The Meaning of Time Constants and Noise measurements in comparison with other LockIn amplifiers

Aim: Comparison of noise measurements between different LockIn amplifiers and diverse filter adjustments.

- Noise is measured with regards to ENBW (equivalent noise band width) and NPD (noise power density), unit of noise is V/sqrt(Hz)
- Calculation of ENBW/NPD is dependent on mode and form of filter implementation
- Time Constant T = 1 / Band width = 1 / BW(-3dB)
- NPD = BW(-3 dB) * "correction factor" [filter level and filter mode]

The "correction factor" can be calculated if following conditions apply:

- The ideal Filter (form = rectangular) with a band width of 1/T detects the same amount of noise like the real implemented filter.
- The filter of the eLockIn204 is similar to the ideal rectangularly filter design. Thus, the correction factor of the eLockIn204 is close to "1".

Examples for "correction factors" for two different lockin ampifiers:

Filter-order	Stanford SRS 810	eLockIn20x
1 = 6 dB	1/(4T)	1.5707 / T
2 = 12 dB	1/(8T)	1.1107 / T
4 = 24 dB	1/(24T)	1.0262 / T

When comparing the input noise of the eLockIns with other lockin amplifiers, it is impossible to measure the same noise by applying a similar time constant T.

How to choose the correct time constant for **noise** comparison:

Calculation of ENBW for similar numerical settings of TimeConstant and RollOff:

SRS810:	100 ms/12 dB	ENBW = 1/(8*0.1) =	1.25 Hz
eLockIn204:	100 ms/12 dB	ENBW = 1.1107/ 0.1 =	11.107 Hz

When the same noise is measured (e.g.: noise = 100 nV/sqrt(Hz)), both lockin amplifiers show the following noise:

SRS810:	100 ms/12 dB	100 nV/sqrt(Hz) * sqrt(ENBW) =	111.8 nV
eLockIn204:	100 ms/12 dB	100 nV/sqrt(Hz) * sqrt(ENBW) =	333.3 nV

In order to compare the results of two different lockin amplifiers, the same ENBW has to be used:

e.g.: ENBW ~ 1 Hz → required settings are:

SRS810:	100 ms, 12 dB	= 1,12 Hz
eLockIn204:	**1 s,** 12 dB	= **1,12 Hz**

Important Note: the eLockIns require a longer Time Constant to reach the same output noise (see measurement below).

BUT: this does not mean they measure slower!

Just another example for a backward calculation of the signal's noise:

Assume, both lockin amplifiers show on their displays a signal amplitude of 1 µV with T = 100 ms at 12 dB:

SRS810: 100 ms, 12 dB: Noise = 1 µV/sqrt(1.25 Hz) = 894 nV/sqrt(Hz)

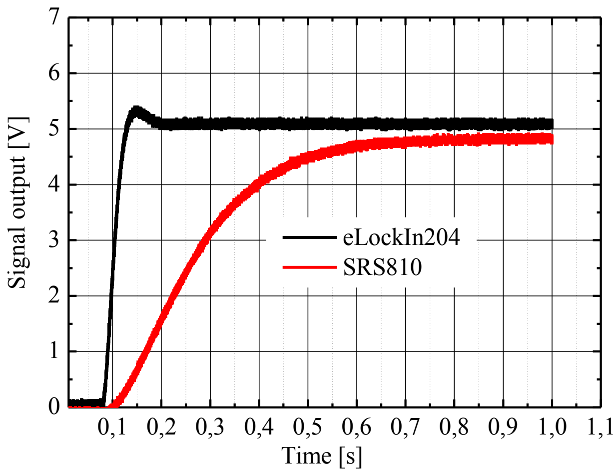
eLockIn204: 100 ms, 12 dB: Noise = 1 µV/sqrt(11.1 Hz) = 301 nV/sqrt(Hz)

- Noise measurements with the eLockIn204 require longer time constant settings to achieve comparable results.
- The ideal filter design causes a shorter response time during the measurement. Thus, there is an advantage for measurements of time-dependent signals.

Comparison of the response time on a step input:

Adjustments for both devices: 100 ms, 12 dB, low noise input, f = 100 kHz, sensitivity: 20 mV;

Signal: step from 0 mV to 10 mV

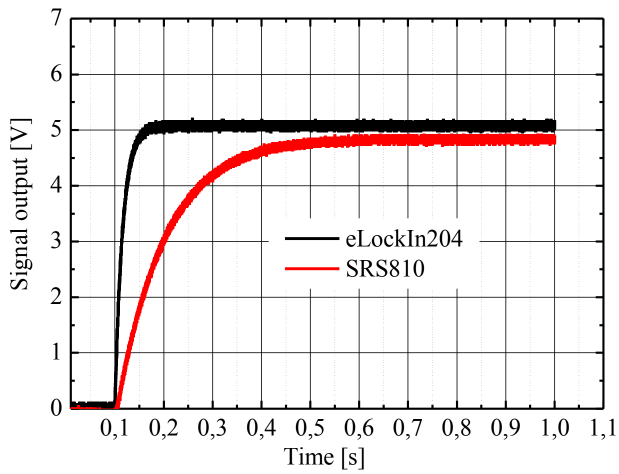


eLockIn204: response time is faster than T = 100 ms; a small ringing is shown (due to the filter-characteristics of the Butterworth-filter 2nd order).

SRS810: requires 8-times more time to reach almost the same output signal (corresponds to the difference in the calculated filter correction).

If 6 dB are used instead of 12 dB, the ringing effect of the Butterworth-filter vanishes for the eLockIn204. The SRS810 takes 4-times more time reaching the same output signal.

Further advantage of the eLockIn204: the used time constant relates to the response time of the system.



Test:

recording a response curve to detect the reaction time of the system (measurement of a resonance curve)

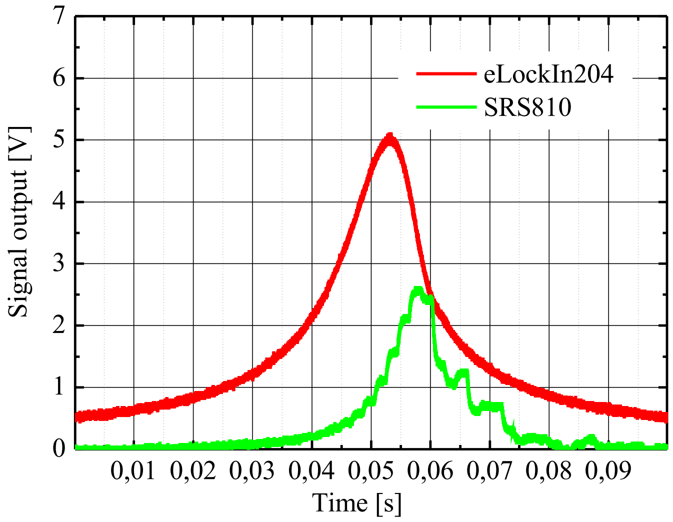
Sine wave generated with AFG-function generator (Tektronix).

Sweep of output frequency from 95 kHz to 105 kHz in a time interval of 500 ms (20 Hz/ms) with the AFG function generator.

Output amplitude: 100 mVrms

Parallel measurements with both lockin amplifiers.

Lockin amplifier settings:
f = 100 kHz, 100 ms, 6 dB



The shown result is recorded with an oscilloscope. The oscilloscope is externally triggered with the function generator (cycle rate: 50/50, on falling slope, so that the trigger is exactly at 100 kHz output frequency). The oscilloscope displays 100 kHz exactly in the screen center at 0.05 s.

Vertical axis of oscilloscope: 20 mV/division

eLockIn204: Has its maxima about 0.25 T after the external maximum. It reaches the maximum value (would be 5 V, because of the 20 mV scaling).

SRS810: Reaches the maxima about 100 ms later. Has only 0.5 x amplitude. Steps are dependent on the frontpanel output (1 kHz output rate). Steps would vanish if X is displayed as a direct output quantity.