INSTRON
The difference is measurable

Technical Note | Data Acquisition: Bandwidth, Accuracy, and R&R

The US National Security Agency (NSA) collects surveillance data from satellites and by other means. The NSA supercomputers sort through billions of phone calls, faxes, emails, and radio transmissions; it has been estimated that five million emails are transmitted each minute and 35 million voice communications are completed each hour. Unfortunately, it takes some intelligence to cut through all the "chatter" – otherwise, you have inaccurate information and the results could be disastrous.

A similar situation exists in the data acquisition world. By definition, data acquisition systems are designed to gather and store data. However, this definition has led many managers and engineers to spend large amounts of money on systems that do just that - gather data - but are good for little else.

The True Purpose of Data Acquisition

In reality, the true purpose of data acquisition systems is to obtain relevant, critical information. Engineers and managers need to know what that data means and how it relates to their material or product.

A question frequently asked about the required data rate to meet a given accuracy is: How many data points per second are required to characterize a test? Instead, the correct questions should be: 1) What is the bandwidth of the transducer conditioning system required in order to give an accurate measurement and 2) What is the required data rate?

Without ensuring that the *bandwidth* is correct, the user could be collecting large amounts of data at high data rates that are not accurate representations of measured parameters. Without addressing these questions, you simply have a data acquisition system that does little more than gather and store data (and often faulty data at best) – the well-known situation summarized as "garbage in – garbage out!"

Measurement Noise and Filters – Separating the Wheat from the Chaff

Acquiring data is the process of inputting an analog signal from a sensor (e.g. load or strain, into an analog input subsystem), and then converting the signal into bits that the computer can read.

Noise is defined as something that masks wanted signals and does not have a strong correlation to the signal. Noise can be added to a signal at various stages – the measured parameter can be noisy, the sensor and cabling can add noise, etc. We generally aim to maximize the signal to noise ratio by minimizing the noise, maximizing the signal, or a combination of both.

Systems employ filters to reduce unwanted noise. However, there is no "universal" filter and there are trade-offs:

1. A filter with very high frequency bandwidth will pass through more of the original signal but may still pass unnecessary noise and spikes (which will lead to incorrect peaks, yield, and other readings, affecting modulus calculations, etc.)

2. A filter with too low a bandwidth will reduce noise but may remove too much of the input – as the speed of testing a specimen increases with increasing test machine crosshead rate, a point is reached where the load or strain signal will become significantly distorted.

INSTRON

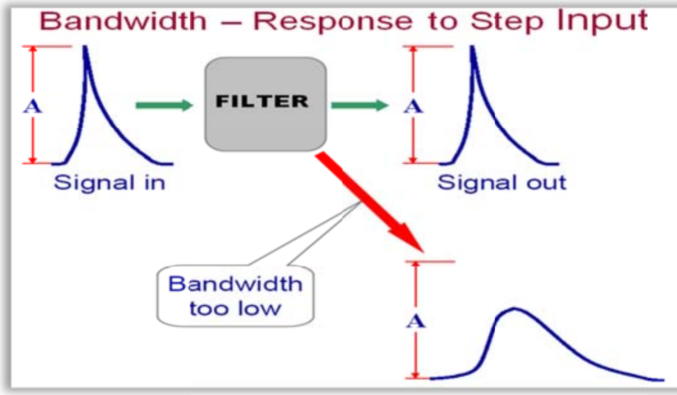
The difference is measurable®

Bandwidth and Data Rate

In practice, you may never need to deal with noise because the equipment you are using is effective in removing unwanted noise. Most systems have signal conditioning with filtering at a set bandwidth (similar to radios or music players without equalizers). ASTM [ref STP 1208] reported that for tests lasting 10 seconds, the bandwidth need not exceed 0.3 Hz for less than a 1% error and the data sampling rate need not to exceed 0.3 × 31 = 9.3 points per second. ASTM E1856 states that a bandwidth of at least 0.2 Hz was usually sufficient for ASTM E8 test conditions.

However, the requirements change if the test has sharp spikes with peaks that must be measured accurately. A test of 1 second would require a bandwidth of 20 Hz and a data rate of 20 × 31 = 620 points per second.

Historically, if the bandwidth is not available, the test must be run proportionately slower – which may be impractical since materials may be strain-rate sensitive or when the operator wants to simulate real life test conditions.



"It is difficult to give an exact number for the minimum required bandwidth of a quasi-static testing machine, but it is important to ensure that the response being observed during a test is not limited by the bandwidth of the testing machine. On the other hand, an excessively high bandwidth can be detrimental to the system's performance as accuracy may degrade and noise may increase."

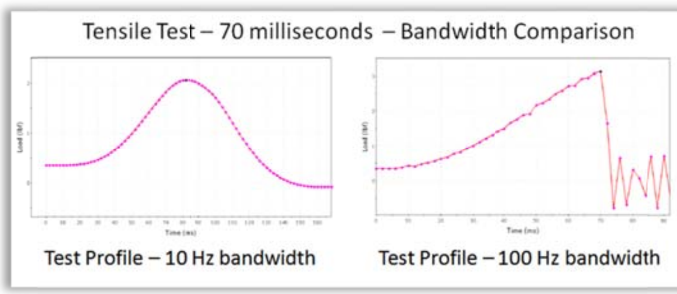
– ASTM E1856

Instron® 5900 Series and Selectable 10, 100 Hz Bandwidths

ASTM E8, ASTM D680, and the majority of standard tests last much longer than 1 - 2 seconds and a 10 Hz bandwidth is sufficient and proven in thousands of customer applications.

However, there are some test applications beyond the practical range of the 10 Hz default setting. Conditions beyond the range of a 10 Hz bandwidth setting may be:

- Events shorter than 40 milliseconds will have an effect (load-displacement phase/timing)
- Events shorter than 40 milliseconds could truncate a significant peak
- Any test or cycle on the order of 1 - 2 seconds
- "Quick" peaks, e.g. during peel or composite tests



The Instron 5900 Testing Systems offers both a 10 Hz and 100 Hz bandwidth setting and the higher bandwidth should be used for test events less than 40 msec or tests lasting less than 2 seconds.

INSTRON®

The difference is measurable®

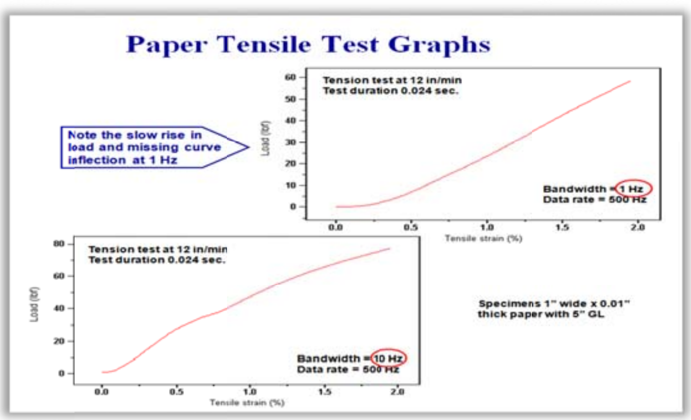
Bandwidth Effects on Accuracy, Repeatability and Reproducibility

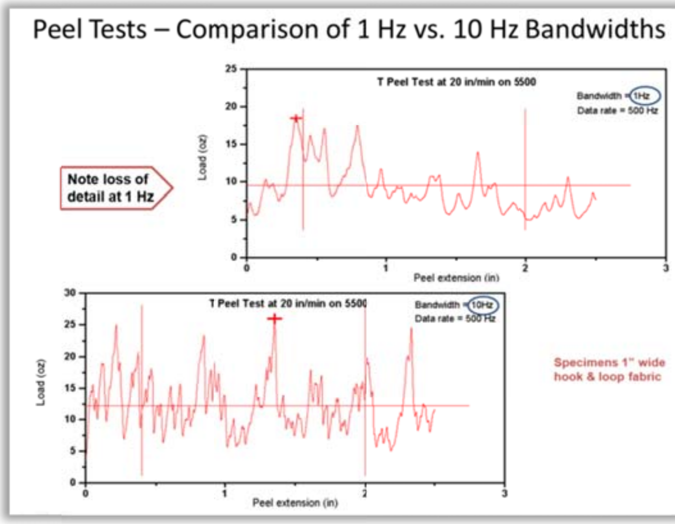
To ensure the benefit derived from using measurement data is of value and cost effective; attention must be focused on the quality of the measurement data. Most common reasons for low-quality data include system inaccuracy and too much variation in the measurement data.

A testing system with an inappropriately high bandwidth would have a large amount of noise in its data and may not be appropriate for any material or product analysis since the system's variation may mask the variation of the test sample itself. Too much noise present in the initial slope of the test curve can lead to errors in calculating modulus, data spikes can mistakenly be reported as peaks and troughs, etc. "R&R" would be adversely affected due to higher variability, leading to more parts rejection and troubleshooting.

A testing system with too low a bandwidth would miss important test data, including recording the test's actual load vs. displacement/strain profile – leading to incorrect modulus and energy calculations (most likely lower values), and incorrect reporting of preset, peak, and break values. Accuracy of test measurements and calculated results are severely affected.

Some systems may try to use an extremely high bandwidth for capturing a single point, e.g. peak load, while using a much lower bandwidth for test data acquisition (otherwise, they will overflow with data). In such cases, it cannot be determined whether the peak point was actually a spike due to excessive noise.





Summary

Bandwidth has historically been neglected as a data acquisition parameter due to simple assumptions and the inability to observe a physical pen's slew rate when technology evolved from chart recorders to digital data acquisition.

Instron® research and customer applications have verified that a 10 Hz bandwidth setting has been an ideal compromise for ensuring accurate readings and minimizing noise in the majority of test applications. Lower bandwidths, e.g. 1 Hz used on other systems, distort the actual test profile and result in lower measurements, e.g. peel tests.

However, even a 10 Hz bandwidth has limitations in extremely fast events, e.g. 40 msec or less transitions, or tests of 1 -2 seconds. An Instron 5900 Series System set to a 100 Hz bandwidth, coupled with the required faster data sampling rates, should be considered for such test applications.

Understanding bandwidth and having the flexibility to adjust settings can lead to higher test measurement and results accuracy, repeatability and reproducibility.

The difference is measurable®

Reference

1. Nicholson, A.M. “Event Criteria to Determine Bandwidth and Data Rate in Tensile Testing.” Automation of Mechanical testing, ASTM STP 1208, pp 91 -105
2. ASTM E1856-97 Standard Guide for Evaluating Computerized Data Acquisition Systems Used to Acquire Data from Universal Testing Machines