How To Guide: VersaSCAN SKP/SVET

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AMETEK

Subject: Selecting the Appropriate Lock-in Amplifier Time Constant and Related Scan Parameters

Introduction:

The VersaSCAN techniques, Scanning Kelvin Probe (SKP) and Scanning Vibrating Electrode Technique (SVET) use a lock-in amplifier (LIA) and require the user to set the *Time Constant* (TC) under the *Signal Conditioning* tab. The TC determines which of the LIA's low-pass filters will be used, which in turn, determines the amount of noise that will be filtered from the signal. The filter is applied to a continuous stream of measurements and its output is an exponential defined below.

$$\%\, Output\ of\ the\ Filter = 1 - \exp\left(-\frac{t}{TC}\right) x\ 100\% \qquad \textbf{(1)}$$

where *t* is the time after the change, the change being the movement of the probe, and TC is the user-selected value of the time constant. As will be explained below, *t* is either the *Measure Delay* or Time per point.

The user must consider how quickly data should be acquired during the scan. Waiting for the output of the filter to provide a reasonable value may require waiting a period of time equal to 3-5 TCs.

Typical Time Constant Values:

After 1 TC, the output is 63% of the total response – generally acceptable for a fast-scan

After 3 TC, the output is 95% of the total response – suggested for a high resolution scan

After 5 TC, the output is 99% of the total response – best for values that rapidly change, for example, when a large voltage transition occurs between each point.

Dependence on Movement Mode:

There are two different Movement modes, **Step** and **Sweep**. In either mode, the TC must be considered when setting the parameters, though the approach differs.

In **Step** mode, the duration of the experiment is defined by the *Measure Delay* and the *Speed (measuring)*. *Speed (measuring)* determines how quickly the probe moves between points, while *Measure Delay* determines how long after the probe stops moving that data are collected. The critical parameter to consider in **Step** mode is *Measure Delay*. This value is equivalent to *t* in Eq. (1). This should generally be set to approximately 2 times as long as the selected TC (% of output for 2 TC = 86%) and longer for high resolution or when significant changes in the response are expected from one point to the next.

In **Sweep** mode, the duration of the experiment is defined by the *Speed (measuring)*. This value, in combination with *Step Size* defines the time per point as shown in the Eq. (2) below.

$$\frac{Step\ Size\ \left(\frac{microns}{pt}\right)}{Speed\ (measuring)\ \left(\frac{microns}{s}\right)} = \frac{time\ (s)}{pt} * \frac{1\ Time\ Constant}{X\ (s)} = Time\ Constant\ /_{pt} \qquad \textbf{(2)}$$

Note that the user defines 1 Time Constant as X in seconds or $\frac{1\ Time\ Constant}{X\ (s)}$. In addition, *Step Size* defines the data density and *Speed (measuring)* is equivalent to sweep rate. For example, if the parameters are as follows:

Step size = 100 µm/pt

Speed (measuring) = 50 µm/s

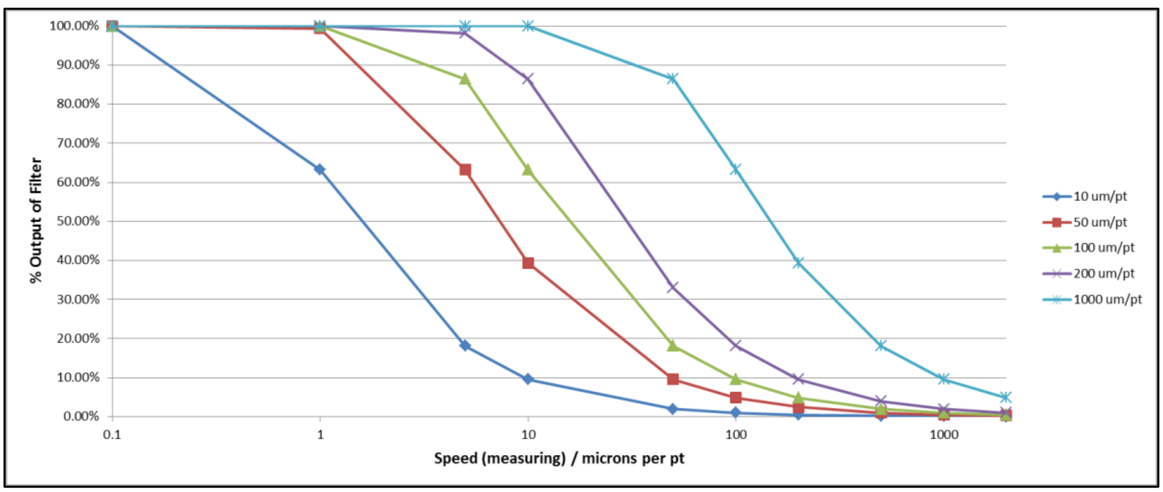
TC = 1 s

the probe will spend 2 time constants at each point, collecting 86% of the total response.

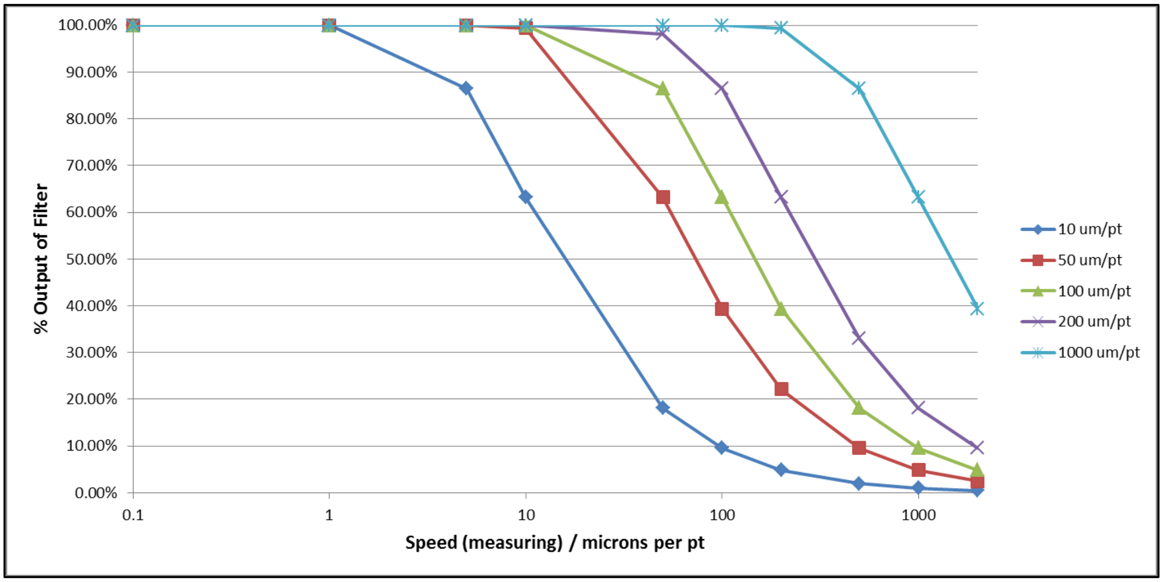
Figure 1 includes graphs plotting the % Output of the Filter vs. Speed (measuring) for various step sizes.

Here is a very useful graph charting different Data Densities (in the X-direction) versus Output of the Filter for a series of Scan Rates for three available Time Constants:

Time Constant = 10 second



Time Constant = 1 second



Time Constant = 0.1 seconds

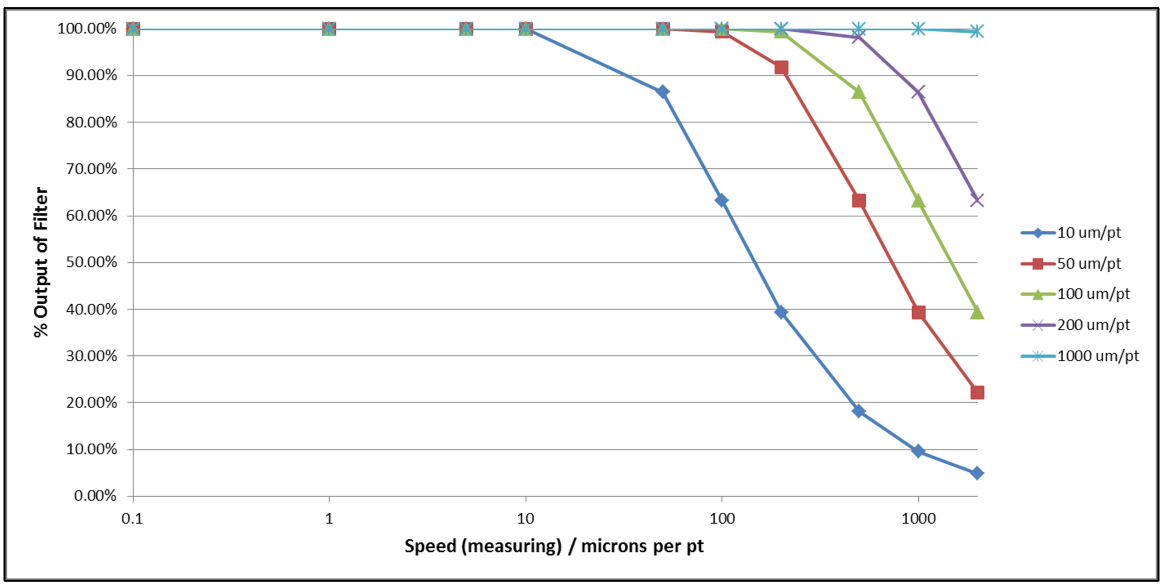


Figure 1: Graphs showing the percent output of the lock-in amplifier's filter as a function of *Speed (measuring)* for 10, 50, 100, 200 and 1000 µm/pt, as defined by *Step Size*.

Note: You can scan much faster using a lower time constant, but at the expense of sensitivity since less noise is removed from the response.

Considerations for Proper Experiment Design:

The consequence of having too low of a filter output, due to a combination of a long TC and insufficient wait time after a change, is that the response from a single position is "stretched" out over several points/positions. Therefore, some features will not appear as pronounced as they should and may be shifted to a location some number of points away from where they actually occurred. The worst-case-scenario is missing a fast transient large response, or a small local feature. If the output were too low, this response may be missed entirely.

As an example, two X-Y Area Scans were performed on the SKP test sample (galvanized mild steel with a small etched area exposing the underlying steel). The Time Constant was set to 1 s and the Measure Delay was set to 100 ms or 3 s, while the other parameters were held constant.

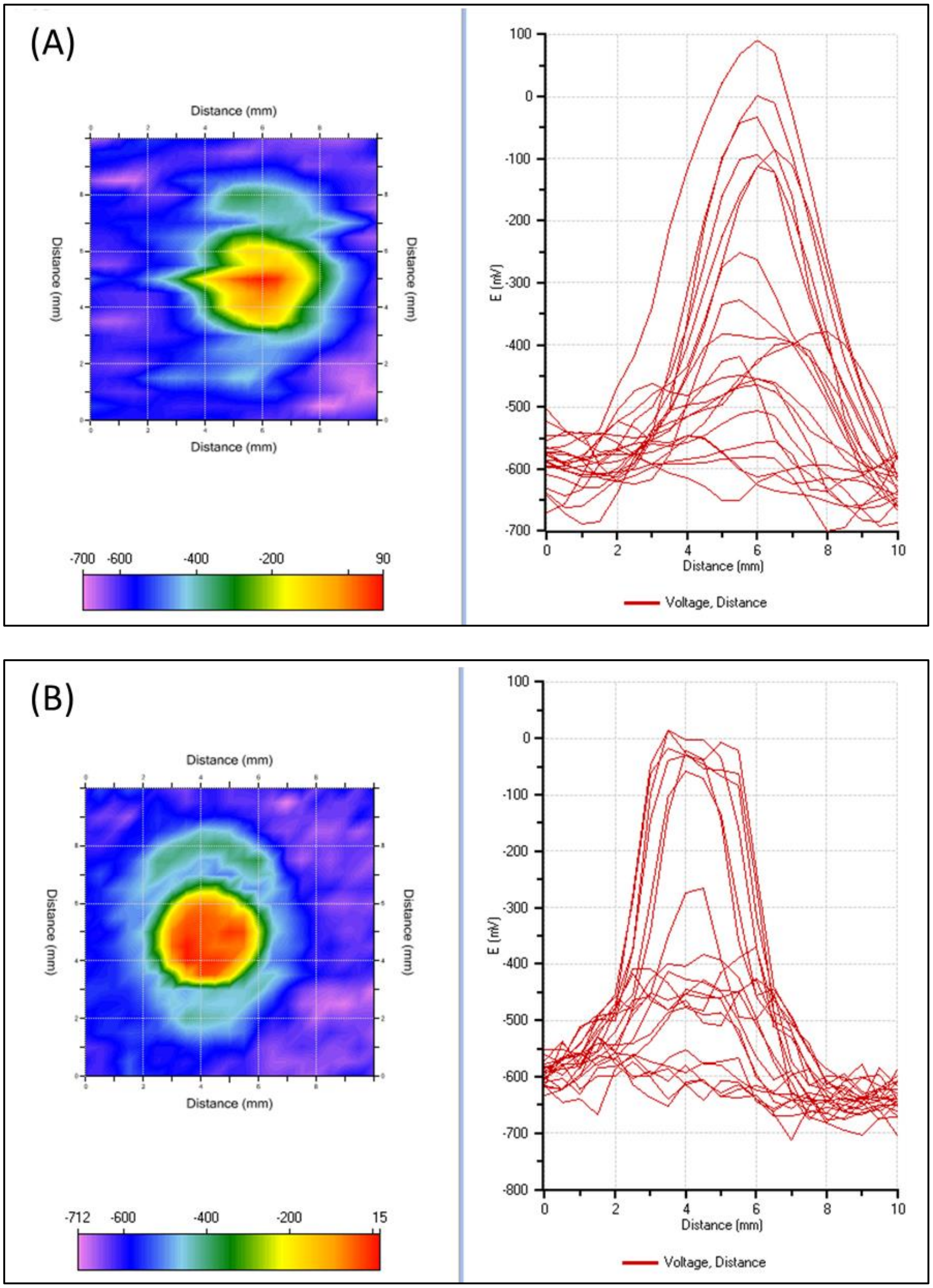


Figure 2: X-Y Area Scans of the SKP test sample using a 1 s TC, the Measure Delay was set to (A) 0.1 s and (B) 3 s.

Figure 2 (A) clearly illustrates that using a 100 ms *Measure Delay* time with a TC of 1 s results in the feature representing the etched region being shifted from its actual position and broadened. Since the probe is scanning from left to right and the delay time is too short, the peak appears further to the right than it should. Figure 2 (B) shows an ideal scenario where the *Measure Delay* was set to 3 TCs or 3 s. The consequence of having too high of an output with a large time constant is that the experiment duration can be extremely long since the *Speed (measuring)* must be much lower.

For the majority of experiments, 1 to 2 time constants are sufficient for fast scans. Most samples will not have sharply defined large responses between points, so using a longer TC with a lower output is usually acceptable. This is especially evident in SVET experiments where the potential gradients disperse in solution to smooth transitions.