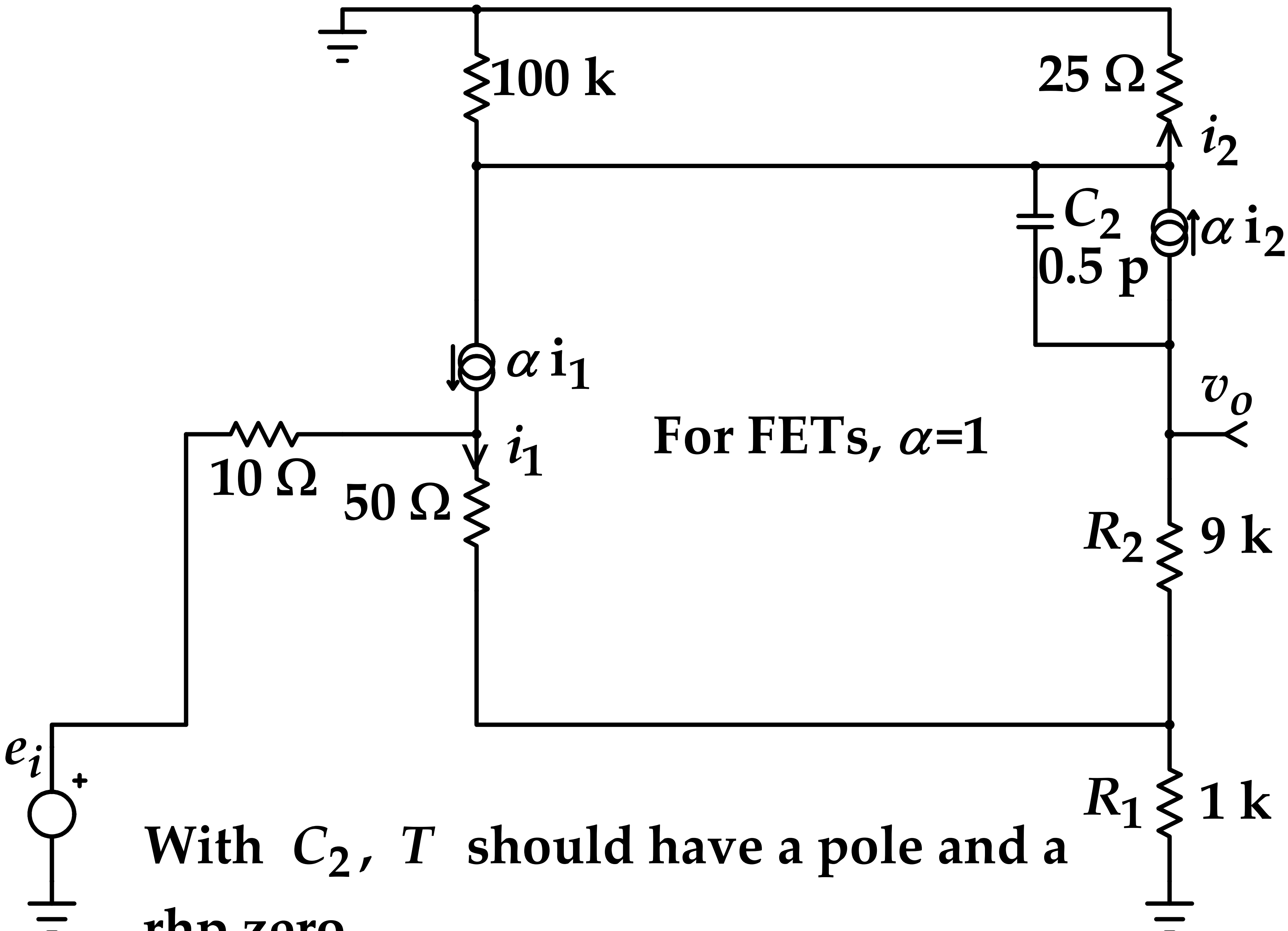
EXAMPLE

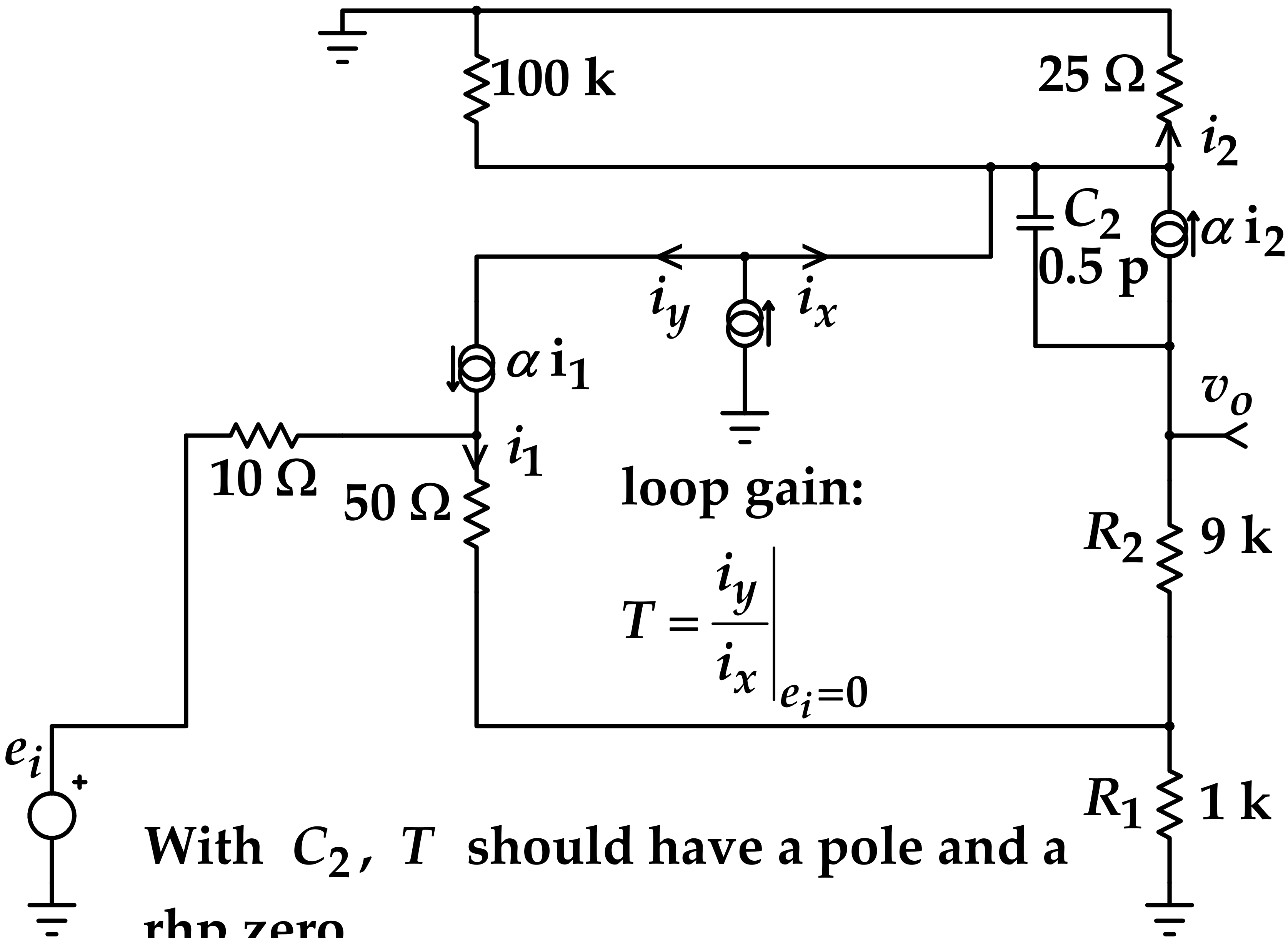
14. A 2CE/S FEEDBACK AMPLIFIER

A 2-stage Common-Emitter/-Source Amplifier



With C_2, T should have a pole and a rhp zero

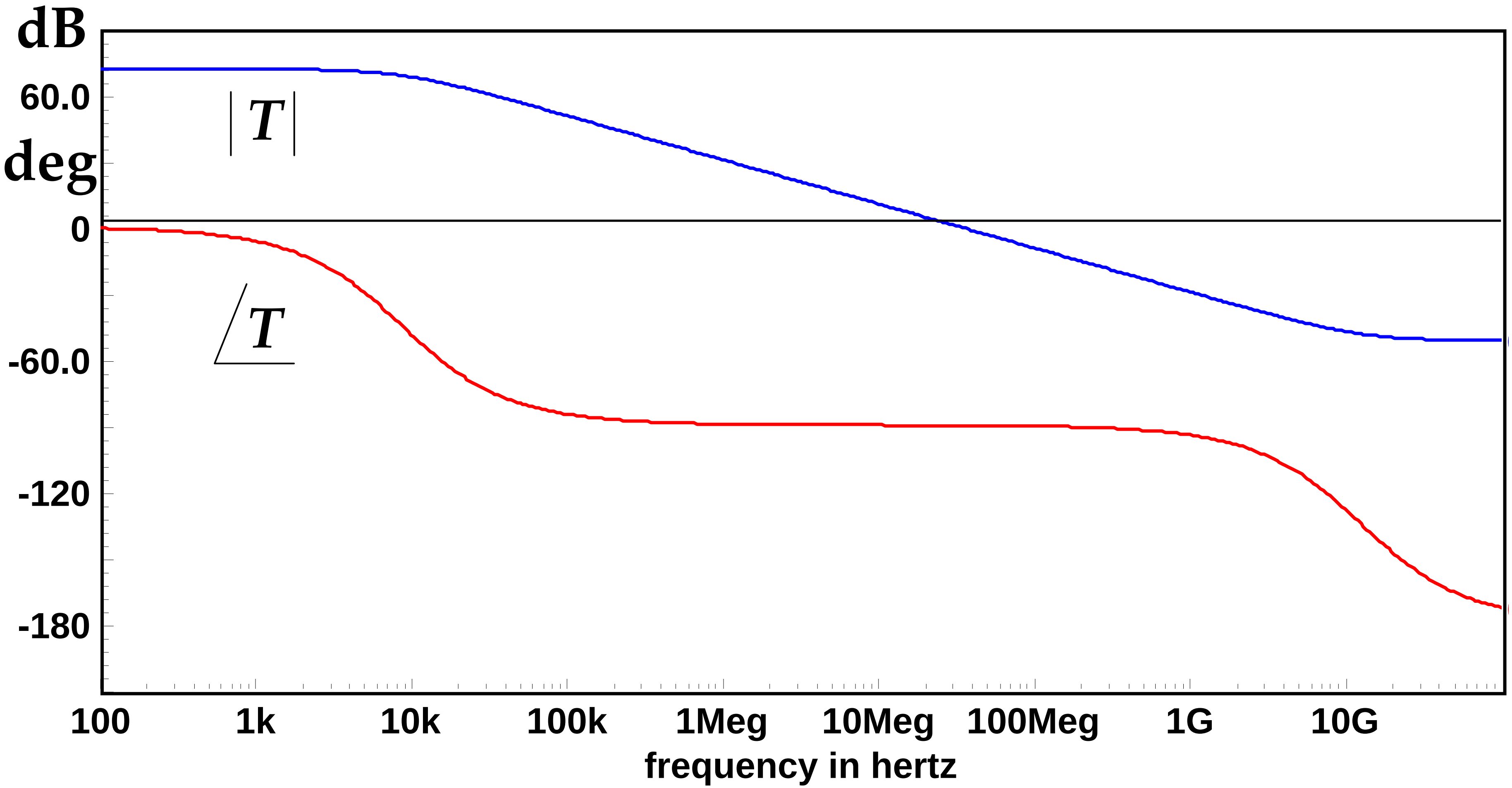
An ideal test current injection point is at the output of the first stage:



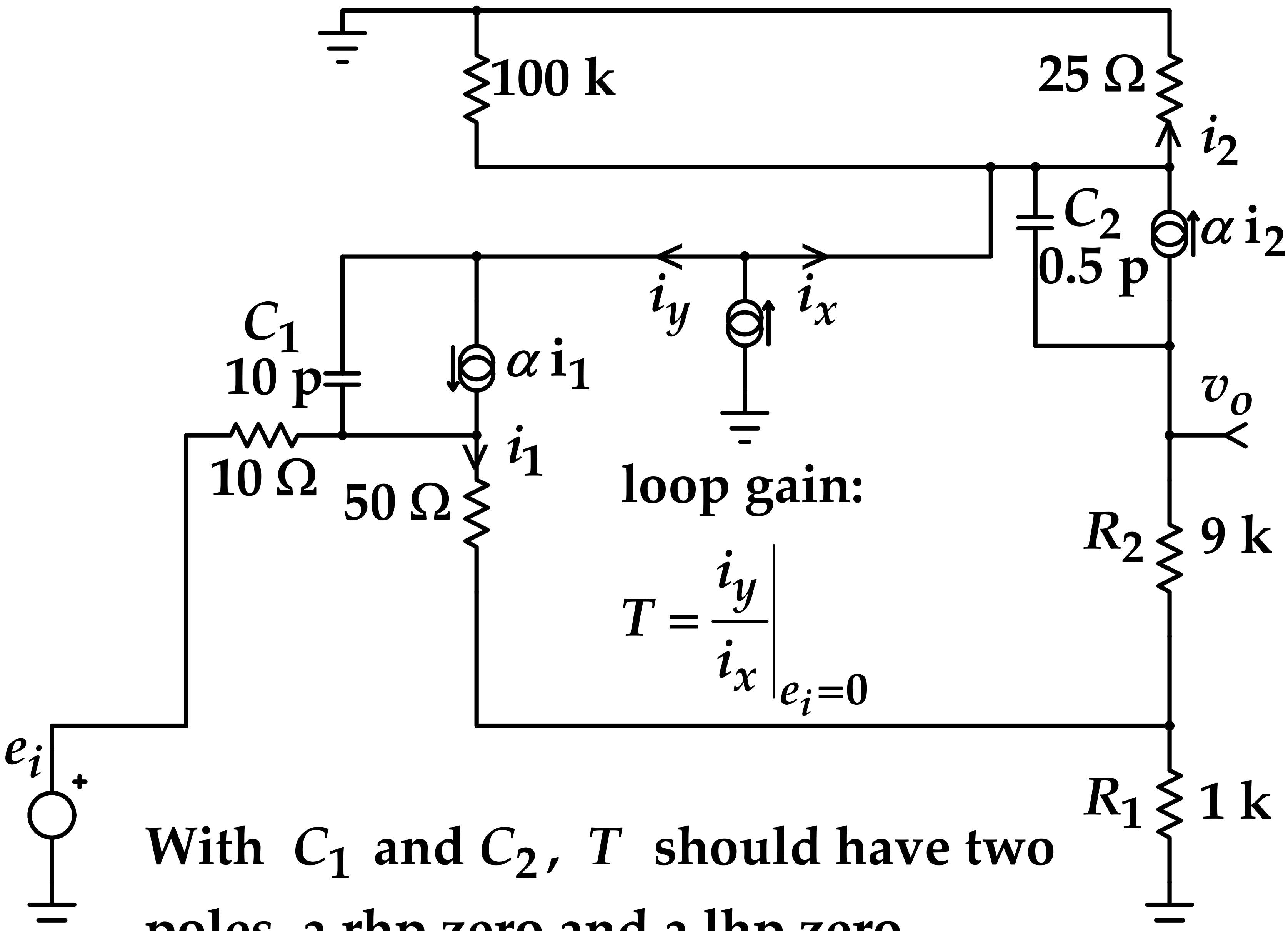
loop gain:

$$T = \left.\frac{i_y}{i_x}\right|_{e_i=0}$$

With C_2, T should have a pole and a rhp zero



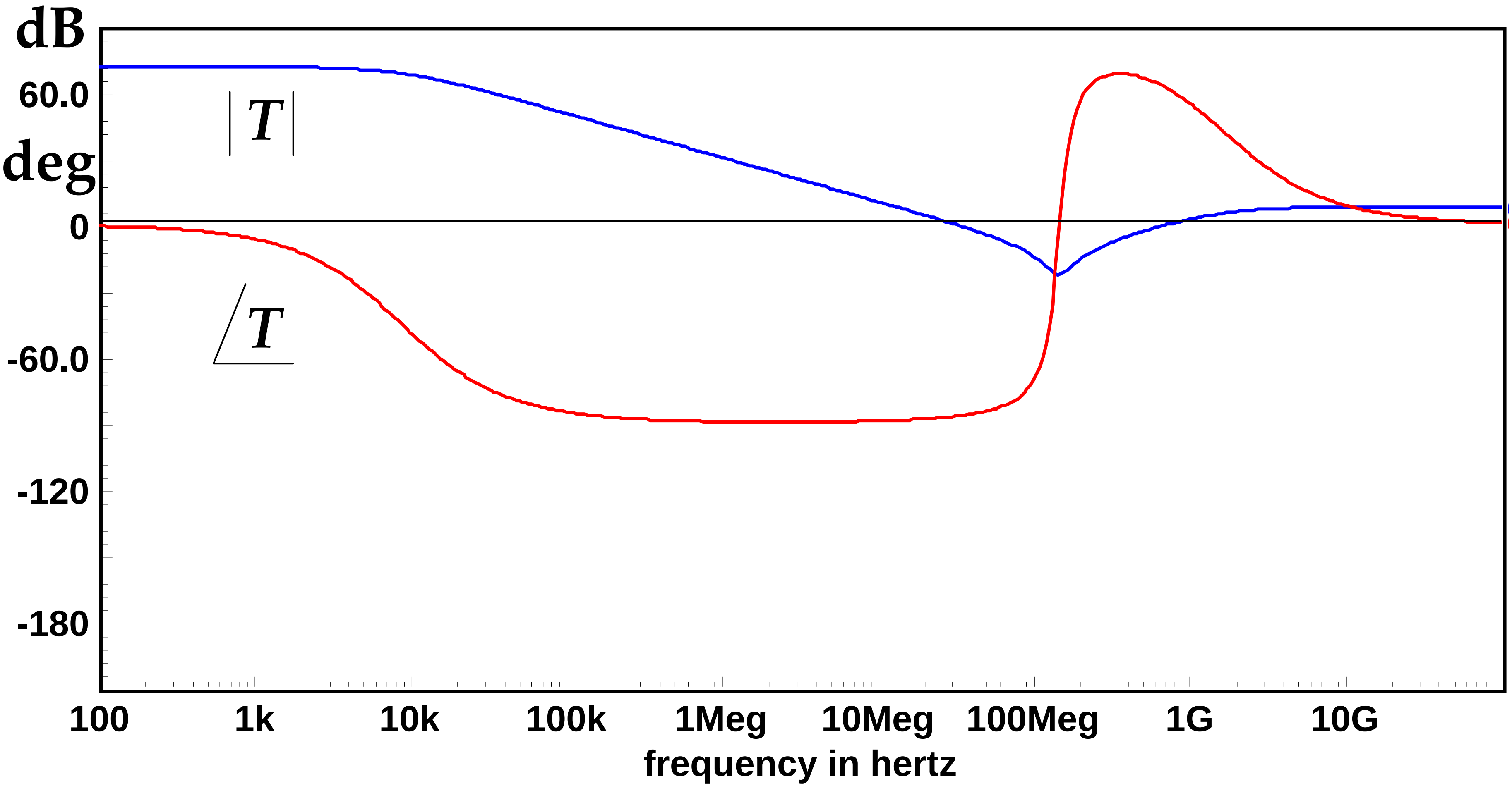
With C_2: "right" answer



loop gain:

$$T = \left.\frac{i_y}{i_x}\right|_{e_i=0}$$

With C_1 and C_2, T should have two poles, a rhp zero and a lhp zero



With C_1 and C_2 : "wrong" answer

Why?

In the presence of C_2, the selected test current injection point is no longer "ideal", and in fact there is no ideal injection point for either a test current or a test voltage

A 1975[*] paper showed that *successive* injection, at a nonideal point, of current and voltage test signals to give T_i and T_v could be combined to give the correct result for T :

$$\frac{1}{1+T}=\frac{1}{1+T_i}+\frac{1}{1+T_v} \quad \text{or} \quad T=\frac{T_iT_v-1}{2+T_i+T_v}$$

[*] R.D.Middlebrook, "Measurement of loop gain in feedback systems," Int. J. Electronics, 1975, vol. 38, No. 4, pp. 485 – 512.

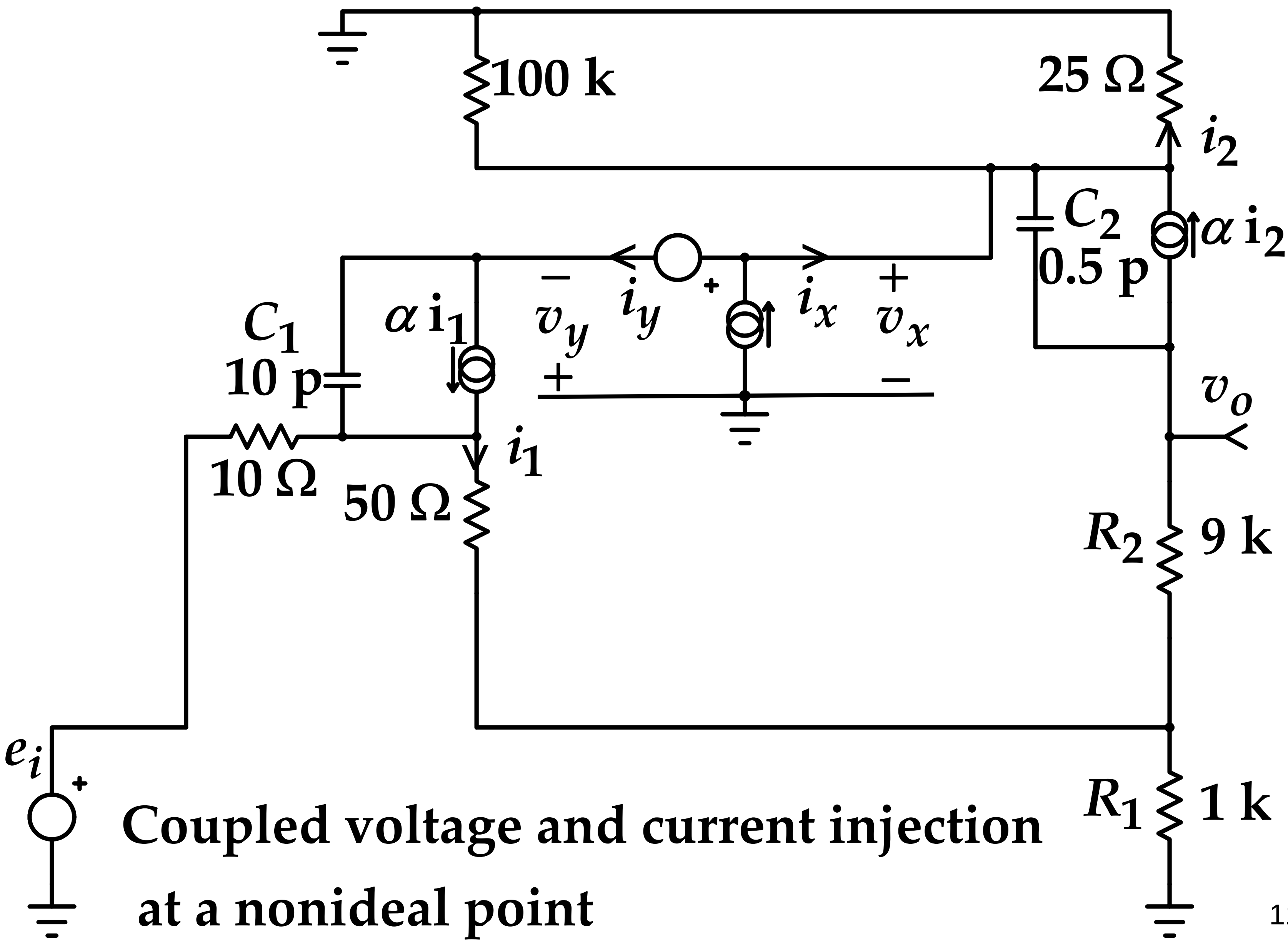
The same paper also showed that *simultaneous* injection of current and voltage test signals, adjusted to give the short-circuit current loop gain $T_i^{v_y}$ and open-circuit voltage loop gain $T_v^{i_y}$ could be combined to give the correct result

$$\frac{1}{T} = \frac{1}{T_i^{v_y}} + \frac{1}{T_v^{i_y}}$$

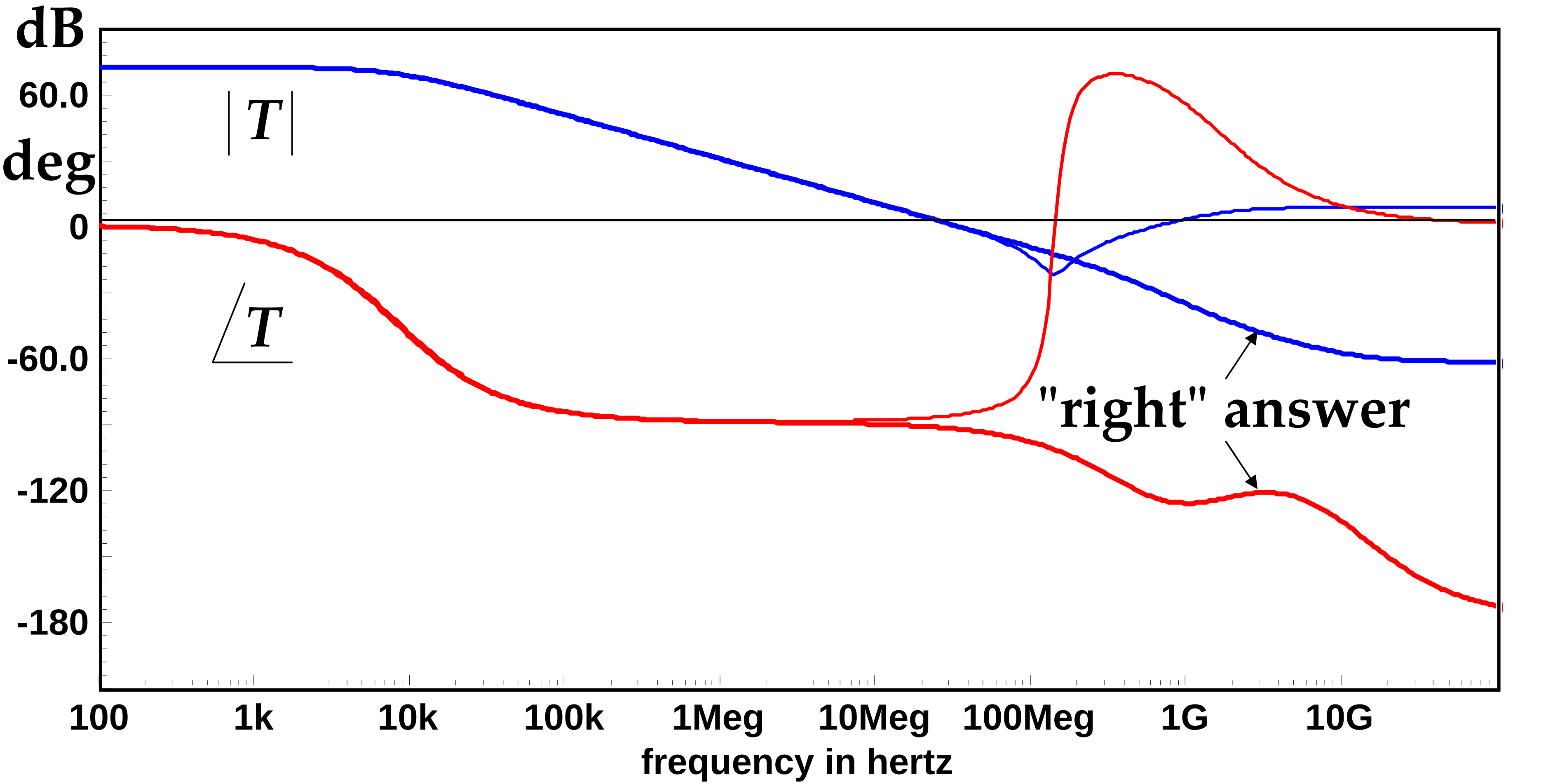
The advantage of this method is that the ndi calculations of $T_i^{v_y}$ and $T_v^{i_y}$ are symbolically simpler and easier than the si calculations of T_i and T_v.

Nevertheless, the conclusions of that paper were incomplete, because the nonidealities were still ignored.

The 2GFT includes the nonidealities, and gives the correct answer for T :

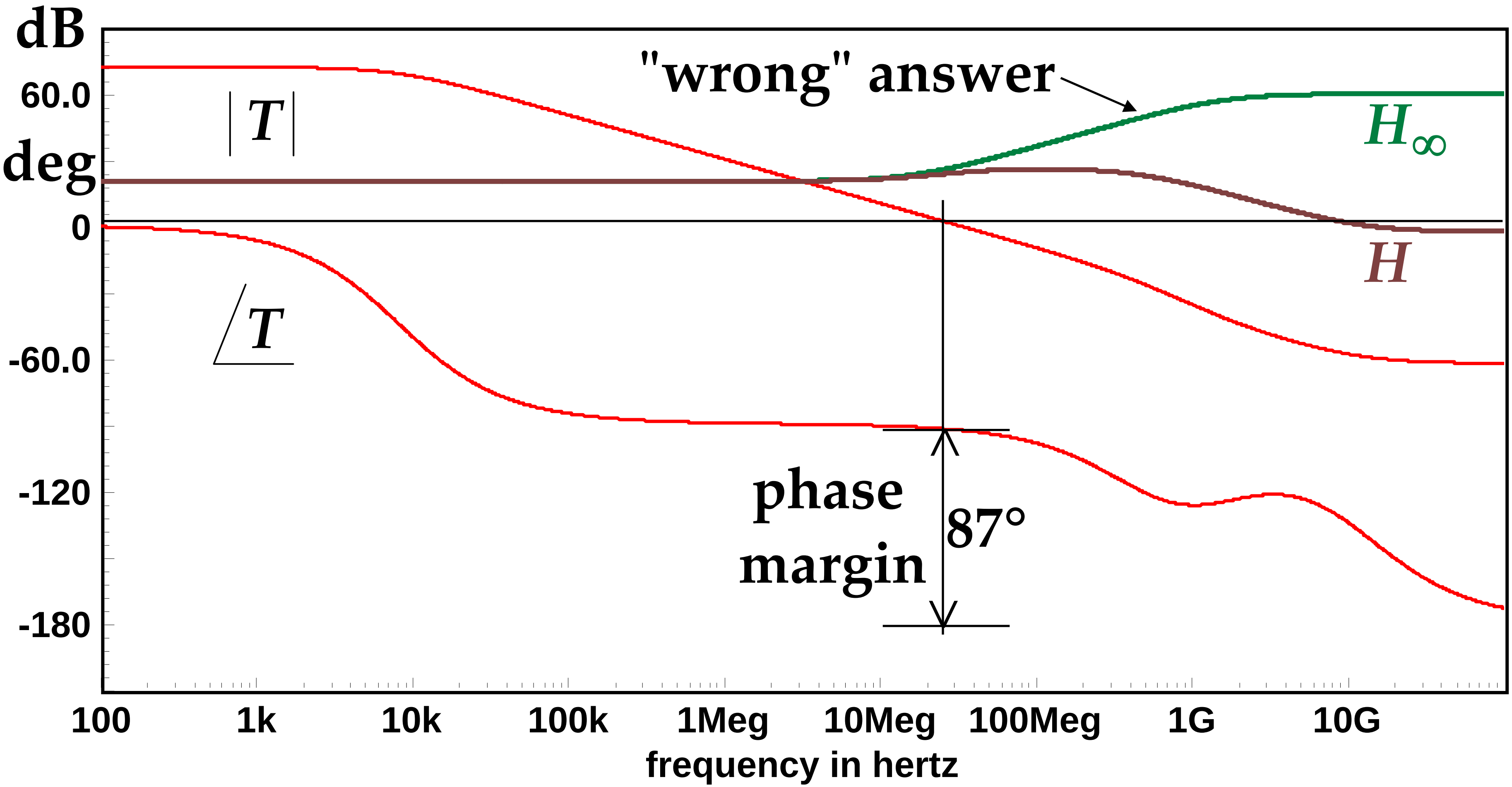


Coupled voltage and current injection at a nonideal point



The "right" answer (*T* has two poles, a lhp and a rhp zero) is obtained by coupled voltage and current injection (GFTv Template) at a nonideal point.

But, there is another problem:



H_∞ is not equal to $1/K$

Why?

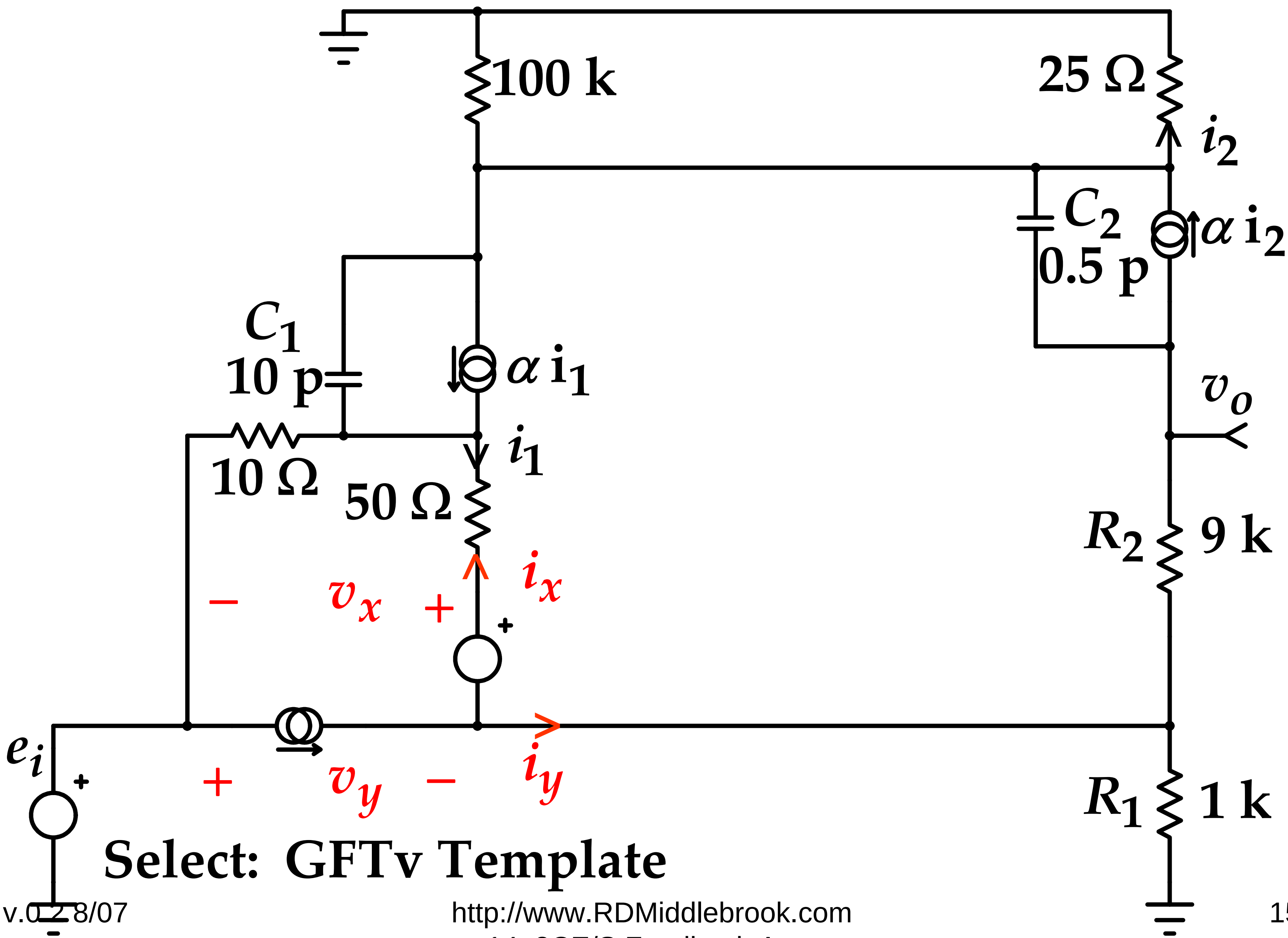
The test signal configuration meets the first criterion, that the test signal must be inside the loop, but it does not meet the second: the test signal must be able to null the error signal.

Therefore, choose a test signal configuration that meets the second criterion as well:

v_y **must be the error voltage, and**

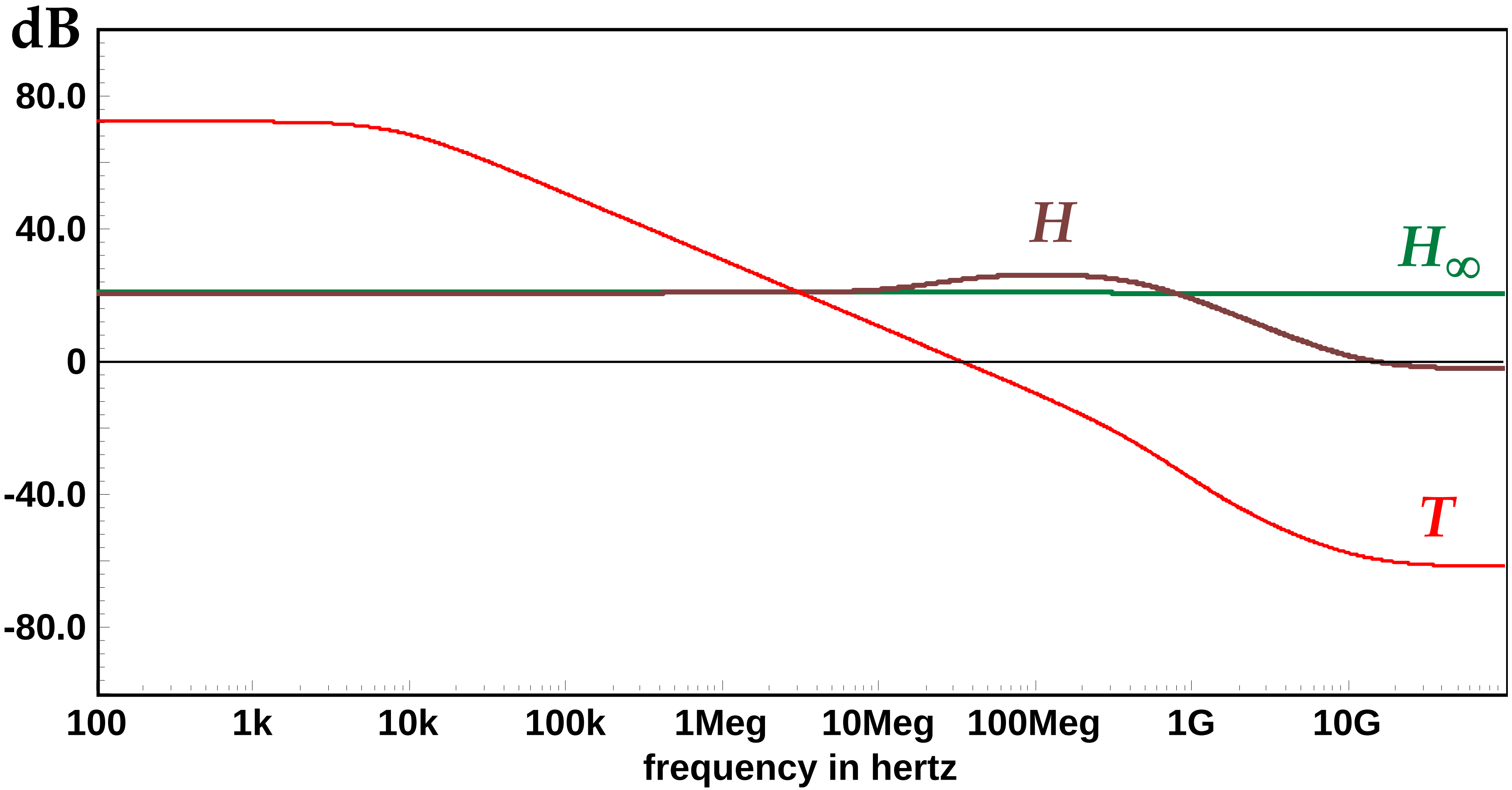
i_y **must be the error current.**

Coupled injection must be used, since v_y and i_y do not null simultaneously with only single injection.

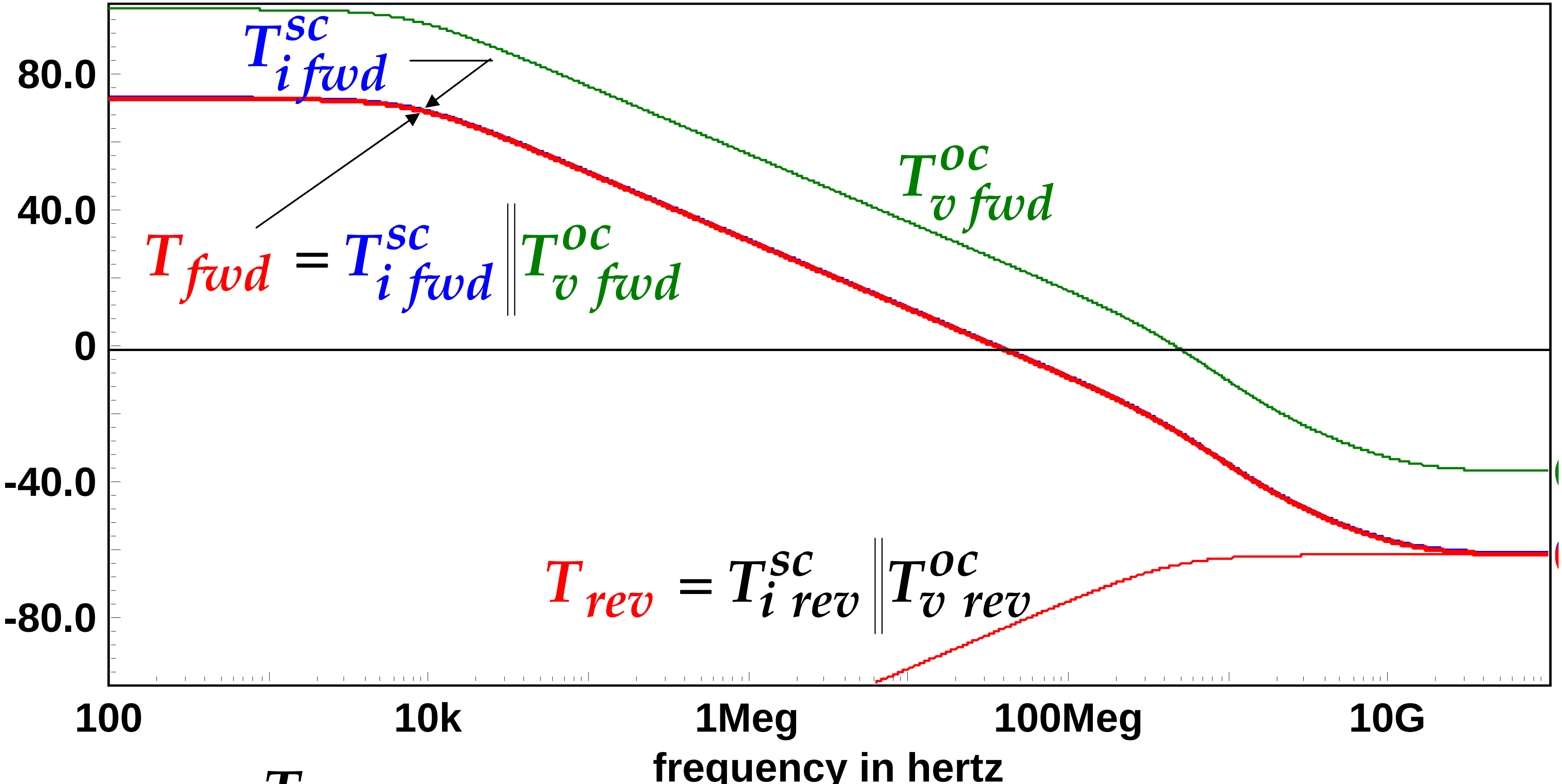


Select: GFTv Template

Check that H_∞ is the expected $1/K = 20$ dB:

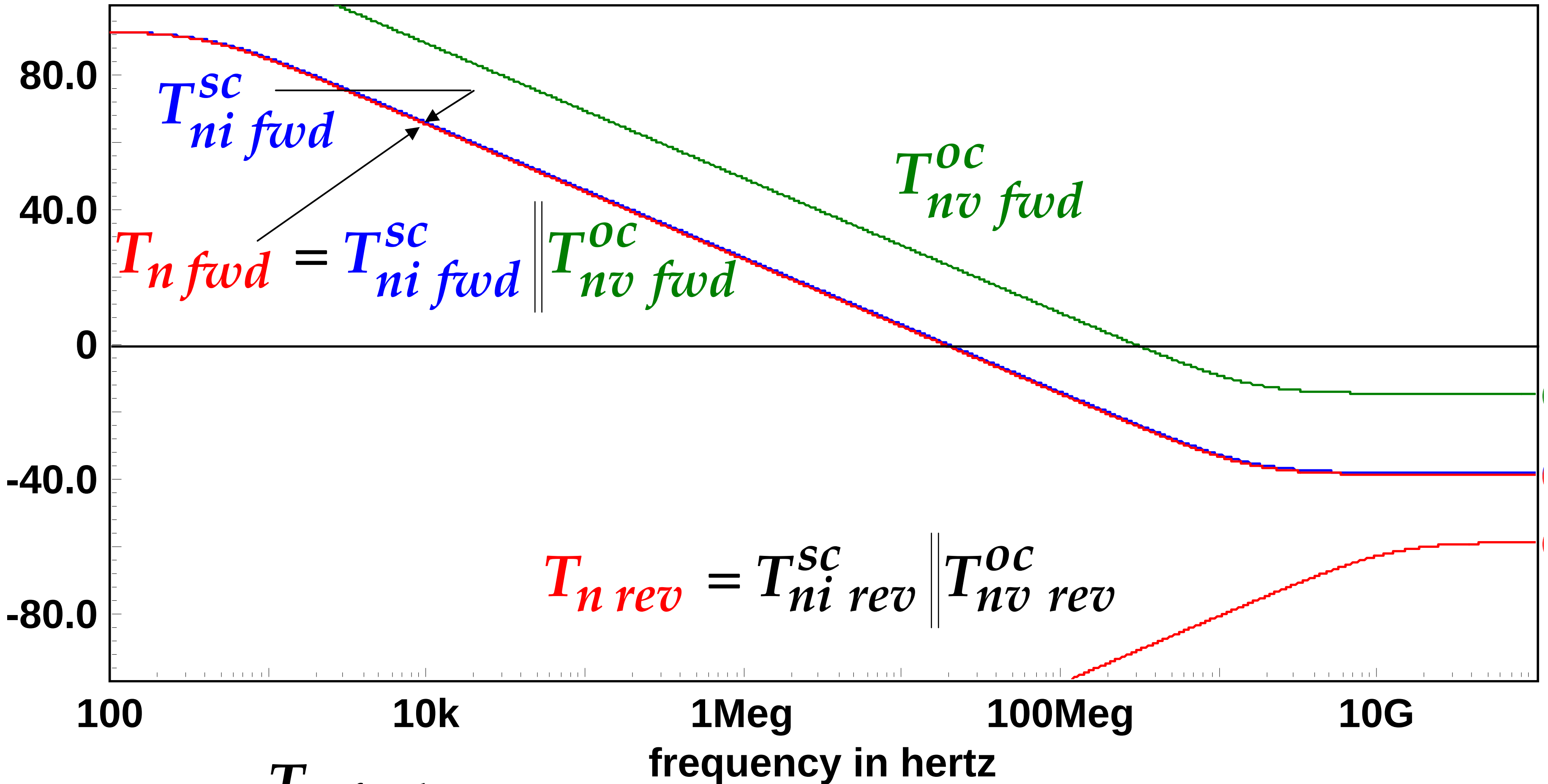


T and H are still the same



$T = \dfrac{T_{fwd}}{1+T_{rev}}$, **and since** $T_{v\,fwd}^{oc} >> 1$ **and** $T_{rev} << 1$,

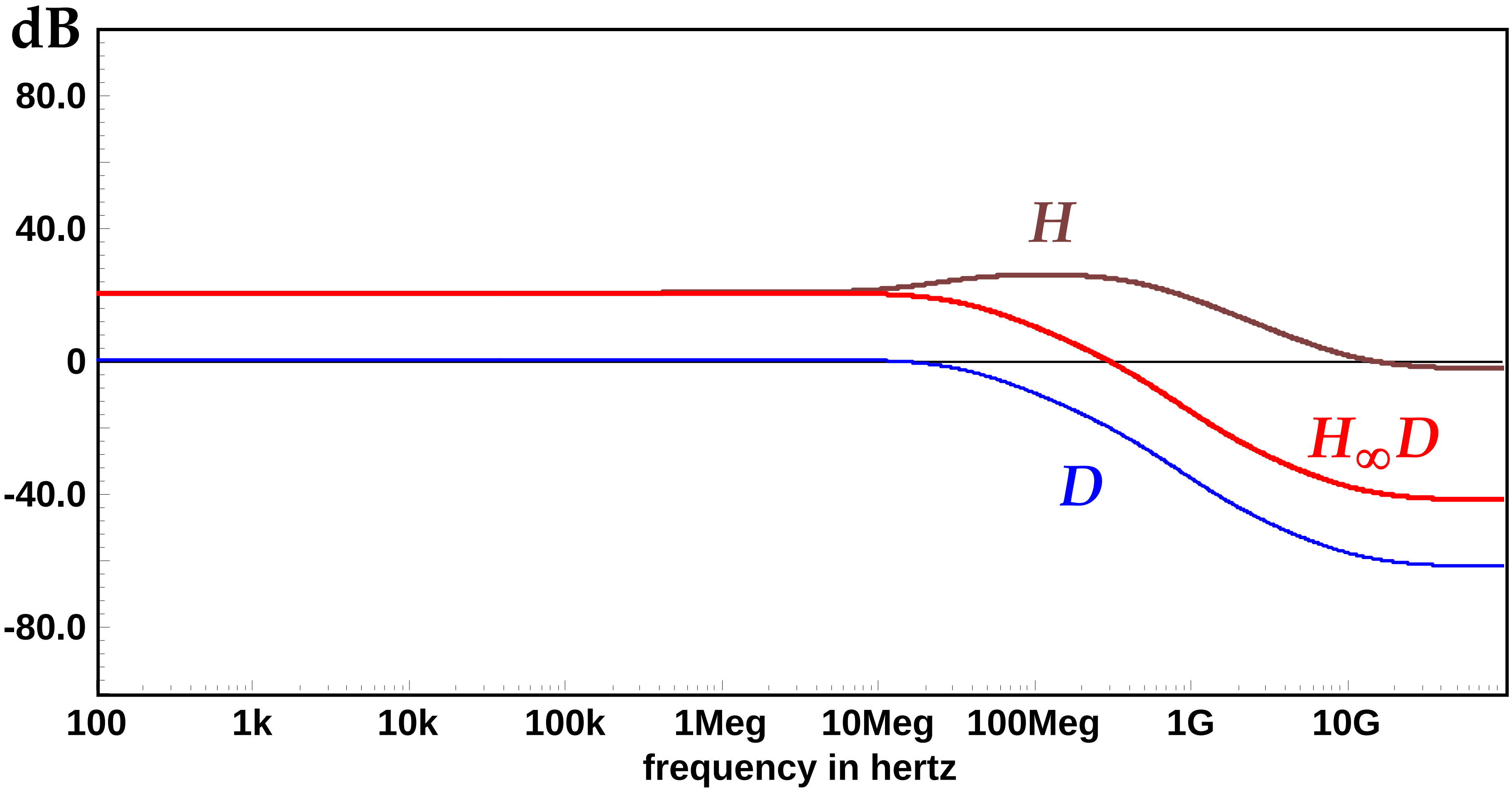
$T \approx T_{i\,fwd}^{sc}$



$$T_n = \frac{T_{n\ fwd}}{1 + T_{n\ rev}}$$, and since $T^{oc}_{nv\ fwd} >> 1$ and $T_{n\ rev} << 1$,

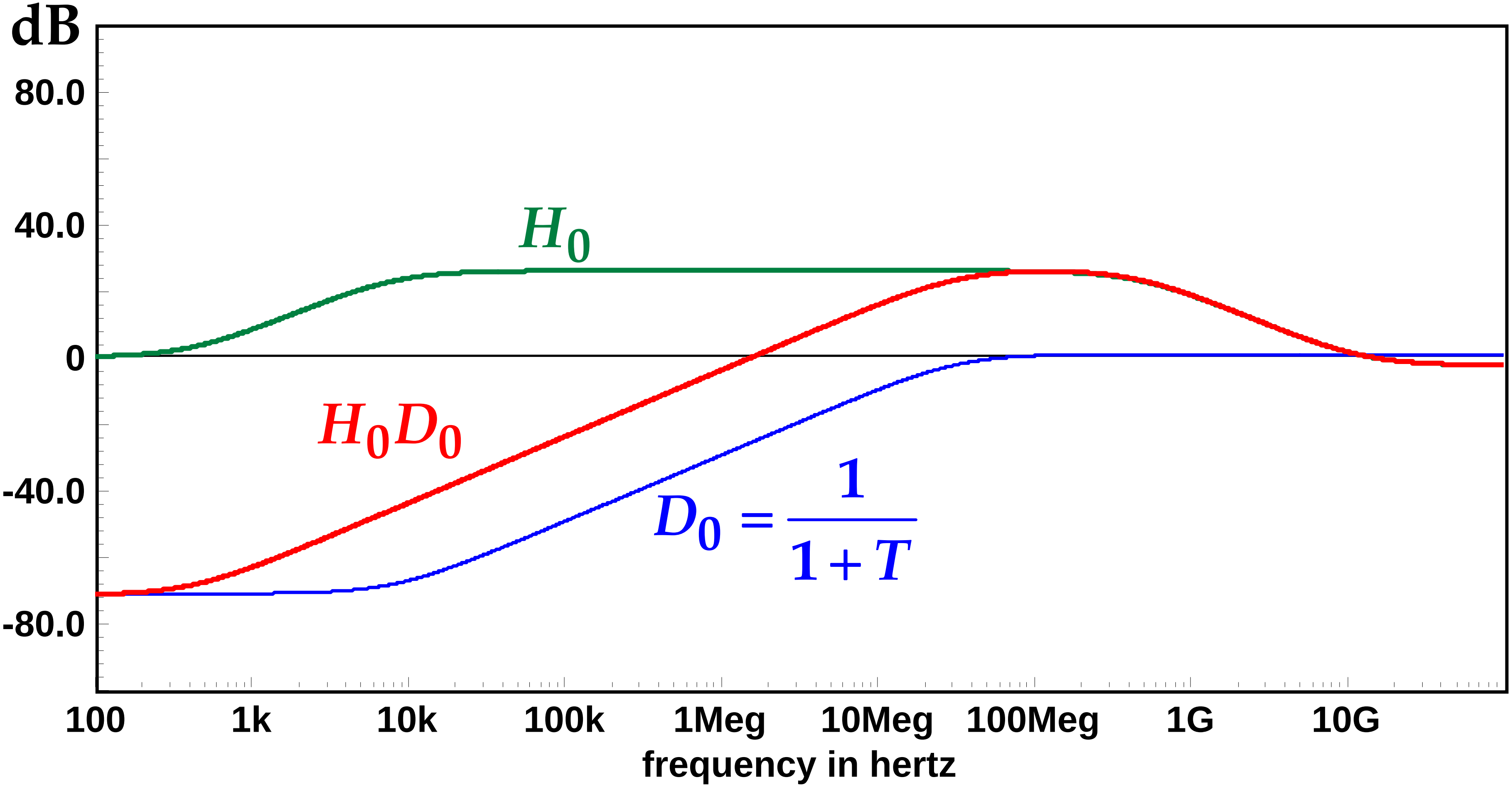
$$T_n \approx T^{sc}_{ni\ fwd}$$

The component $H_\infty D$ of $H = H_\infty D + H_0 D_0$:

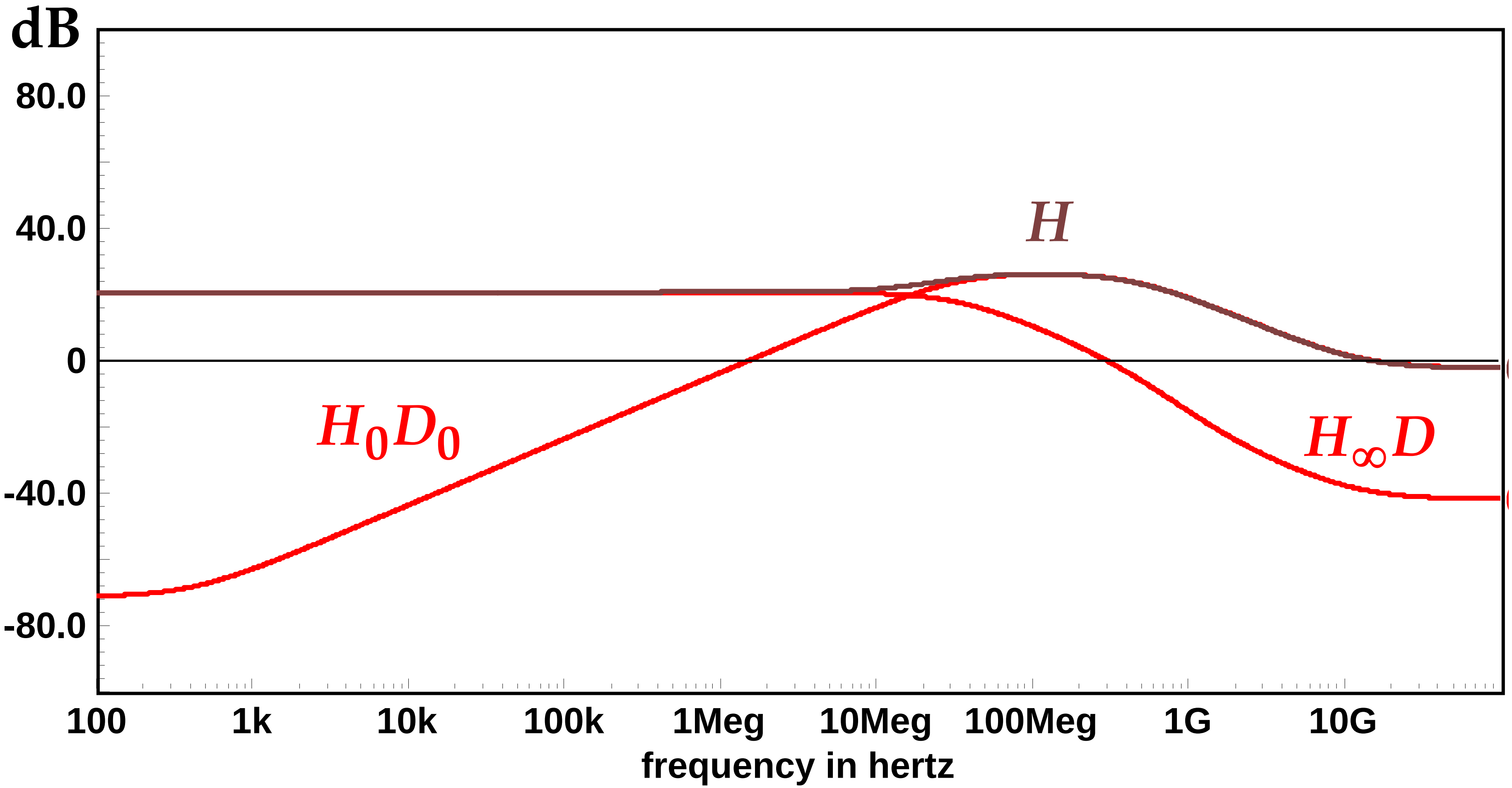


It may be thought that the peaking in H is due to insufficient phase margin, but in fact it comes from H_0 :

The component $H_0 D_0$ of $H = H_\infty D + H_0 D_0$:



Both components of $H = H_\infty D + H_0 D_0$:

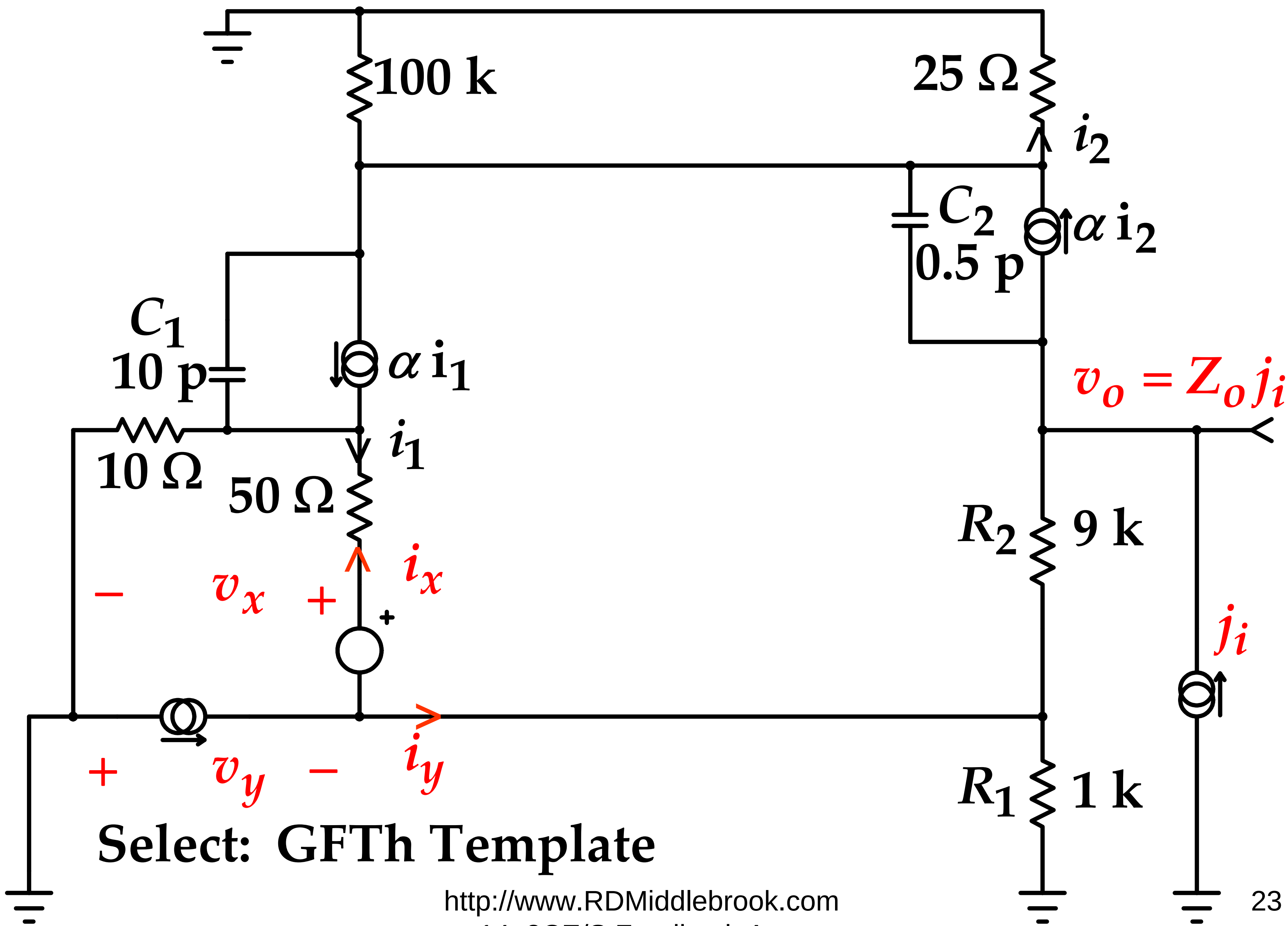


The first-level TF H can be a current gain, transadmittance, transimpedance, or a voltage gain.

As applied to an output impedance Z_o, which is a self-impedance, the GFT becomes

$$Z_{\mathbf{o}} = Z_{o\infty} \frac{T}{1+T} + Z_{o0} \frac{1}{1+T}$$

The "output" is v_o as for voltage gain, but the "input" is now a current j_i driven into the output.

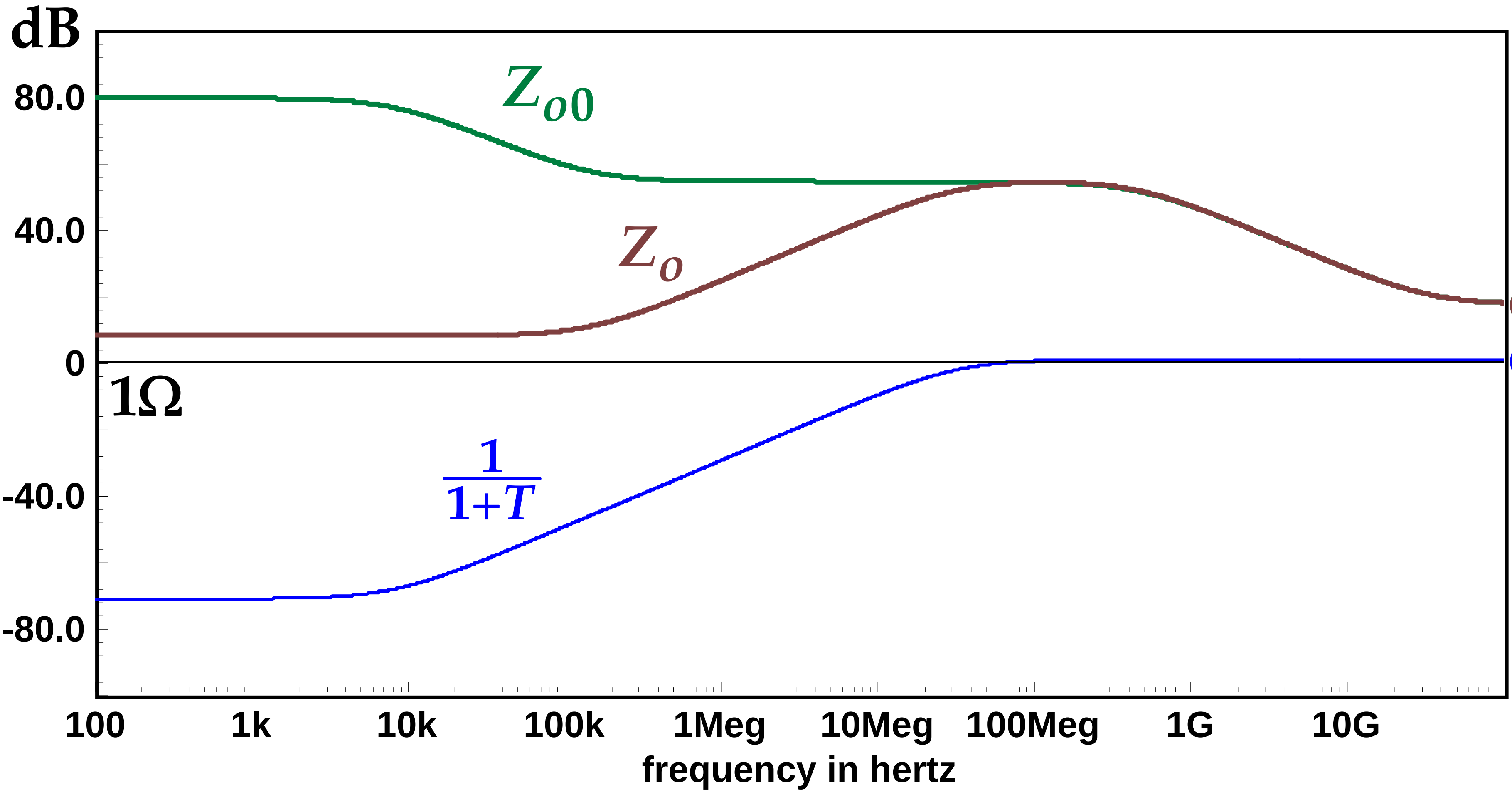


Select: GFTh Template

For voltage feedback, as in this example, $Z_{o\infty}$ is always zero, so

$$Z_{\mathbf{o}} = Z_{o0}\,\frac{1}{1+T}$$

which is the familiar result that the closed-loop output impedance is the open-loop value divided by the feedback factor.



The closed-loop output impedance Z_o rises to the open-loop value Z_{o0} as loop gain crossover is approached.