# aLIGO PSL
# Inner-Loop Power Stabilization
# Photodetector Design (LIGO-T1000634-v1)

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**Abstract**

This document describes the photodetector for the inner-loop power stabilization of the aLIGO PSL. It contains design notes and simulations performed with LISO. Document D1001998-v2 contains the schematic and layout of the photodetector.

## 1 Operating Point

The photodetector is designed for an average photocurrent of 3 mA, which has a relative shot noise of $1 \times 10^{-8}\,\mathrm{Hz}^{-1/2}$. (In principle, the operating point can be changed to photocurrents between 1 mA and 10 mA by replacing the transimpedance resistor.) At 3 mA photocurrent the signal at the DC output is 10 V.

## 2 Transfer Function

The photodetector has a measured bandwidth of about 1.2 MHz with a 2 mm InGaAs photodiode and a $3.3\,\mathrm{k}\Omega$ transimpedance resistor.

The signal of the transimpedance amplifier is passed through a signal conditioning filter. The designed transfer function is

- Poles: 2.79 Hz, 3.78 Hz, 118 Hz
- Zeros: 71.4 mHz, 71.5 mHz
- Factor: -0.203

The transfer function of the signal conditioning filter was simulated with LISO (see Fig. 1). The zpk representation was fitted with LISO. The complete transfer function from photocurrent to FILT output voltage is shown in Fig. 2

## 3 Noise

The shot noise of 3 mA photocurrent is above the electronic noise for a dark photodiode from 1 Hz to 100 kHz. The electronic noise was simulated (see Fig. 3). The equivalent current noise at the photodiode is shown in Fig. 4.

## 4 Dynamic Range

The dynamic range of the photodetector is limited due to the signal conditioning filter. The maximum relative power fluctuations, without saturating the signal conditioning filter, at the photodiode are shown in Fig. 5. In case only the inner-loop power stabilization is engaged, this should be no problem, since the power stability requirements are far below the maximum dynamic range. However, in case the outer-loop power stabilization is engaged as well the dynamic range of the photodetector is the dynamic range of the outer-loop actuator since the outer-loop will use an error point summation of the inner-loop to actuate the power downstream of the MC. Therefore the maximum tolerable power fluctuations introduced by the IO is given by this dynamic range – considering only the requirement that the inner-loop photodetector is not saturating, outer-loop loop-gain might set stricter requirements.

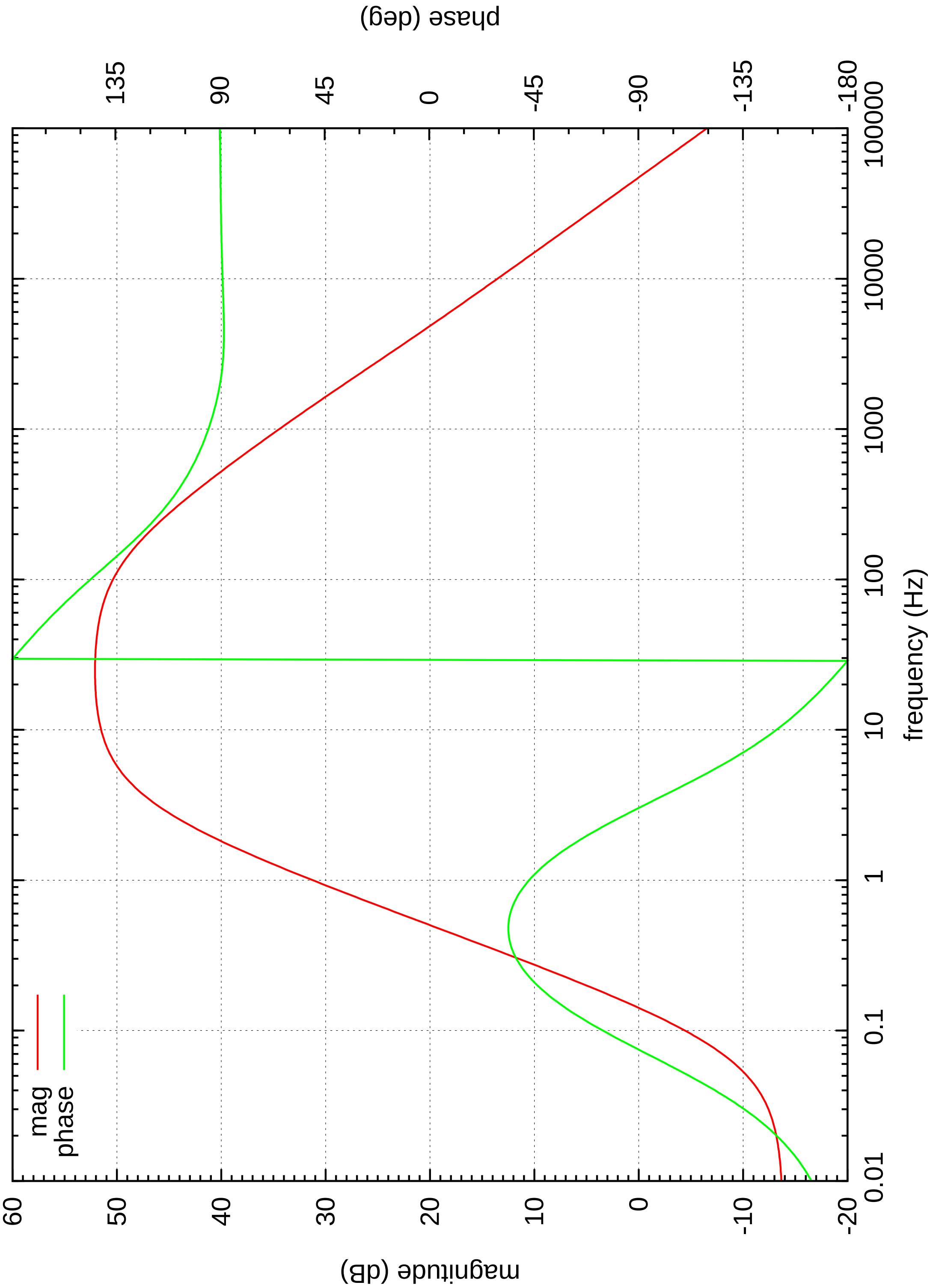


Figure 1: Simulated transfer function of the signal conditioning filter.

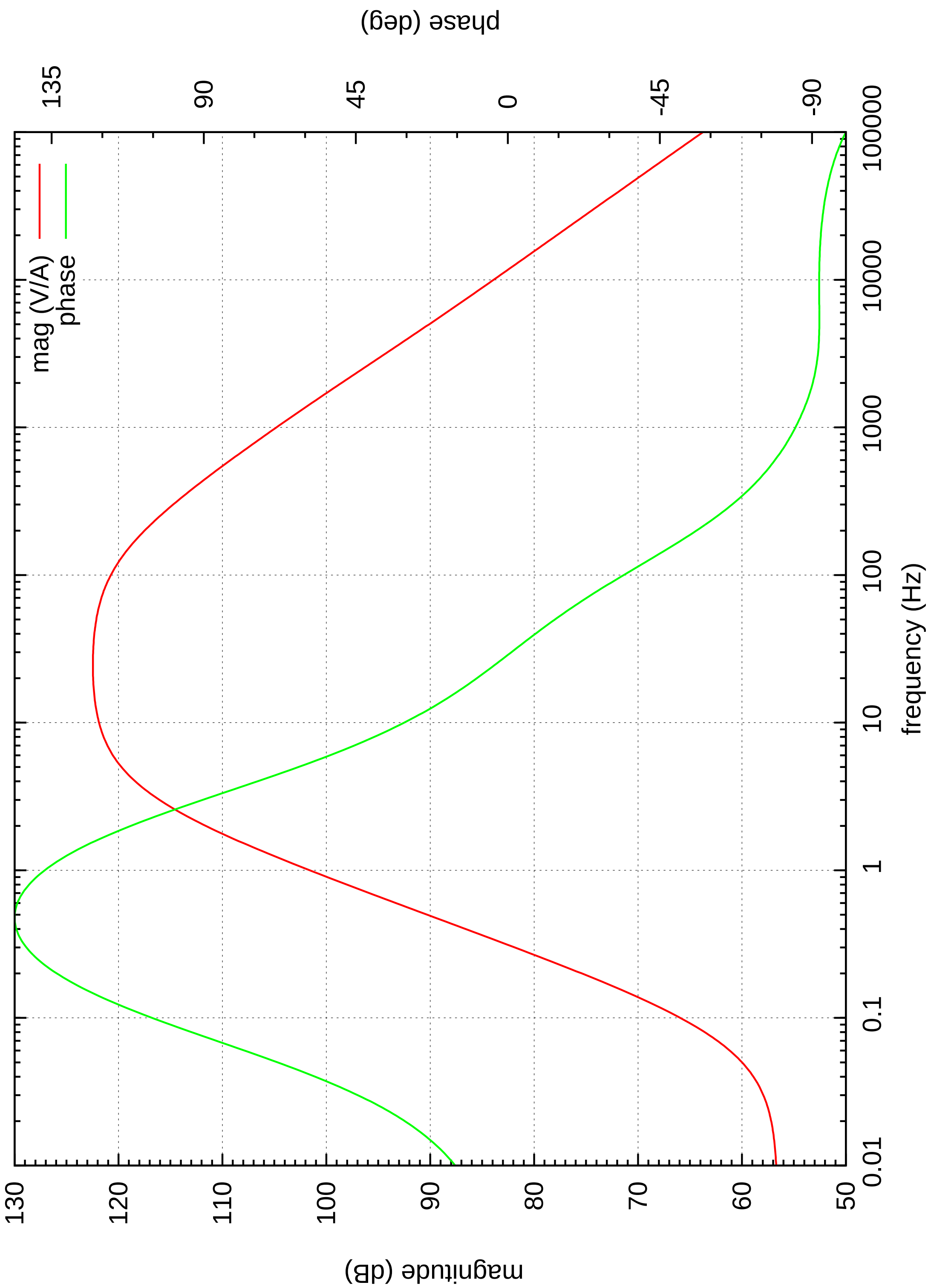


Figure 2: Simulated transfer function from photocurrent to FILT output voltage.

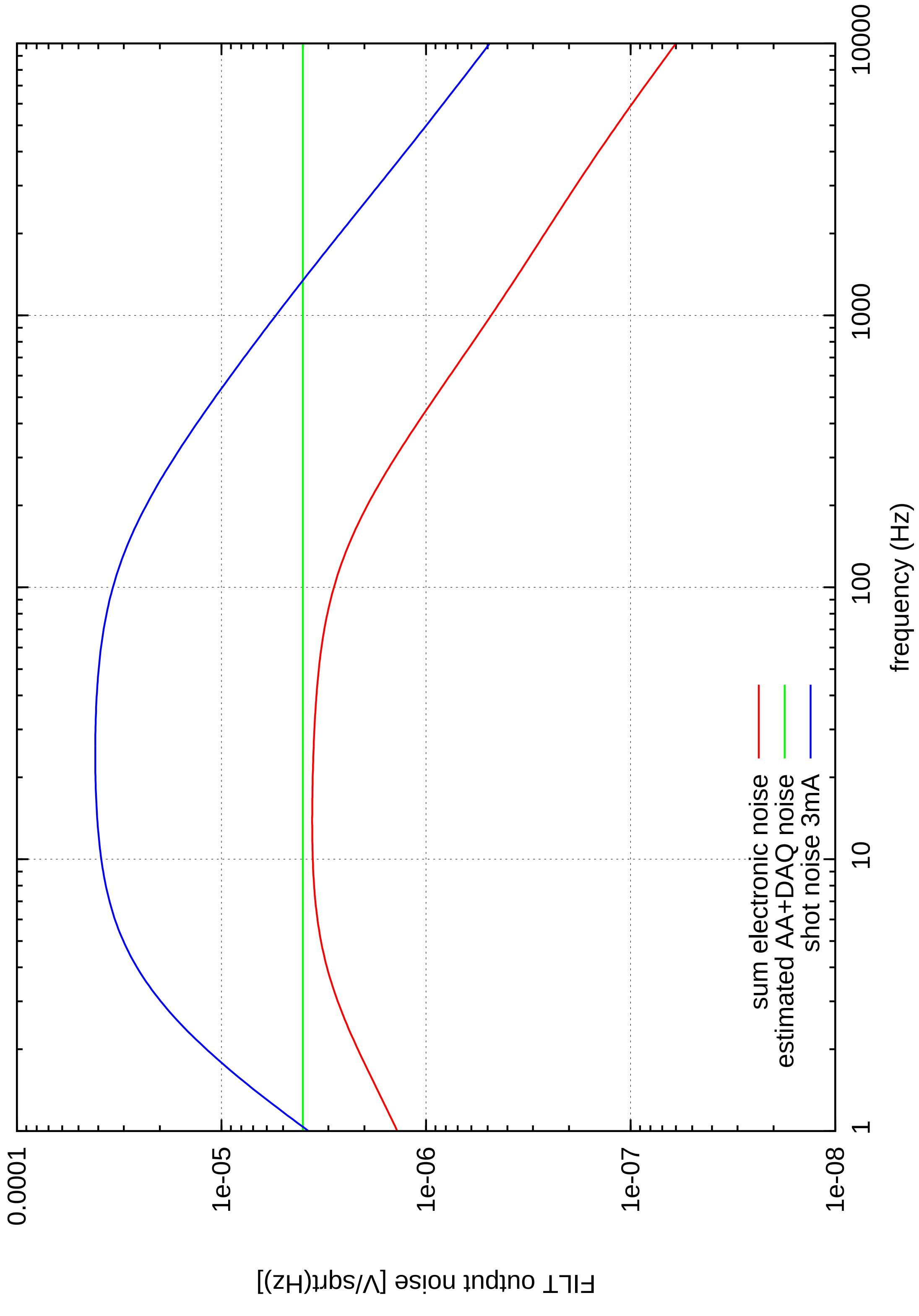


Figure 3: Electronic noise at the FILT output.

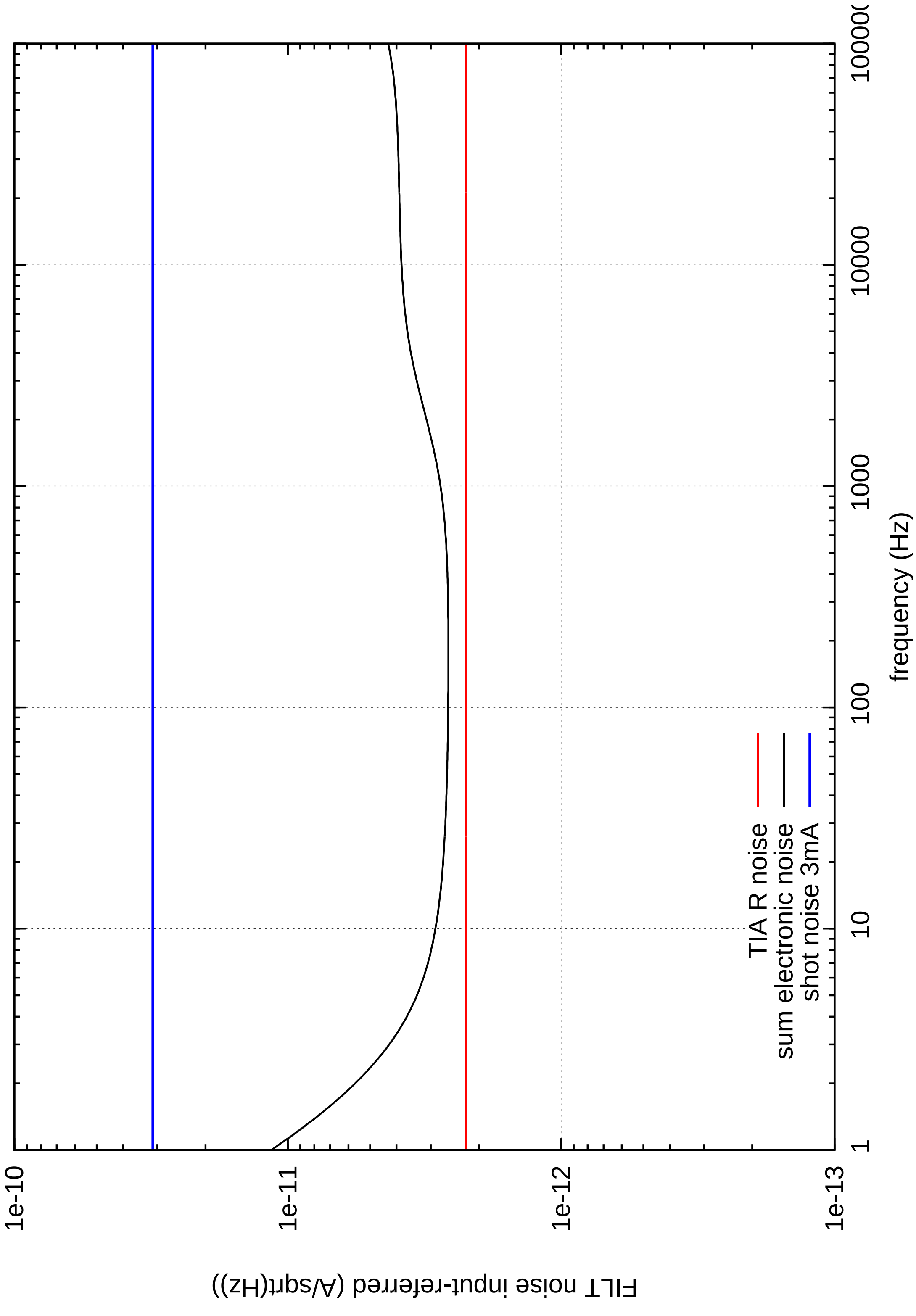


Figure 4: Equivalent current noise at the photodiode.

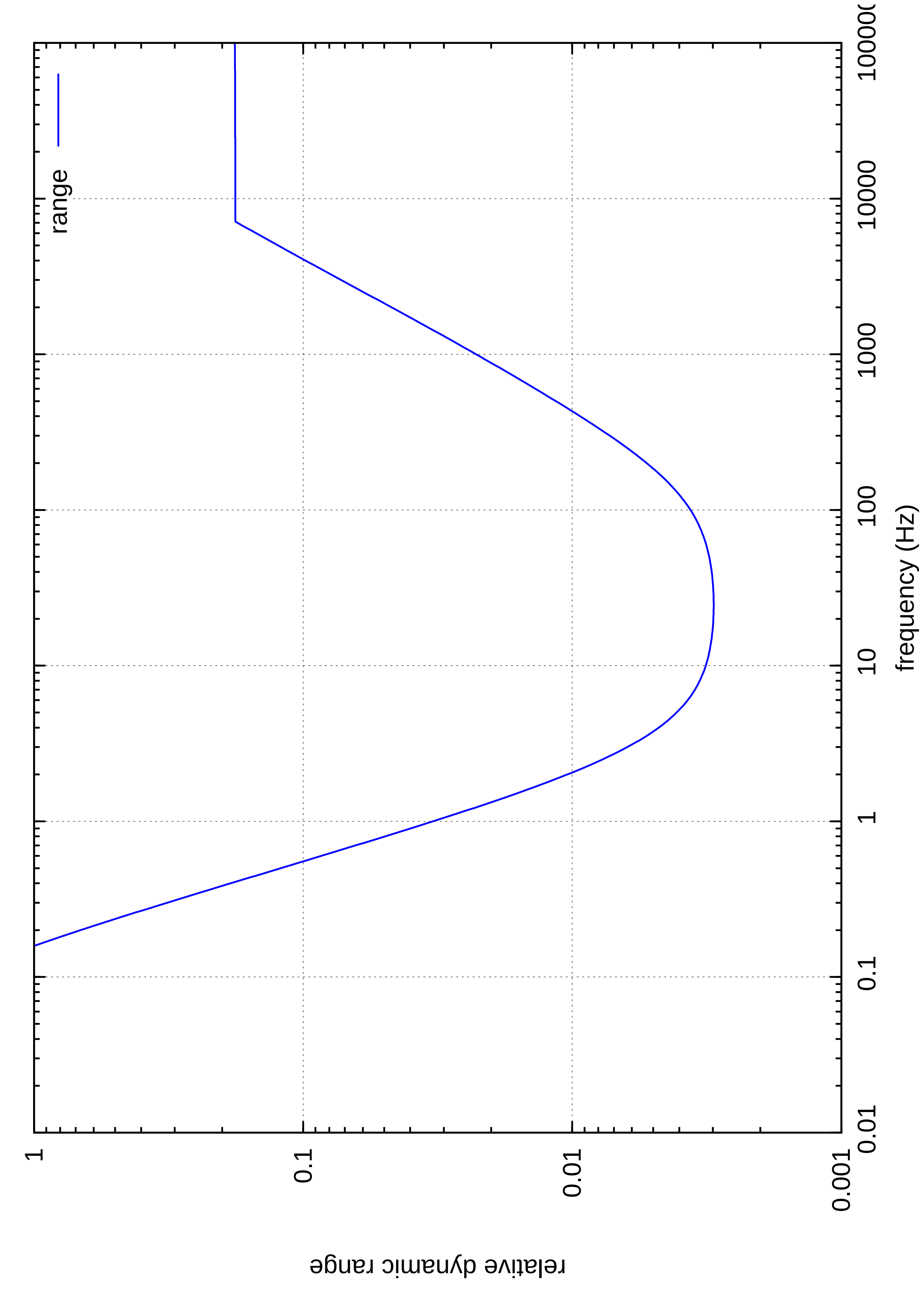


Figure 5: Maximum relative power fluctuations without saturating the signal conditioning filter.