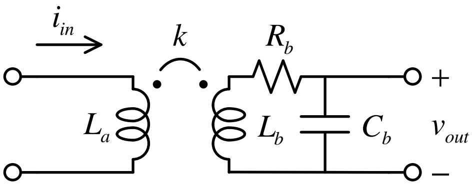
Current transformer



A current transformer can be built as shown in the picture. The transformer is usually a toroid where L_a is the inductance of the wire where current is to be measured passing through the center of the toroid, and L_b is the inductance of a coil would over the toroid, with n turns. If the coupling is good, $L_a = L_b/n^2$. At low frequency, C_b is open, and:

$$V_{out} \approx j\omega M I_{in} = j\omega k\sqrt{L_a L_b} I_{in} \approx j\omega \frac{L_b}{n} I_{in}$$

Considering the impedances of the transformer low, the lower cutoff frequency is:

$$\omega_1 \approx \frac{1}{R_b C_b}$$

At high frequency the transformer has high impedance, and the upper cutoff frequency is:

$$\omega_2 \approx \frac{R_b}{L_b}$$

The transimpedance gain is found replacing ω_1 in the first equation, considering the after the first pole the differentiation is cancelled:

$$\frac{V_{out}}{I_{in}} \approx \frac{1}{R_b C_b}\frac{L_b}{n}$$

The device can be designed by specifying the cutoff frequencies, after measuring L_b.

Example:

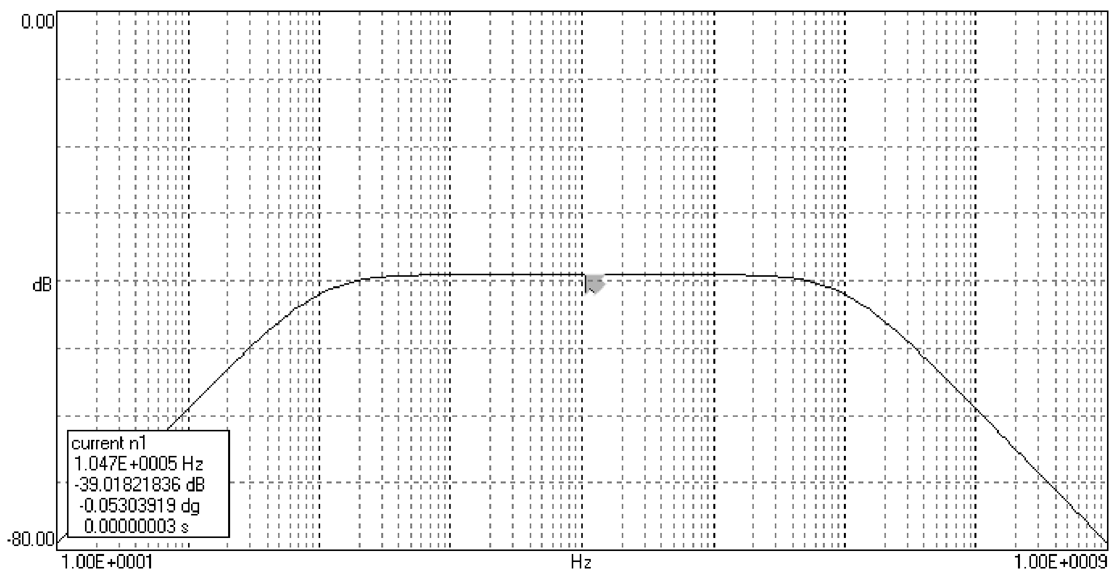
Let L_b = 36 µH, n = 20, and bandwith between 1 kHz and 10 MHz:

$$\frac{R_b}{L_b} = 2\pi\times 10\times 10^6 \therefore R_b = 2262\Omega$$

$$\frac{1}{R_b C_b} = 2\pi\times 10^3 \therefore C_b = 70.36\text{nF}$$

$$\frac{V_{out}}{I_{in}} = \frac{1}{2262\times 70.36\times 10^{-9}}\frac{36\times 10^{-6}}{20} = 11.3\ \text{mV/A}$$

Note that the transimpedance is directly proportional to the number of turns (L_b is proportional to n^2) and to ω_1, and that greater gain reduces the bandwidth. Below is an exact simulation of the design.



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