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Technical Report

The influence of signal smoothing filters on brake test accuracy

CORRSYS DATRON
Sensorsysteme GmbH

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Title: **The influence of signal smoothing filters on brake test accuracy**

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Signal processing, in general, consumes considerable amounts of time and energy. This characteristic is exhibited both by human beings, and by sensor and data acquisition systems.

In both human and electronic systems, limitations in the capacity of the data processing unit result in a delay that is referred to as latency, or as a latent period. Physiologists define the latent period as “the time between stimulus and response: the interval between the application of a stimulus and the start of a response”. Similarly, information theory defines latency as “time taken to cross a network: the time it takes for a data packet to move across a network connection.”

Latency and bandwidth are two primary factors that determine the speed at which signals are processed. In consideration of the degree to which latency can impact measurement results, it is somewhat surprising that the latency of an entire data acquisition and signal processing system is often unknown. Total system latency can be estimated by summing the individual latency periods of each of the components in the system (e.g. sensor, pre-amplifier, data acquisition, etc.). However, this process is often impossible, because few manufacturers actually specify latency.

As do many speed sensors, CORREVIT® Optical Sensors use a moving-average filter to smooth the speed signal. Moving-average filters are simple to implement and do not require high computing power or special signal processor units.

Although early CORREVIT® Sensors incorporated filters with fixed filter times, more recent products offer the possibility to change the filter time from 8ms to 512ms in steps of 2^n. The latency period of a moving average filter can be calculated as follows:

$$\boxed{\tau = \frac{t_{filt} - 1/f_c}{2} \approx \frac{t_{filt}}{2}}$$

In this equation, t_{filt} = filter time in seconds, while f_c represents the clock-in frequency of the filter. With $1/f_c$ being small compared to t_{filt}, the latency can be approximated as t_{filt}, / 2.

Today’s CORREVIT® Optical Sensors, including the L-400 and the S-400, sample at 250 Hz. Therefore, - using $1/f_c$ = 1/250 Hz = 4ms, - typical latency periods of the moving average filter calculate as follows:

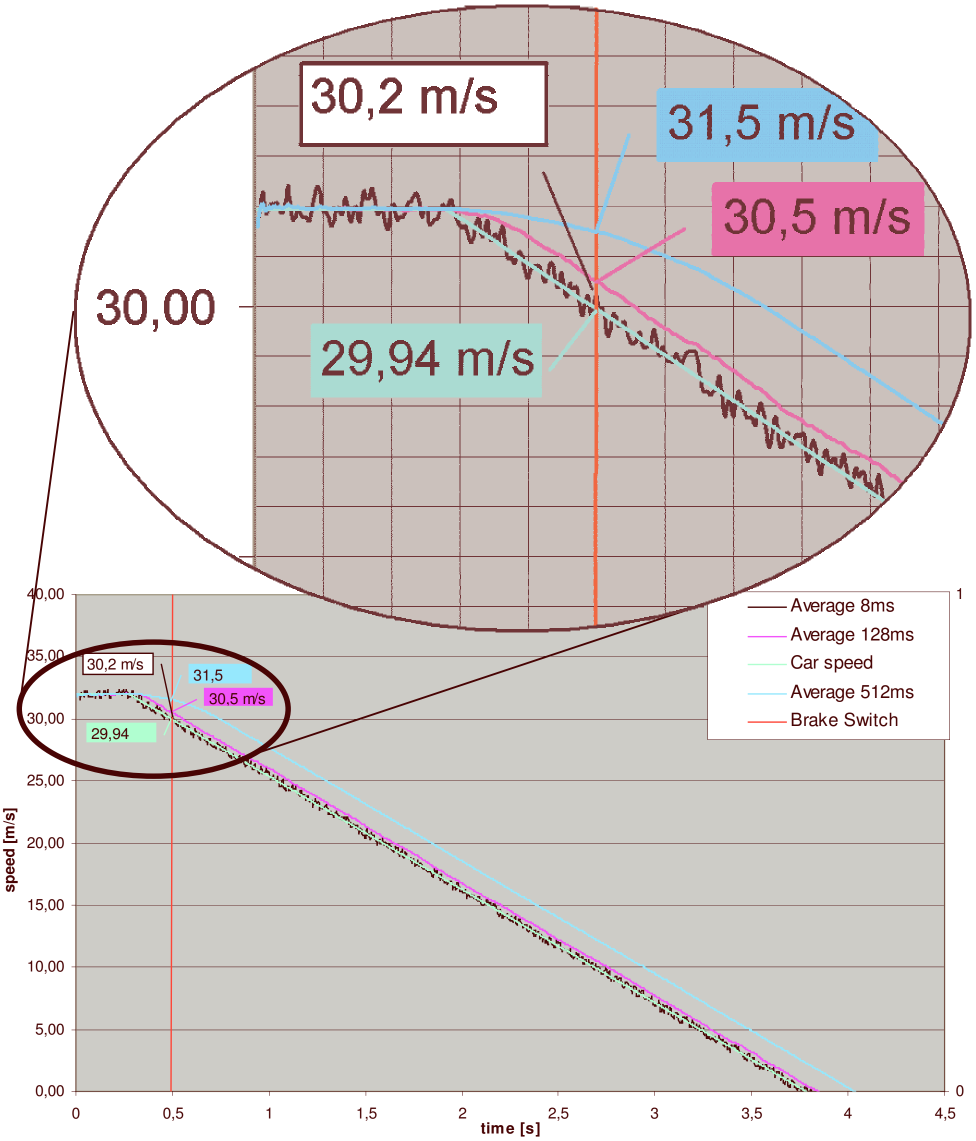
Filter time	latency
8 [ms]	2 [ms]
64 [ms]	30 [ms]
128 [ms]	62 [ms]
512 [ms]	254 [ms]

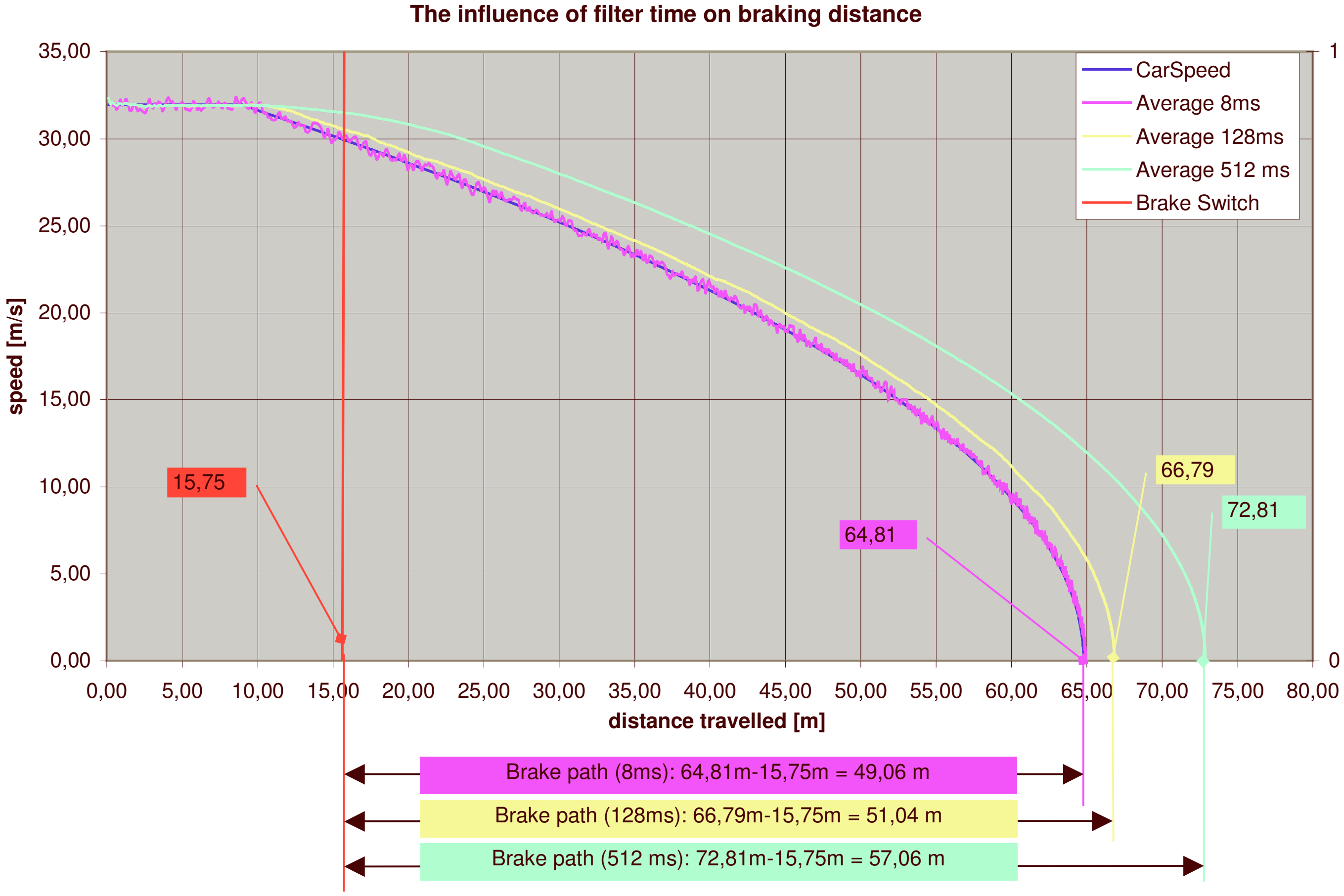
To show the influence of various filter times, a car is equipped with 4 sensors, each using a different filter time.

In this example, the car is traveling at a speed of 115 km/h (or 32m/s). After 0.5 seconds, the driver applies the brakes and/or passes a light barrier (red vertical line), which triggers the brake test. The magnification shows the speed outputs of each sensor.

Clearly, these outputs differ from the car speed, and the deviation is somewhat proportional to the latency produced by the signal-smoothing filter.

Because the trigger is fixed, higher start speeds correlate with longer braking times. The effect of higher starting speed and longer measurement period is displayed in the figure below, showing the same data in the format of speed vs. distance traveled:





Here, trigger position is at 15.75m. Braking distances are obtained from this position to standstill for each speed output. The car reached standstill position after 49.05m. The sensor with the shortest filter time provided the most accurate result: 49.06m.

The sensor using the default sensor set-up of 128 ms filter time, showed a braking distance of 51.04m, which is 1.99 m, or 4% more than the real value. Using the smoothest filter set-up for the speed signal, the deviation reaches 8.0 m, which equals a very significant 16.3% deviation!

Conclusion:

Latency is an inevitable product of signal filtering, which correspondingly tends to increase the braking distance. Therefore, to maximize measurement accuracy in vehicle dynamics testing, latency must be reduced to a minimum. As evidenced by these test results, no sensor using a fixed filter time can be recommended for highly dynamic measurements. In above the example (MFDD of app. 9 m/s^2), the error caused by latency is more than 30% / second. It is by no means an exaggeration to state that - with error of this magnitude – the test result is better classified as a guess than as an actual measurement.