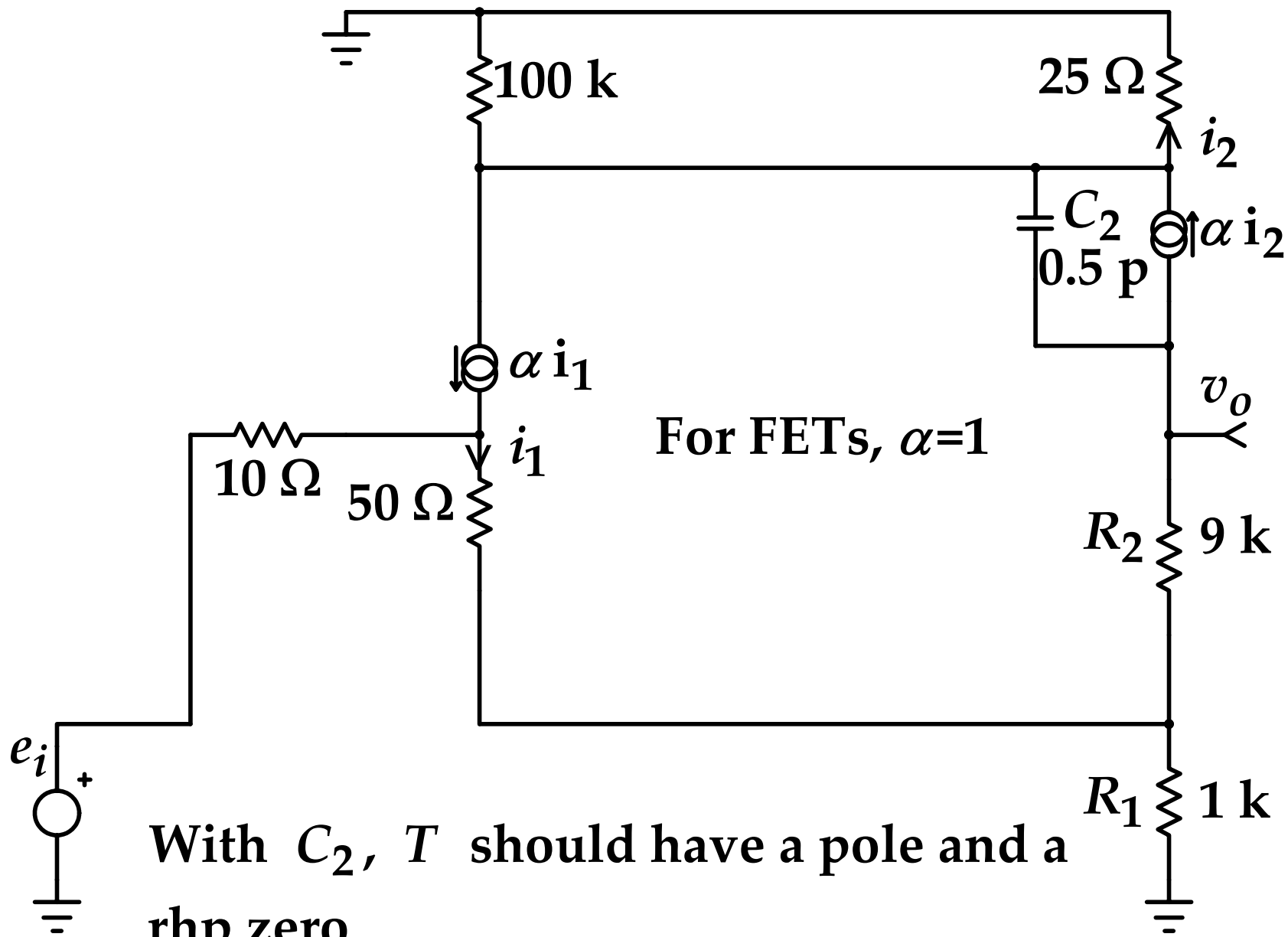


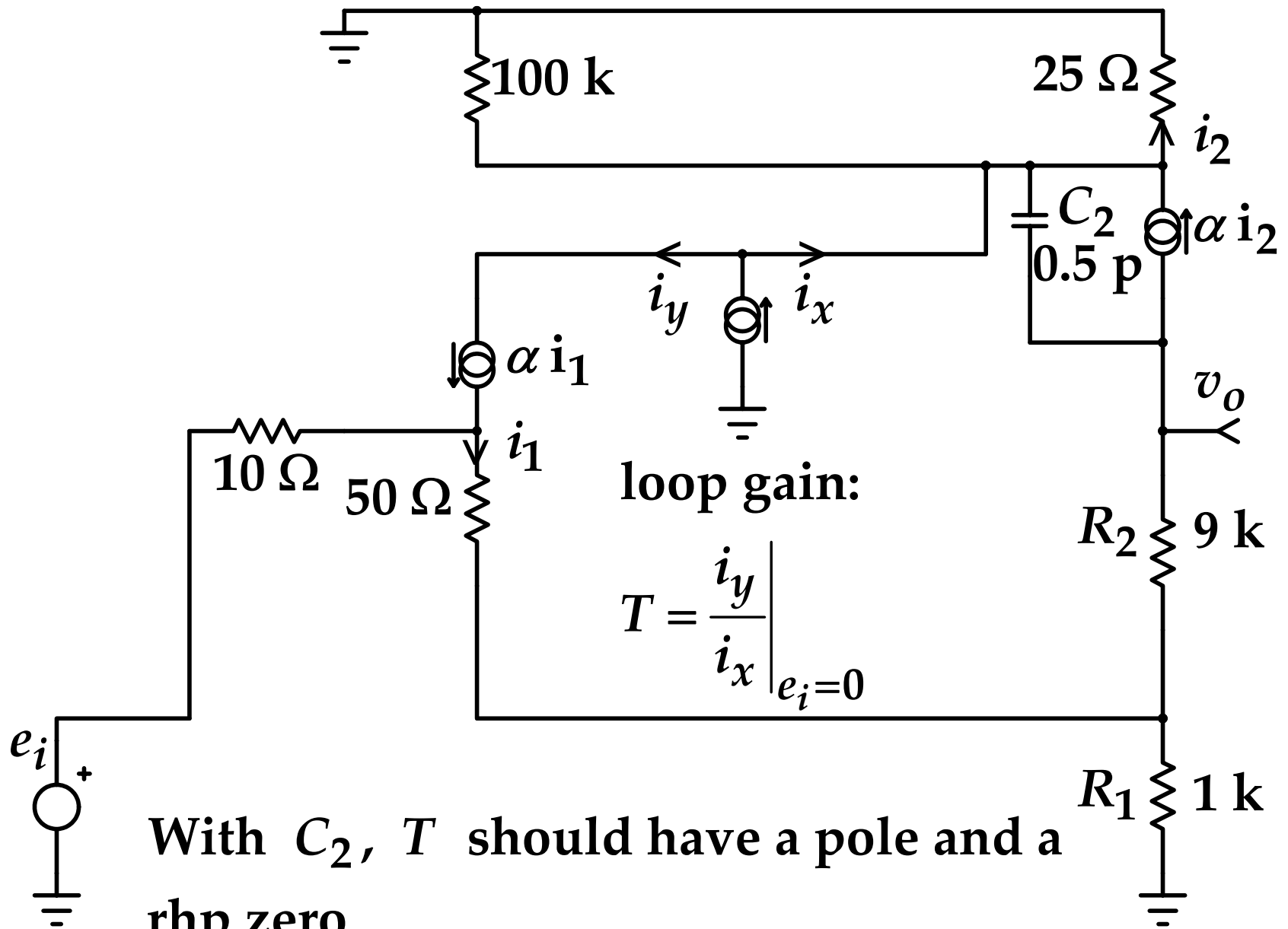
## EXAMPLE

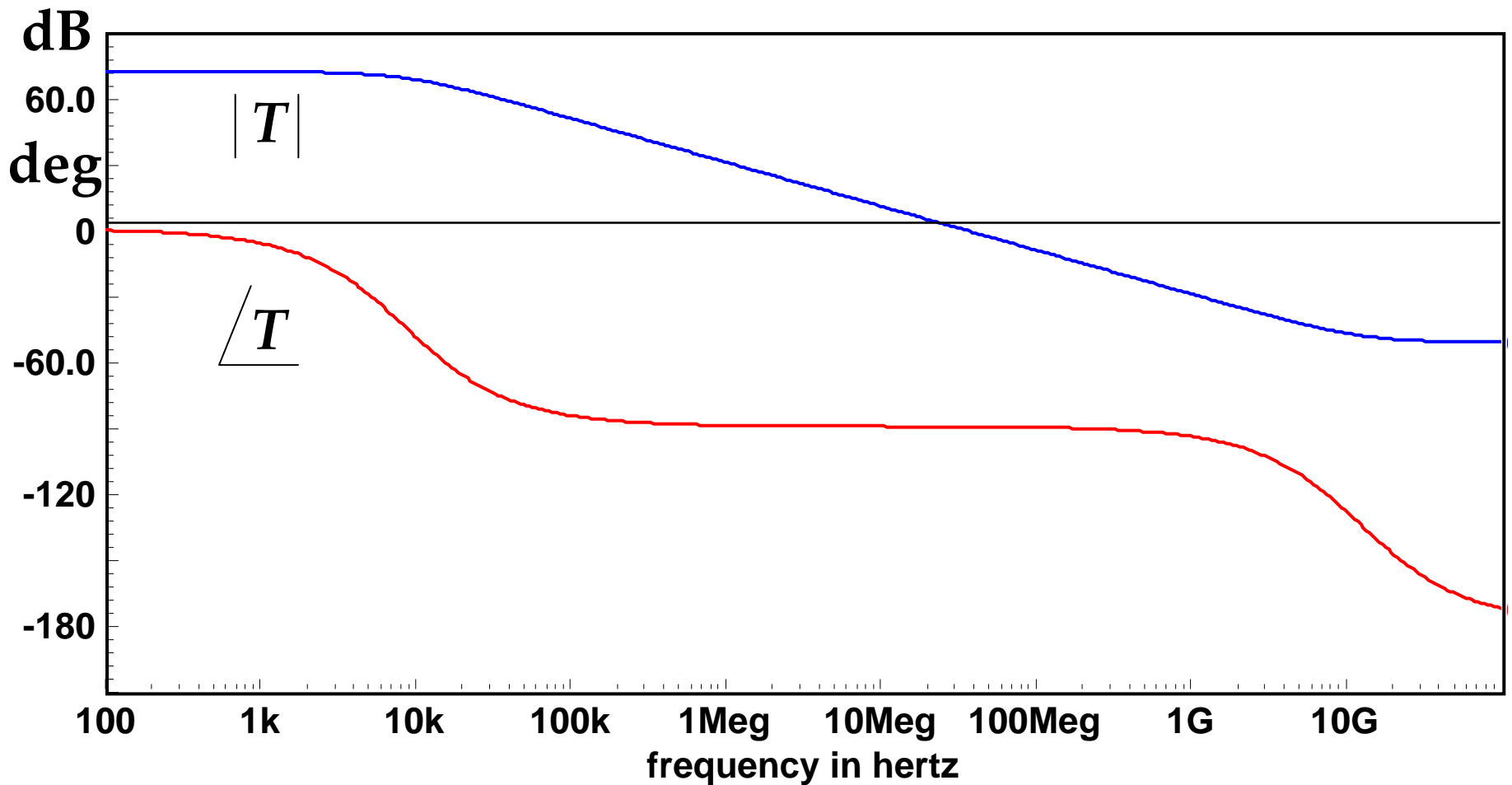
### 14. A 2CE/S FEEDBACK AMPLIFIER

A 2-stage Common-Emitter/-Source Amplifier

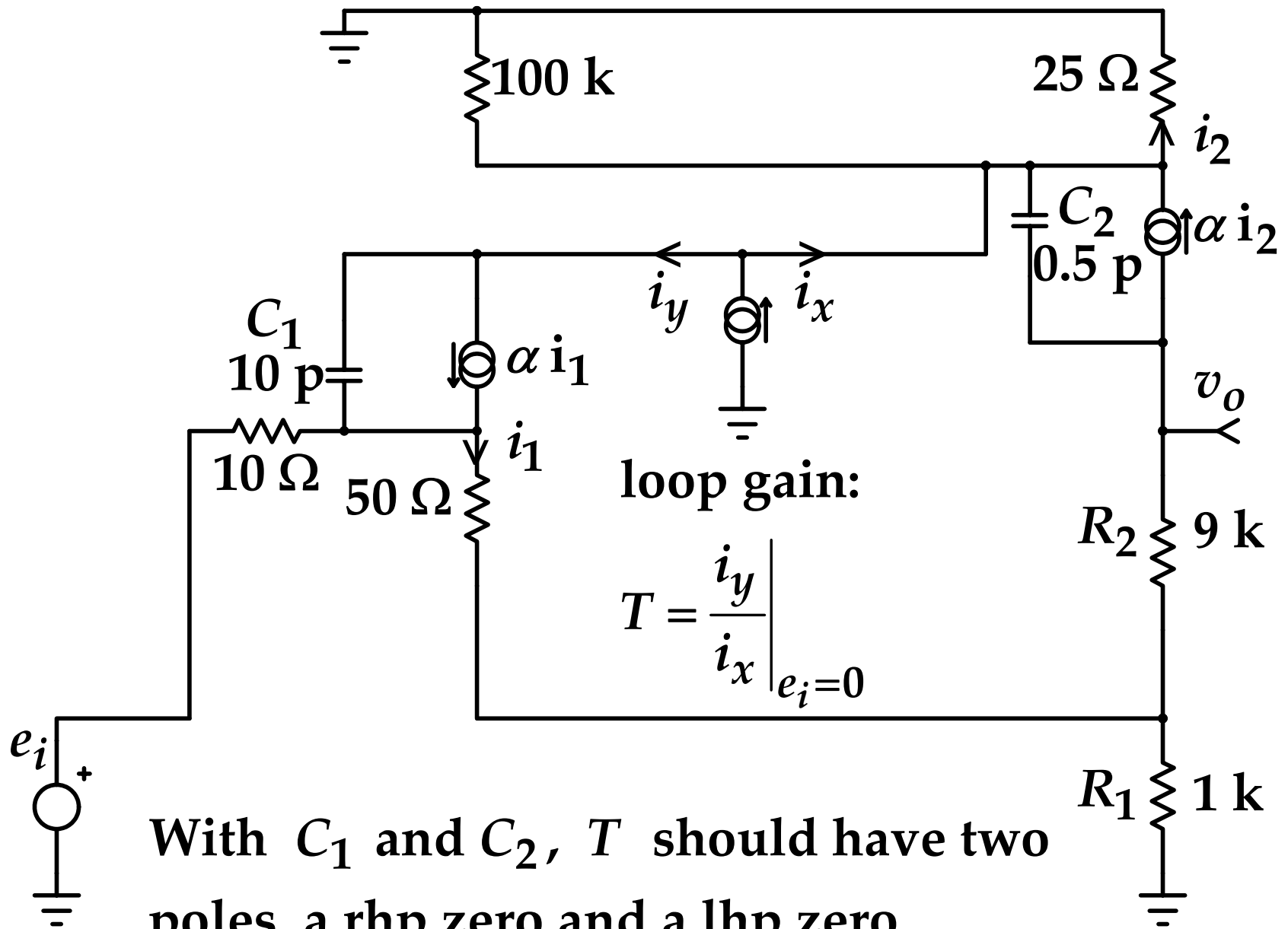


**An ideal test current injection point is at the output of the first stage:**

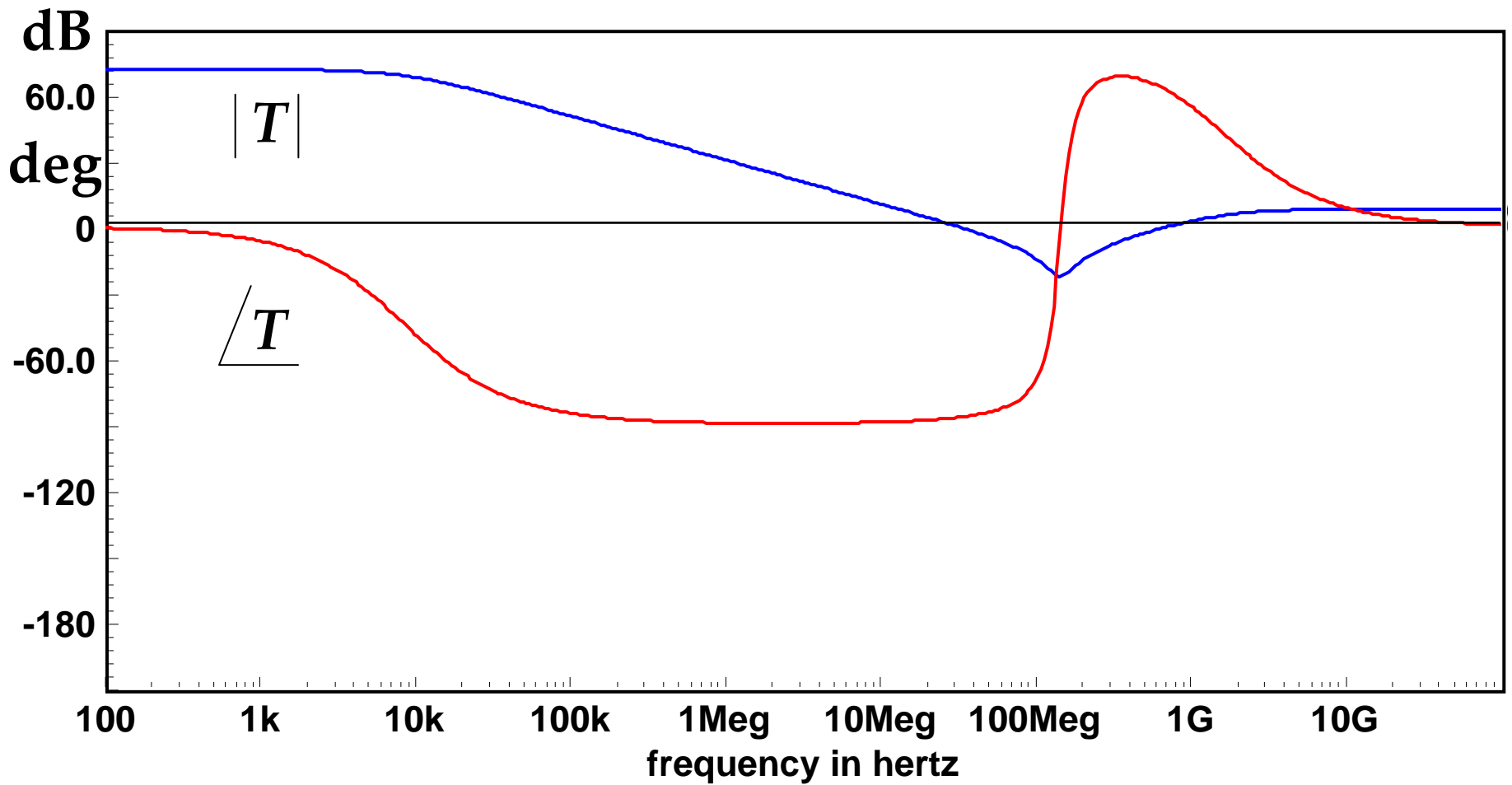




With  $C_2$ : "right" answer



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<sup>\*</sup> 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  $T$  :

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

<sup>\*</sup> R.D.Middlebrook, "Measurement of loop gain in feedback systems,"  
Int. J. Electronics, 1975, vol. 38, No. 4, pp. 485 – 512.

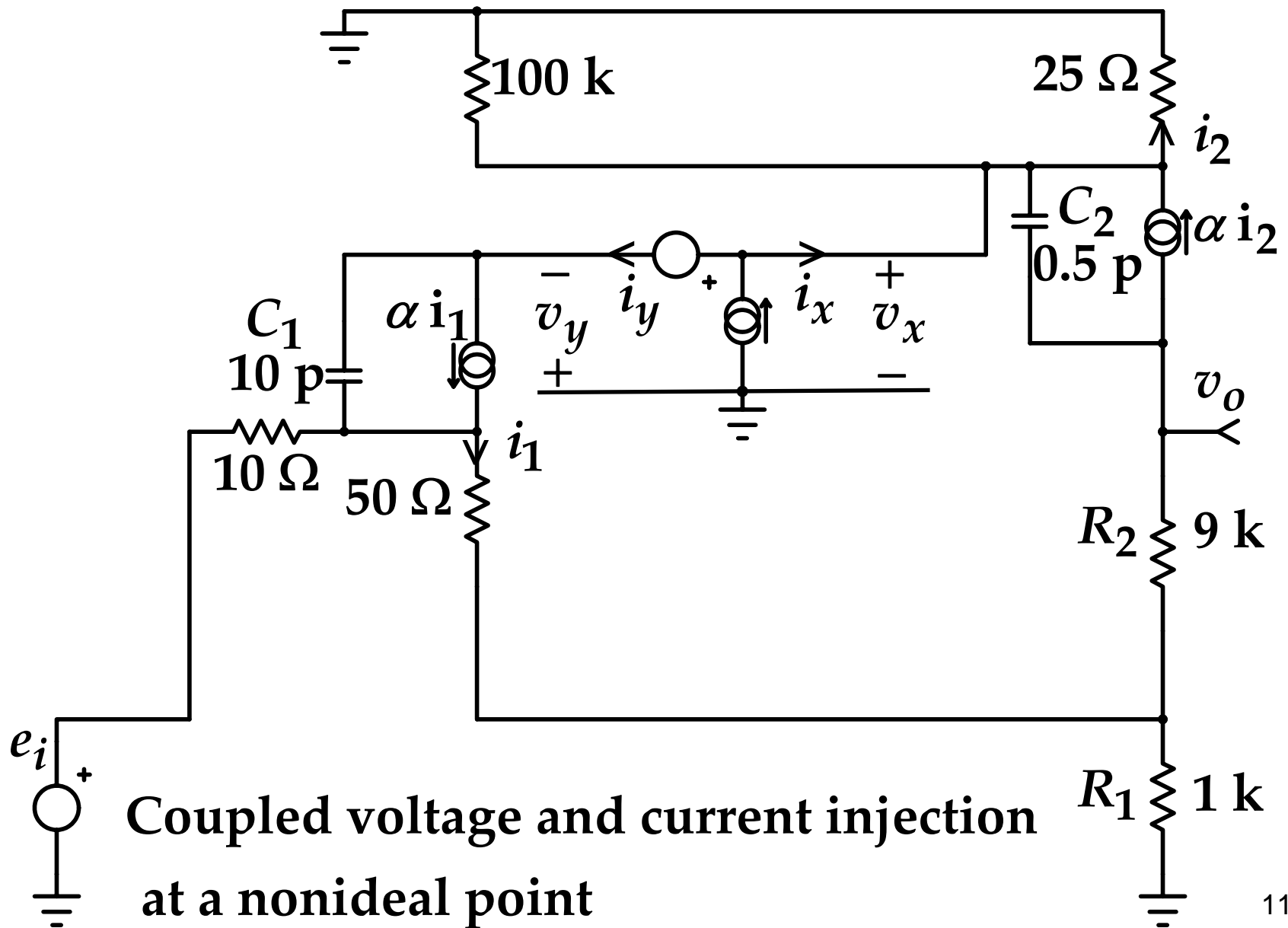
The same paper also showed that *simultaneous* injection of current and voltage test signals, adjusted to give the short-circuit current loop gain  $T_i^{v_y}$  and open-circuit voltage loop gain  $T_v^{i_y}$  could be combined to give the correct result

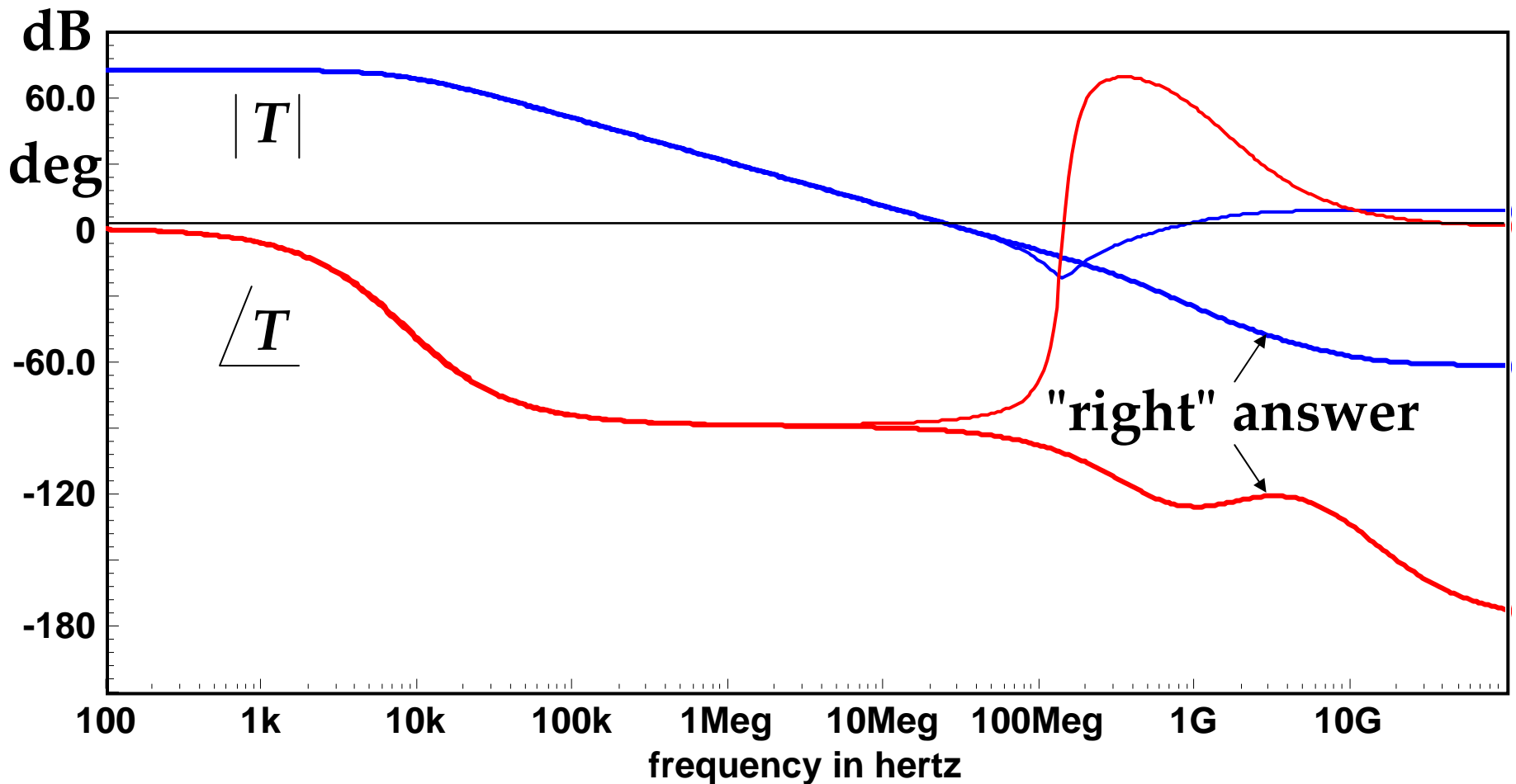
$$\frac{1}{T} = \frac{1}{T_i^{v_y}} + \frac{1}{T_v^{i_y}}$$

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.**

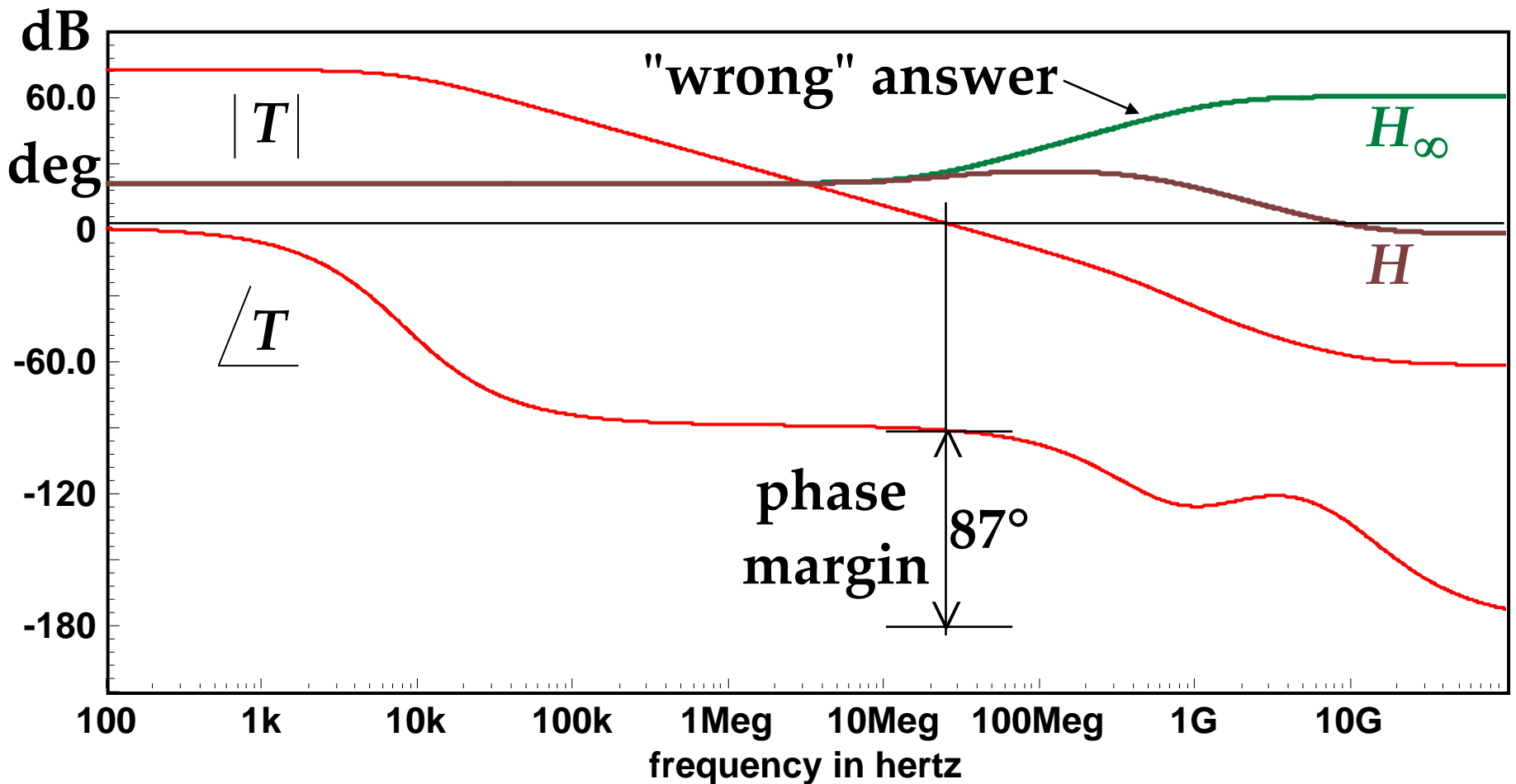
**The 2GFT includes the nonidealities, and gives the correct answer for  $T$  :**





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:



$H_\infty$  is not equal to  $1/K$

## Why?

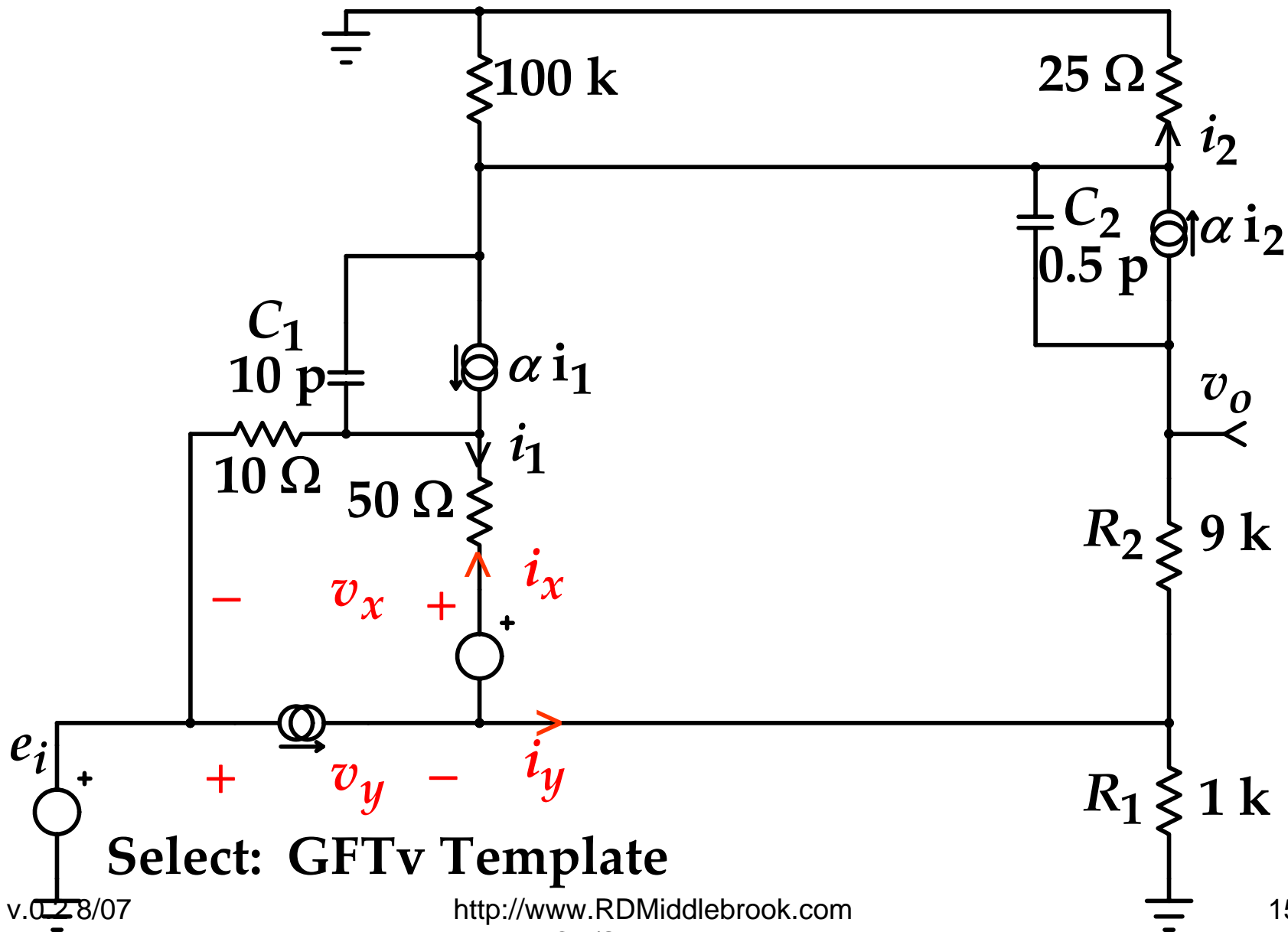
The test signal configuration meets the first criterion, that the test signal must be inside the loop, but it does not meet the second: the test signal must be able to null the error signal.

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

$v_y$  must be the error voltage, and

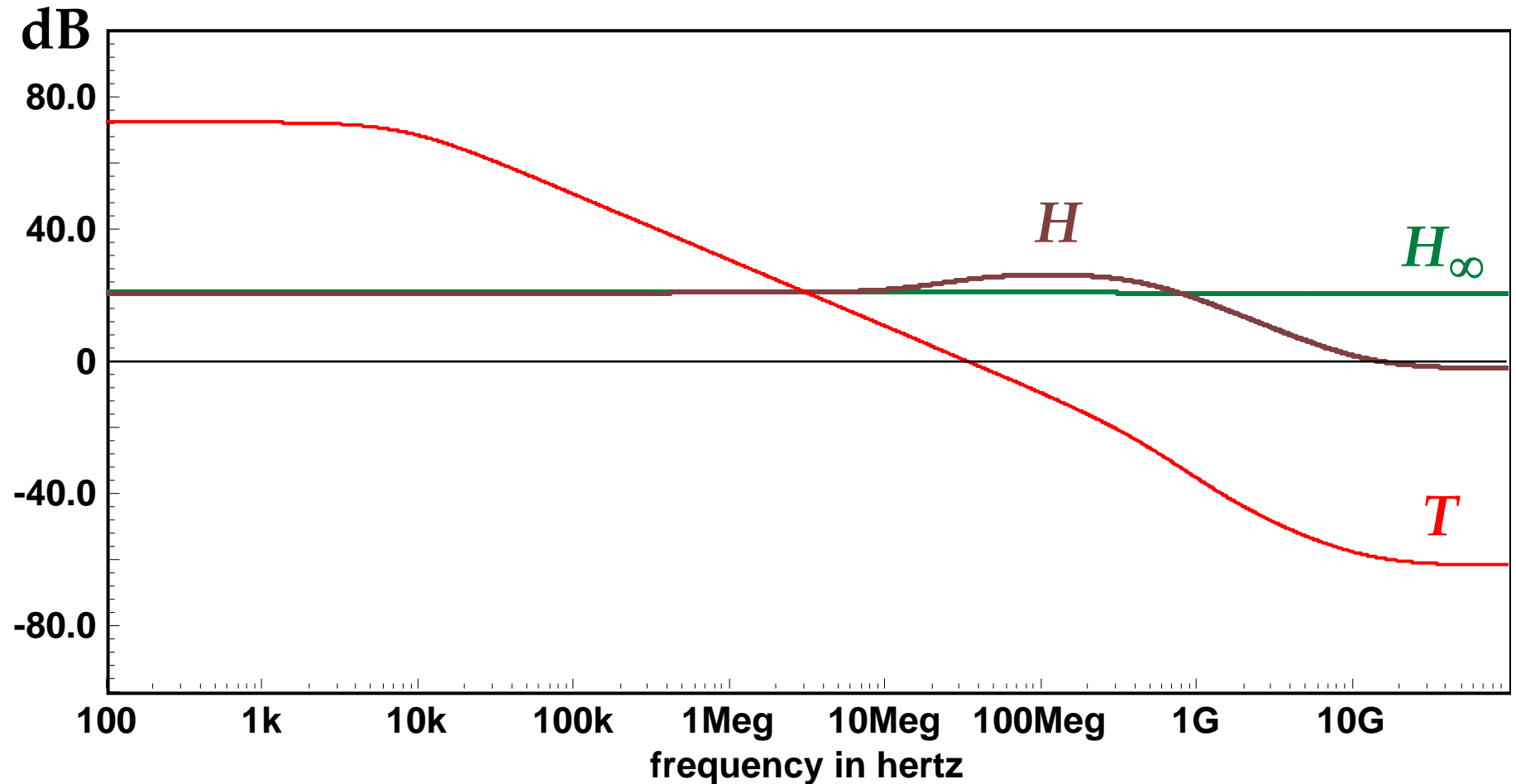
$i_y$  must be the error current.

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

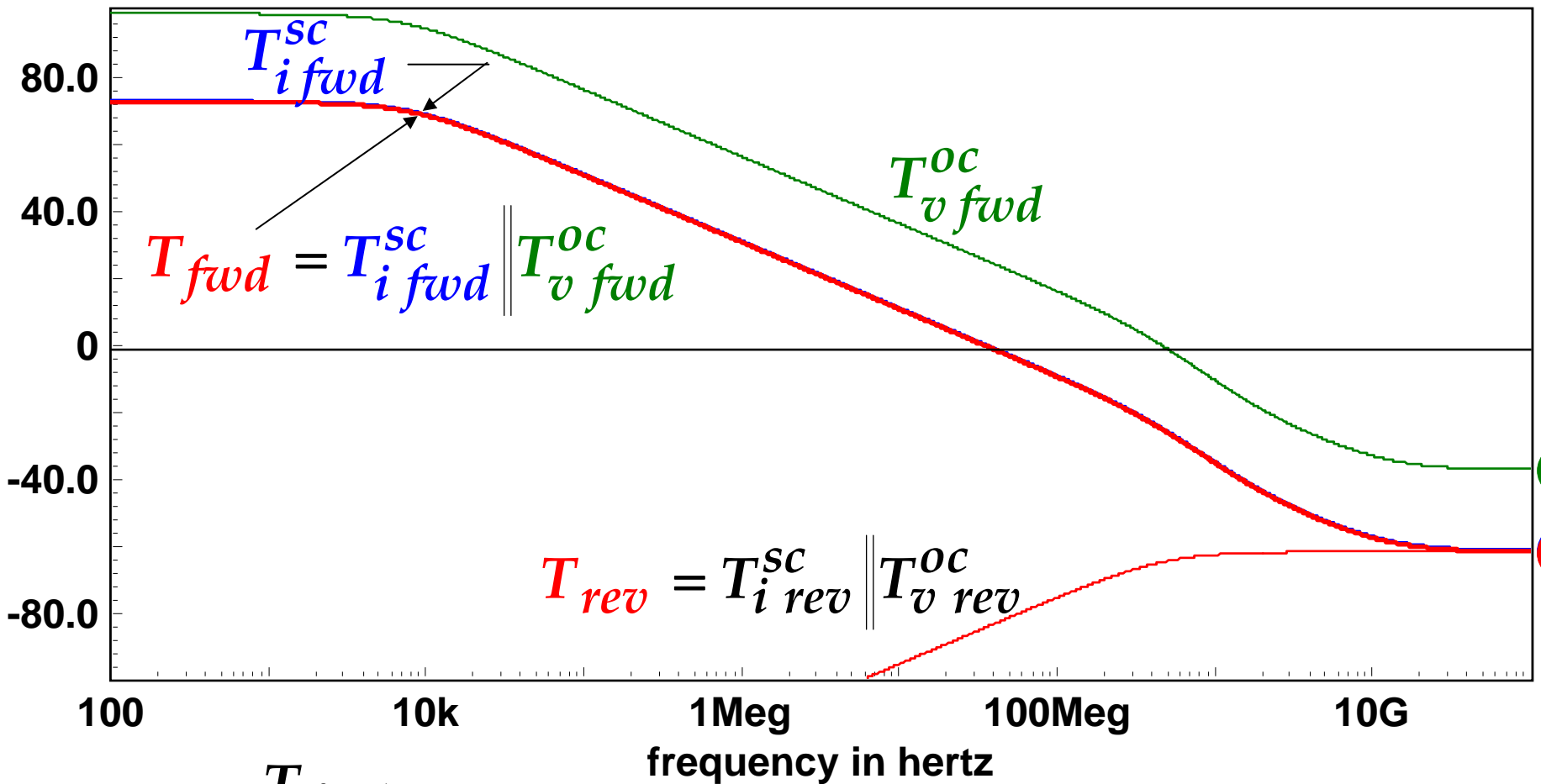


Select: GFTv Template

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

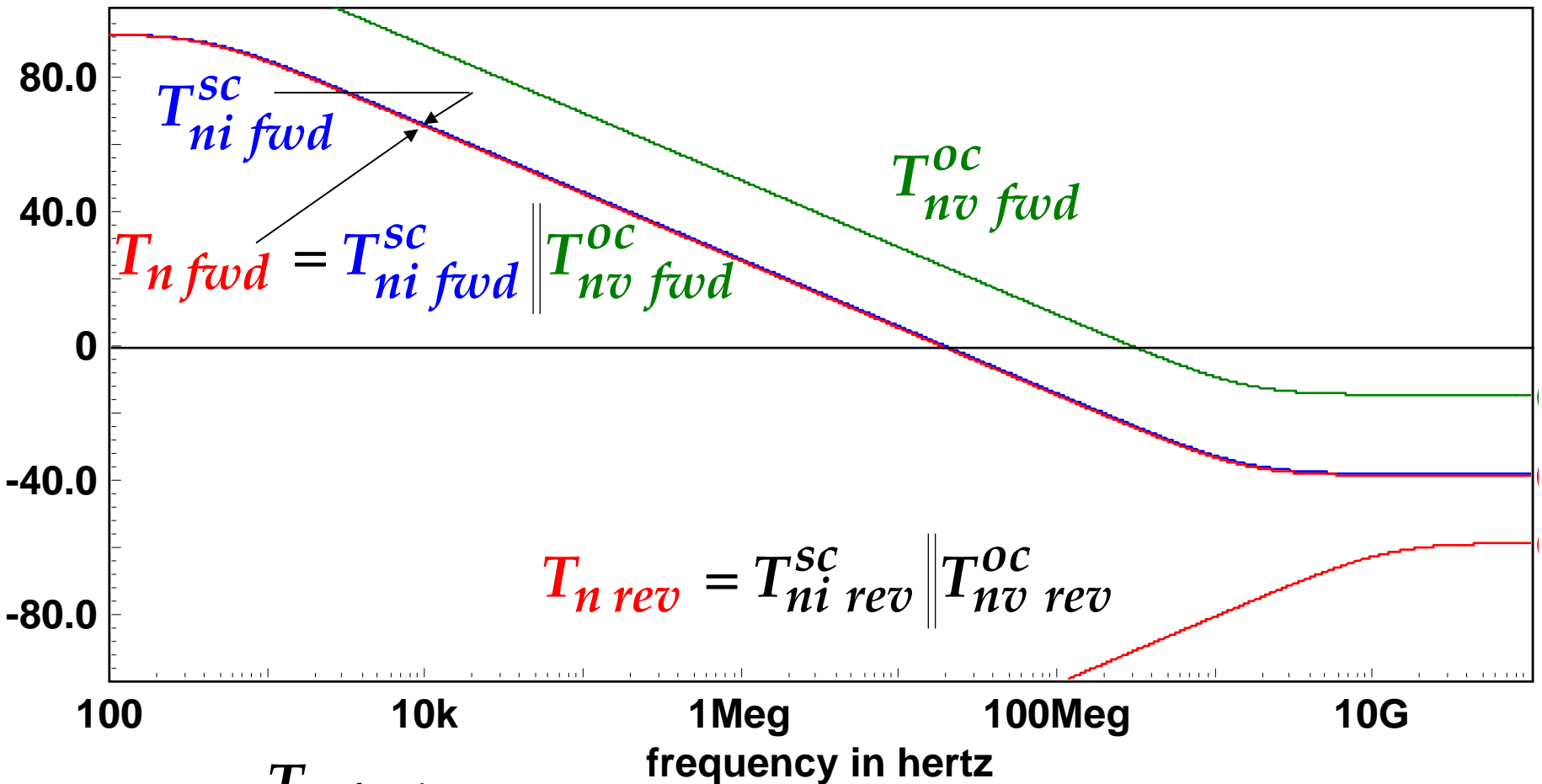


***T* and *H* are still the same**



$$T = \frac{T_{fwd}}{1 + T_{rev}}, \text{ and since } T_{v\ fwd}^{oc} \gg 1 \text{ and } T_{rev} \ll 1,$$

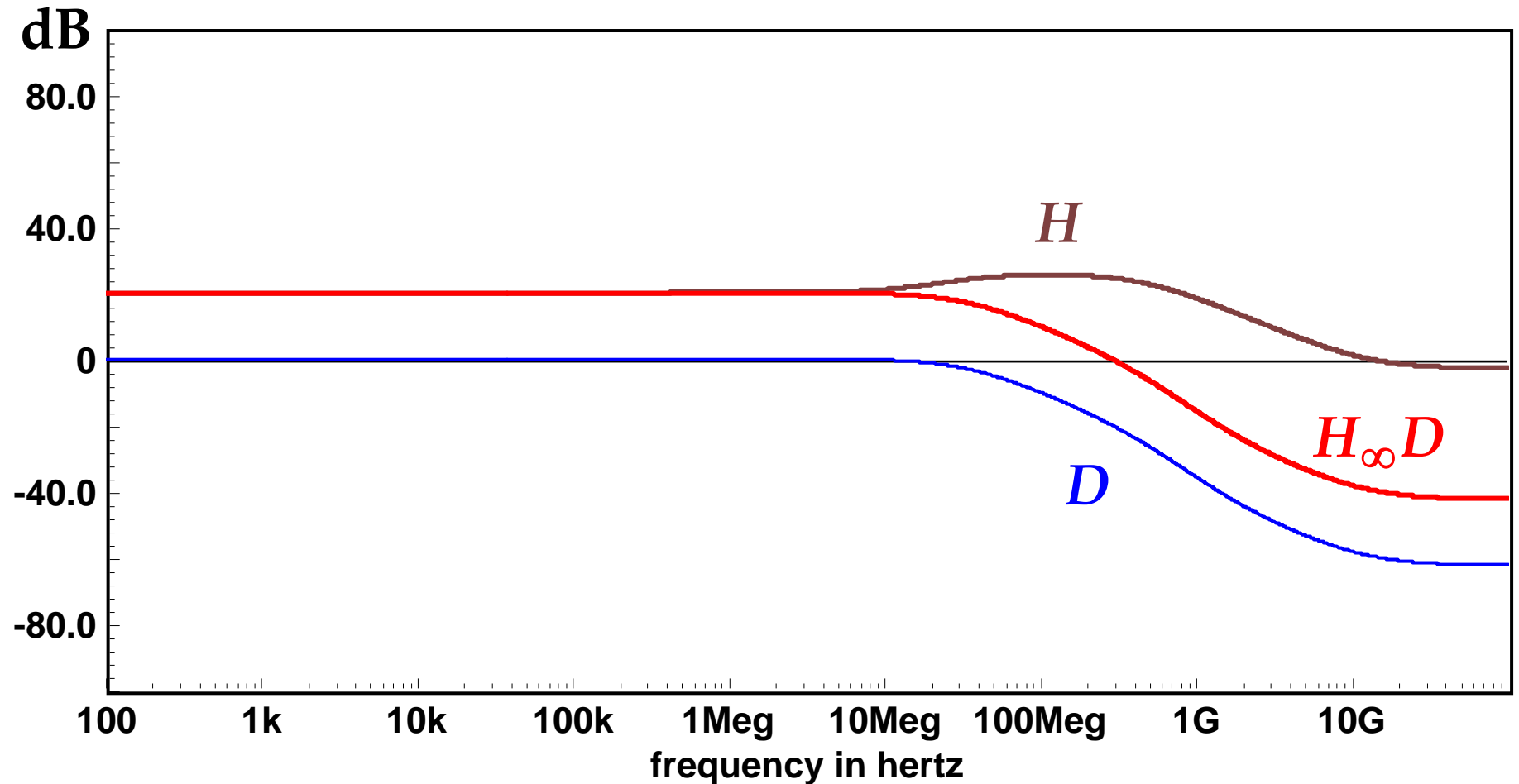
$$T \approx T_{i\ fwd}^{sc}$$



$$T_n = \frac{T_{n\ fwd}}{1 + T_{n\ rev}}, \text{ and since } T_{nv\ fwd}^{OC} \gg 1 \text{ and } T_{n\ rev} \ll 1,$$

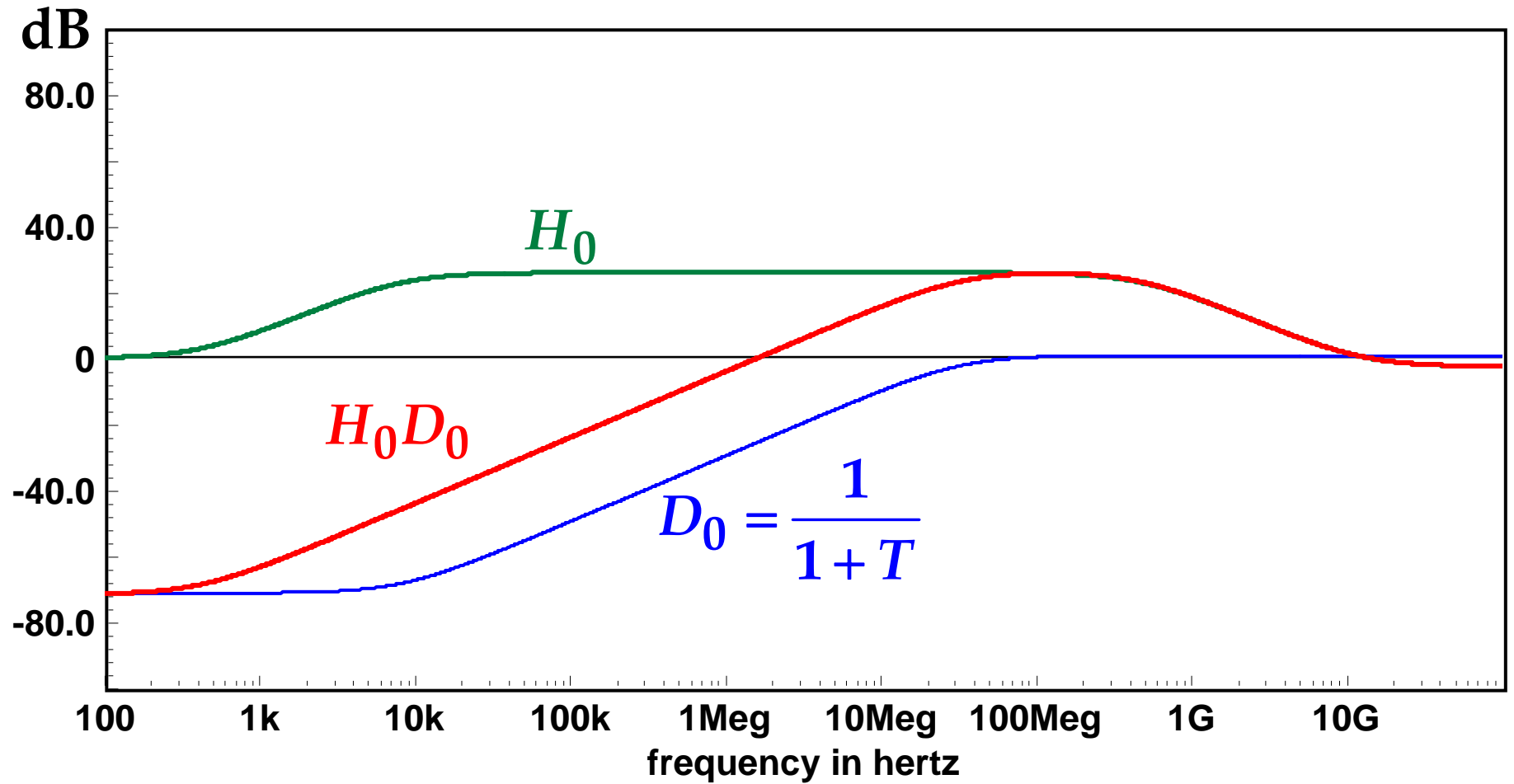
$$T_n \approx T_{ni\ fwd}^{SC}$$

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

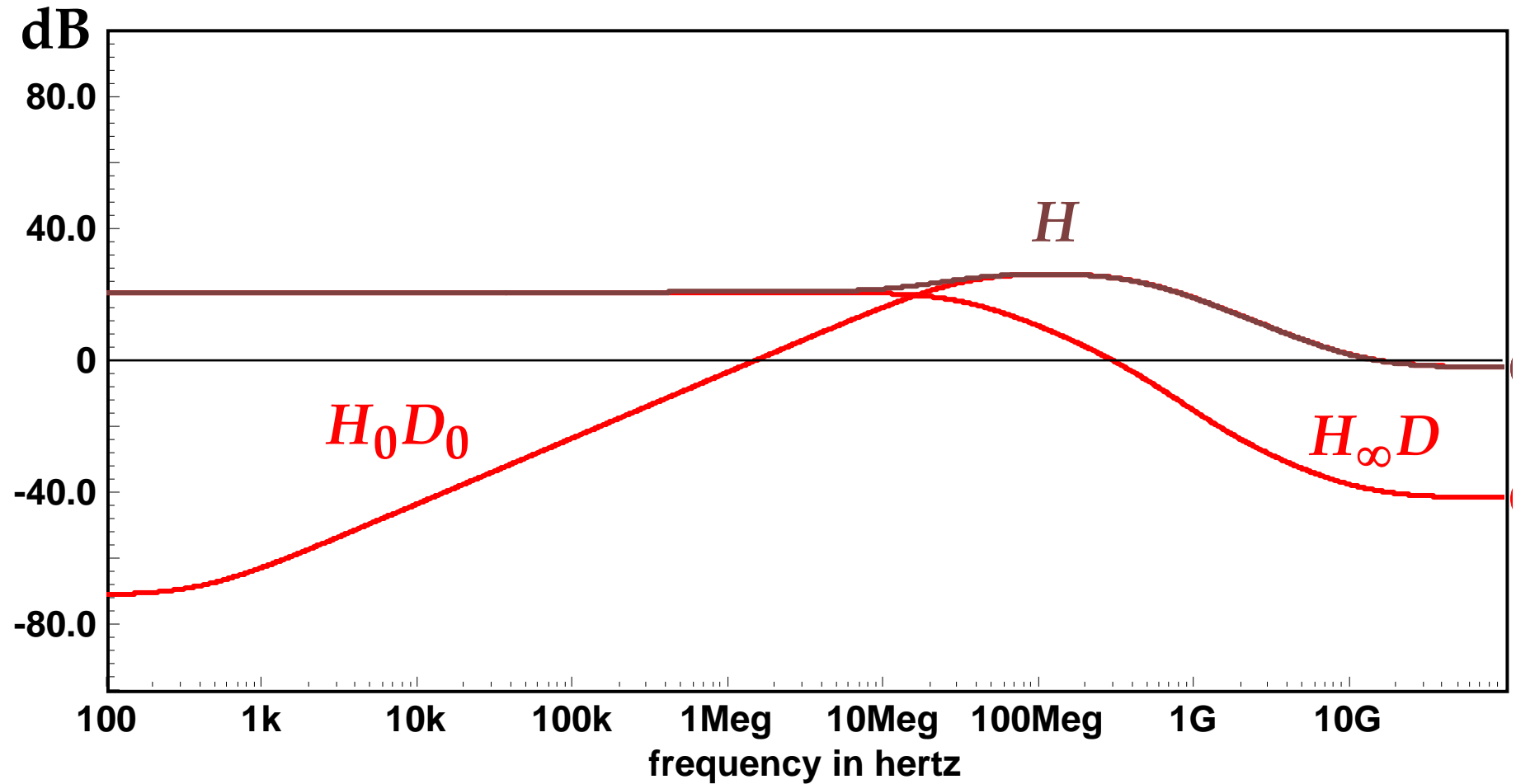


It may be thought that the peaking in  $H$  is due to insufficient phase margin, but in fact it comes from  $H_0$  :

The component  $H_0D_0$  of  $H = H_\infty D + H_0D_0$  :



Both components of  $H = H_{\infty}D + H_0D_0$  :

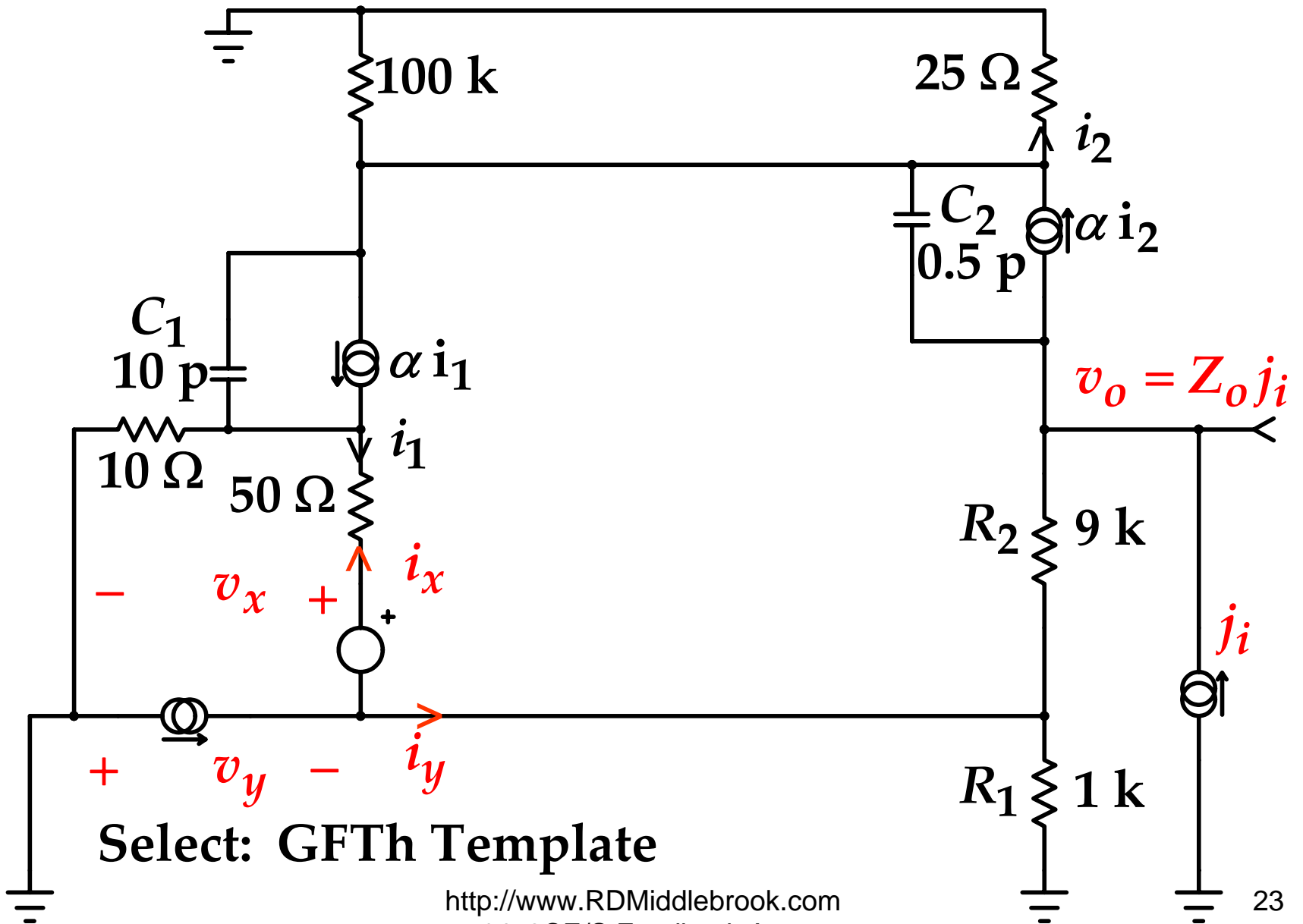


The first-level TF  $H$  can be a current gain, transadmittance, transimpedance, or a voltage gain.

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

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

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

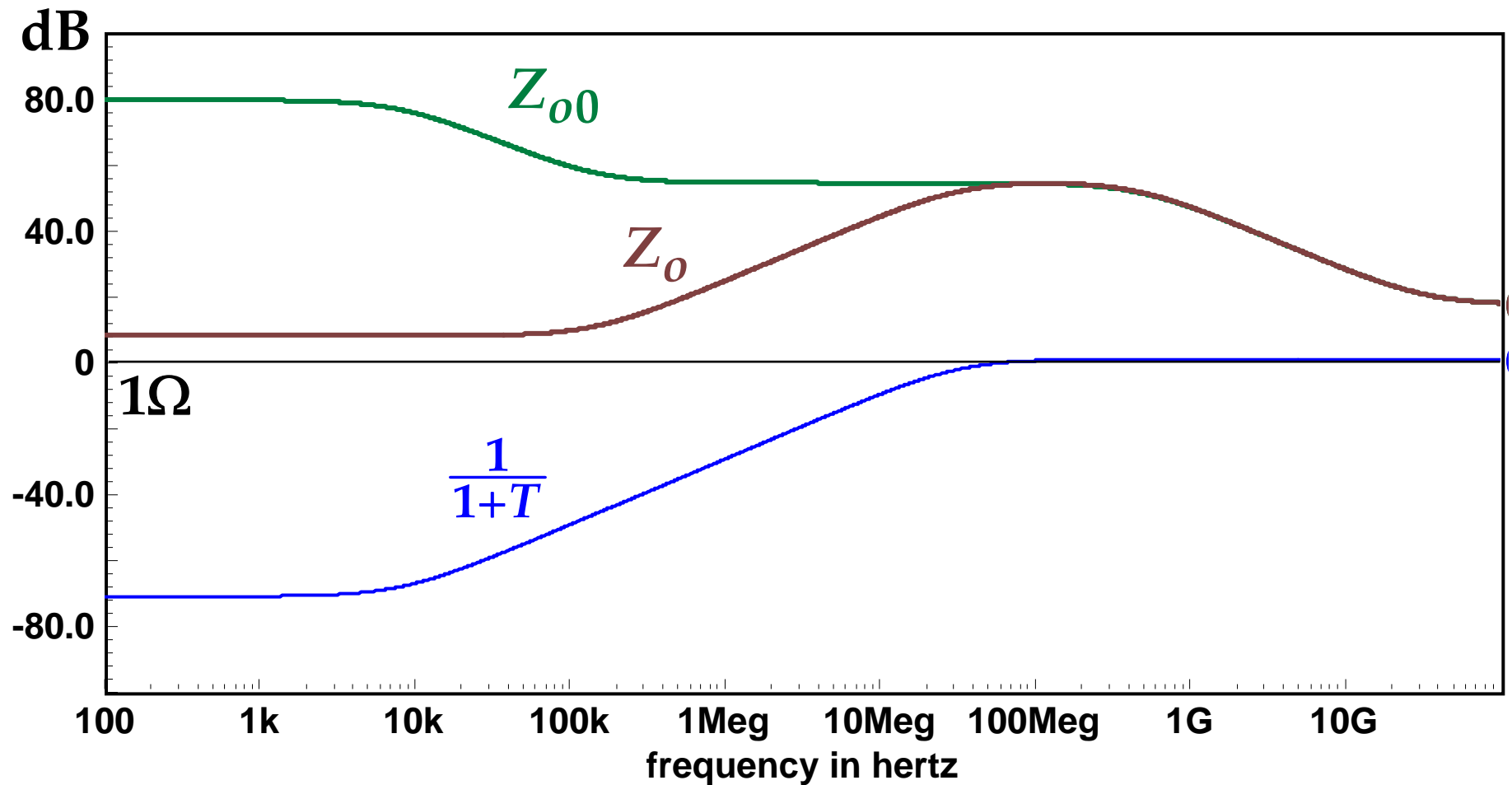


Select: GFTTh Template

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

$$Z_o = Z_{o0} \frac{1}{1+T}$$

**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.