product recommendations for dynamic applications.
- Hydraulic "dither" is a test setting that can cause steady, invariant noise. Adjust frequency / amplitude.
- Hydraulic pumps in the vicinity of the test space can cause vibration *indirectly* through the floor. Consider mechanical isolation of the pump and/or test frame from the floor.
- Hydraulic systems can cause vibration *directly* through the hydraulic lines due to pressure spikes. Adding/ improving hydraulic dampers and accumulators often helps mitigate this common problem.
- If vibration problems cannot be mitigated, they can often be addressed suitably by filtering. Select a lowpass filter frequency which is lower than the noise signal and greater than the test frequency.

Determining the frequency of the oscillation is critical in diagnosing the root cause. Some extensometers, pumps, and test frames have model-specific considerations to address. Frequencies may range from 5-250 Hz depending on the root cause.

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