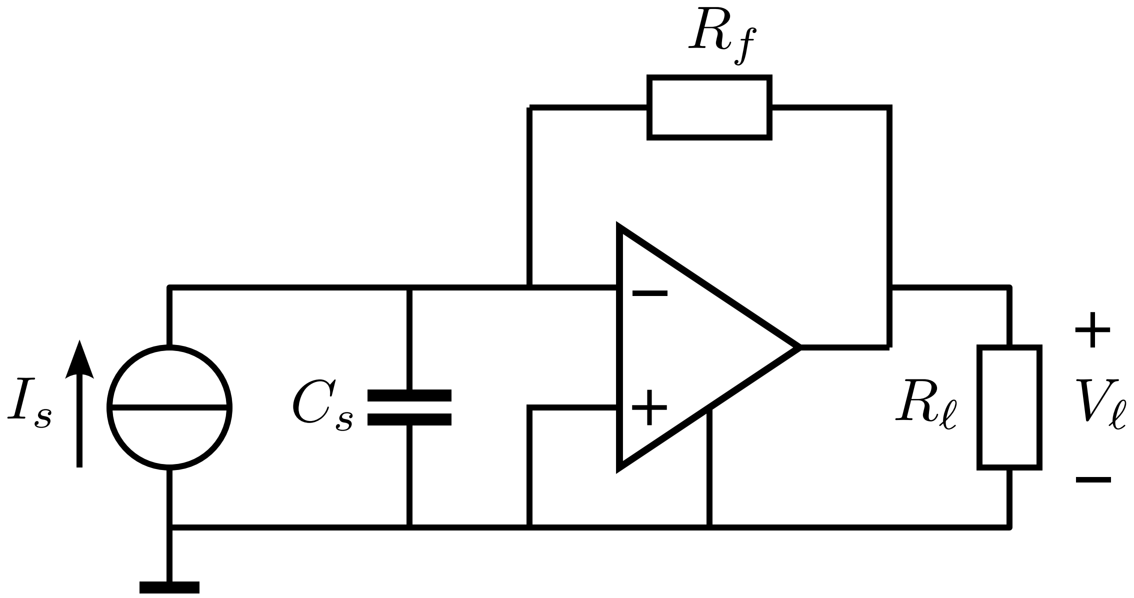
Structured Electronic Design
Examples Phantom Zero Compensation

Example 11.1-11.3

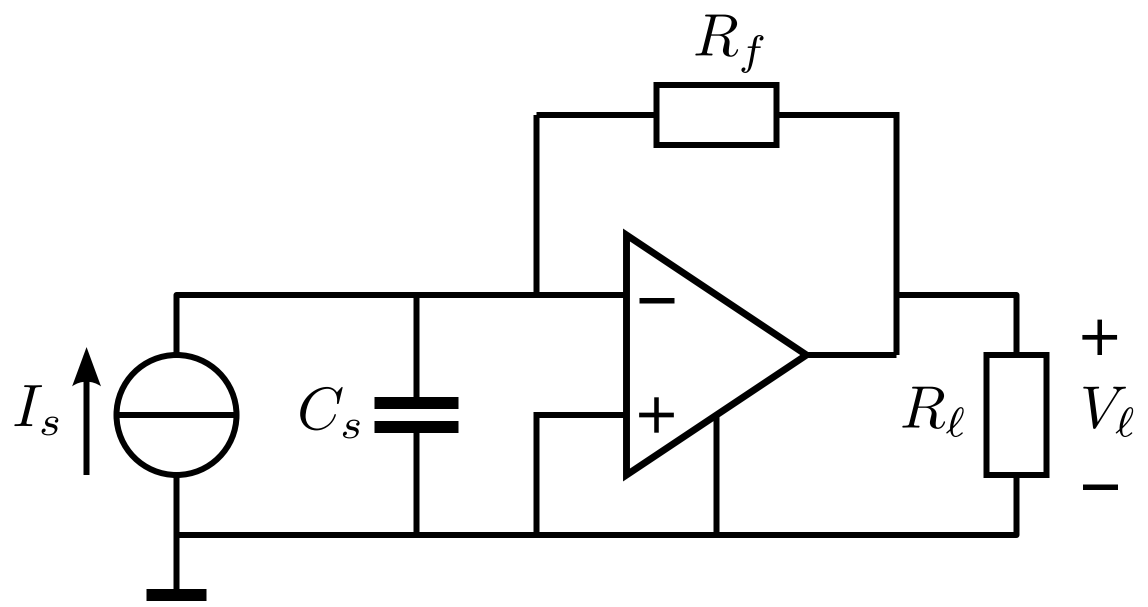
Example 11.1-11.3

Transimpedance Amplifier

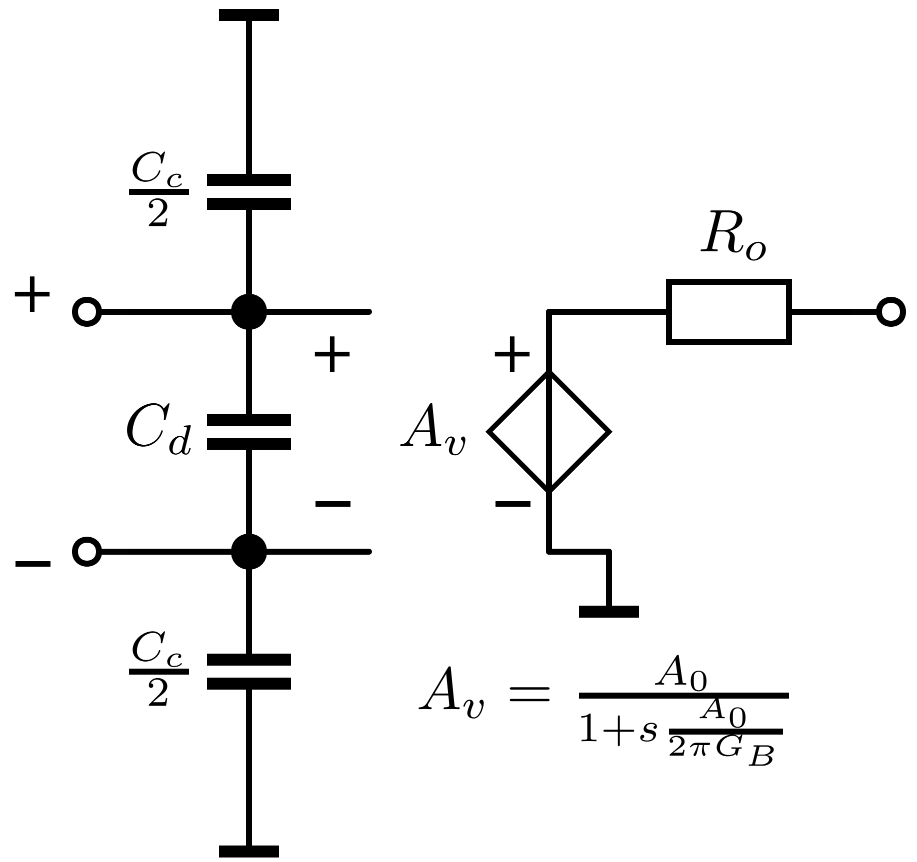


Example 11.1-11.3

Transimpedance Amplifier



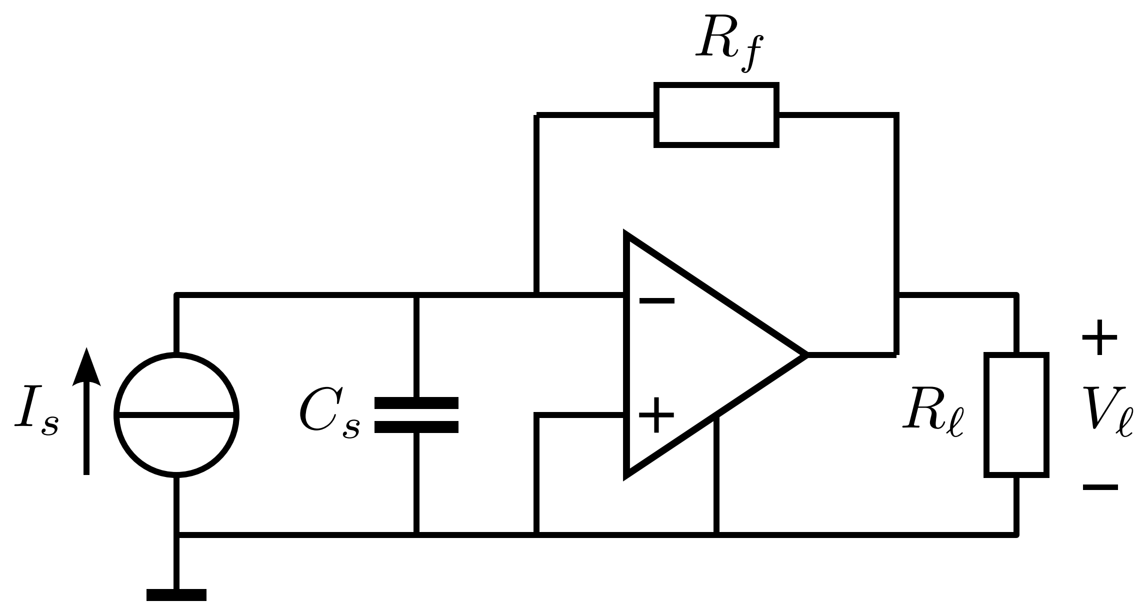
OpAmp small-signal model



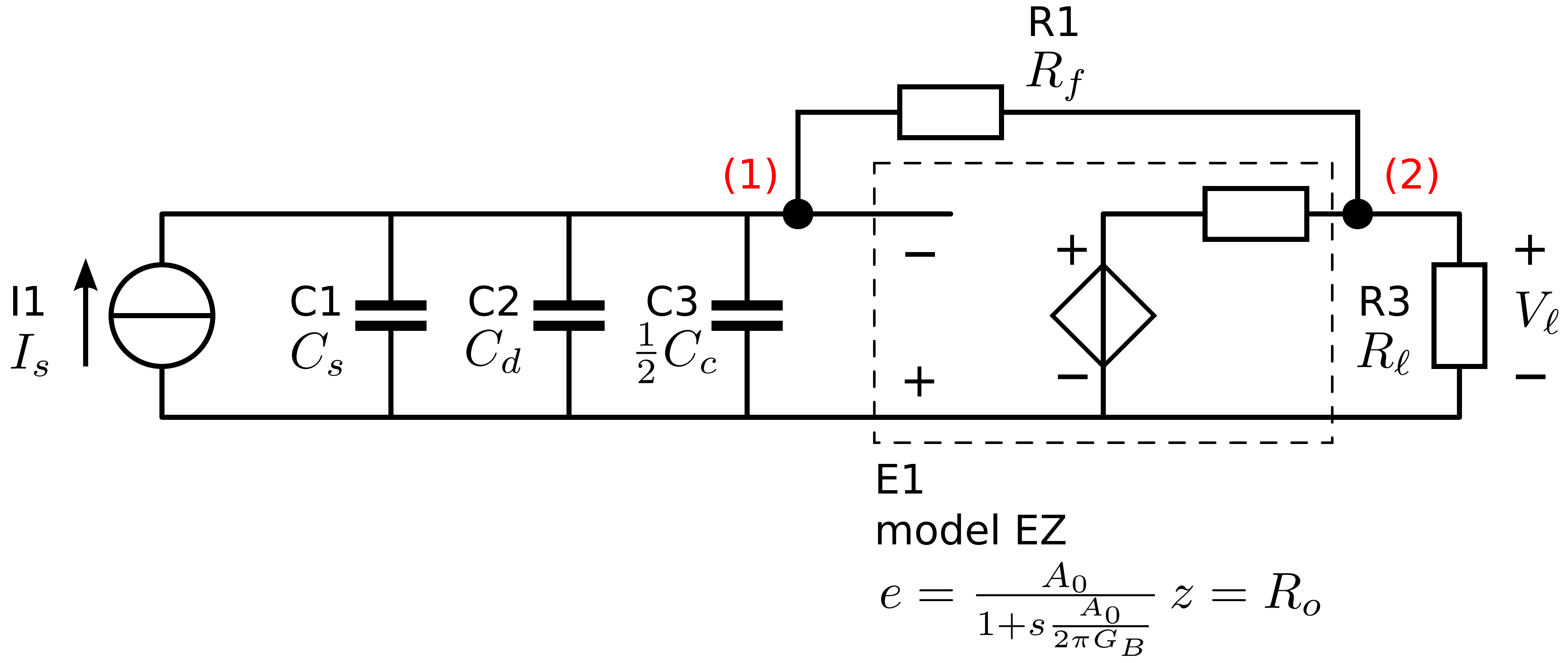
$$A_v = \frac{A_0}{1 + s\frac{A_0}{2\pi G_B}}$$

Example 11.1-11.3

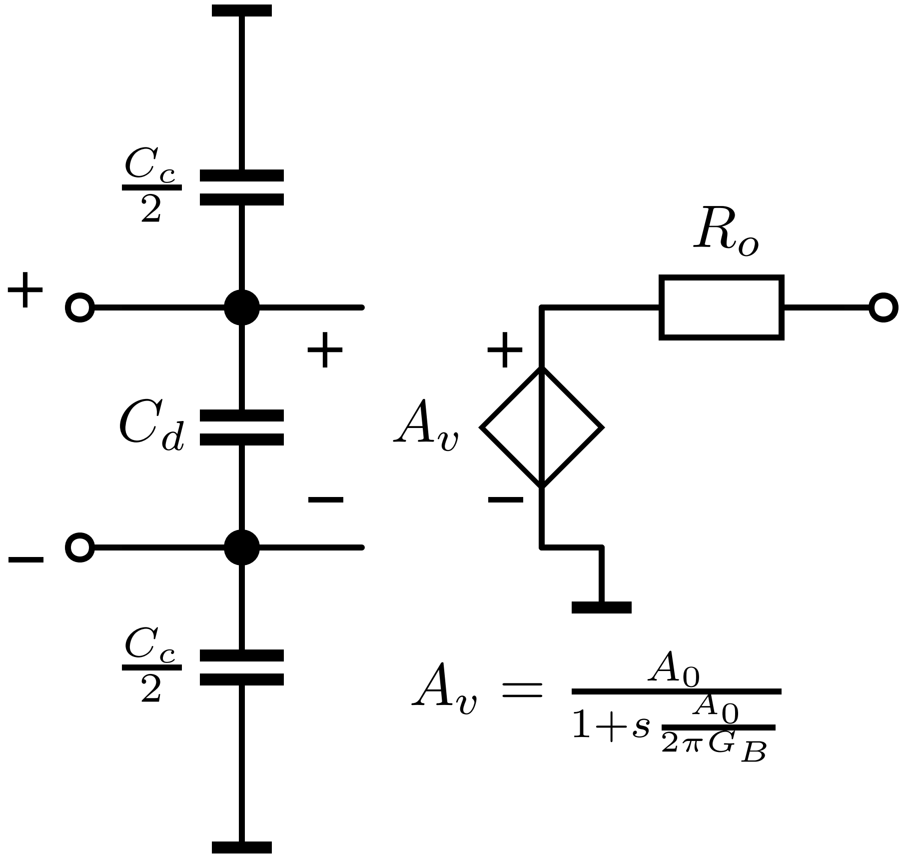
Transimpedance Amplifier



Complete small-signal model

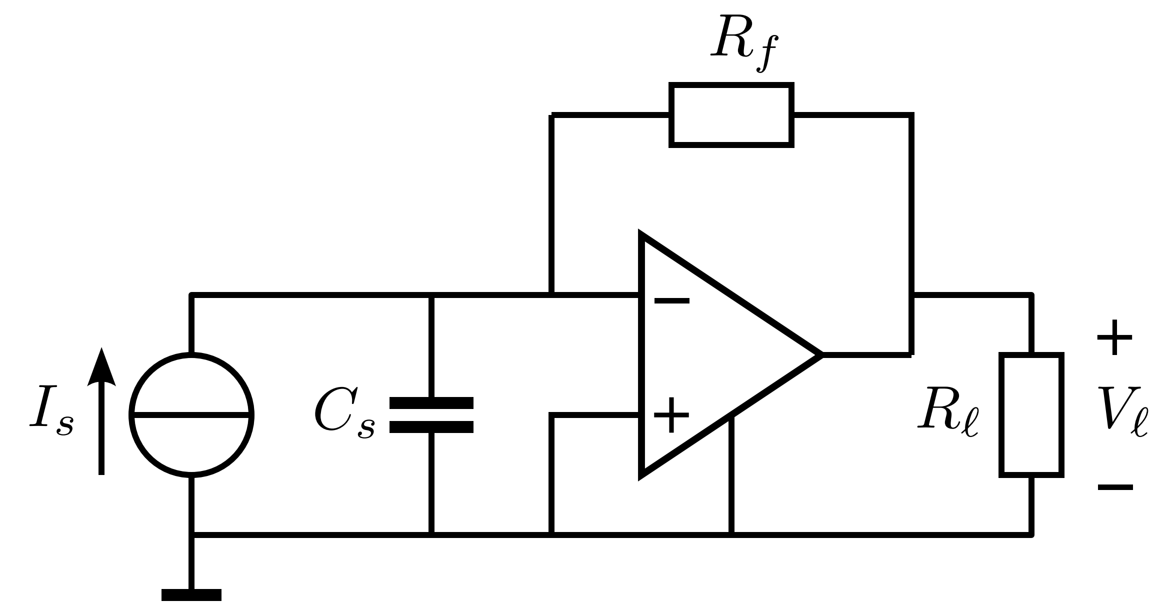


OpAmp small-signal model

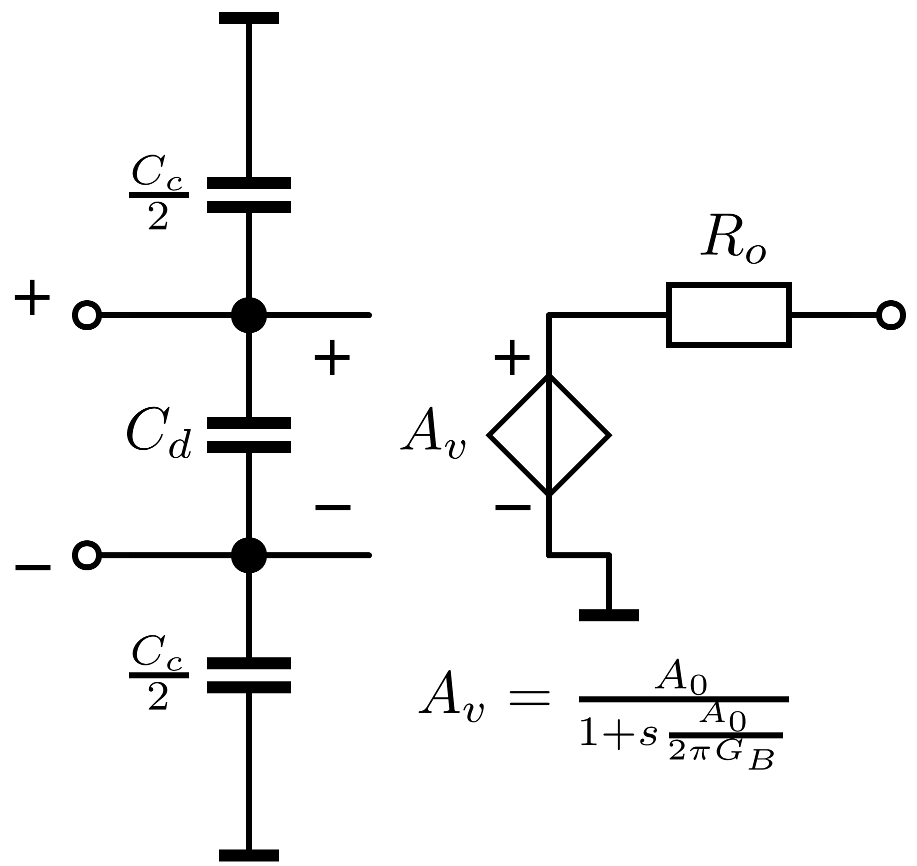


Example 11.1-11.3

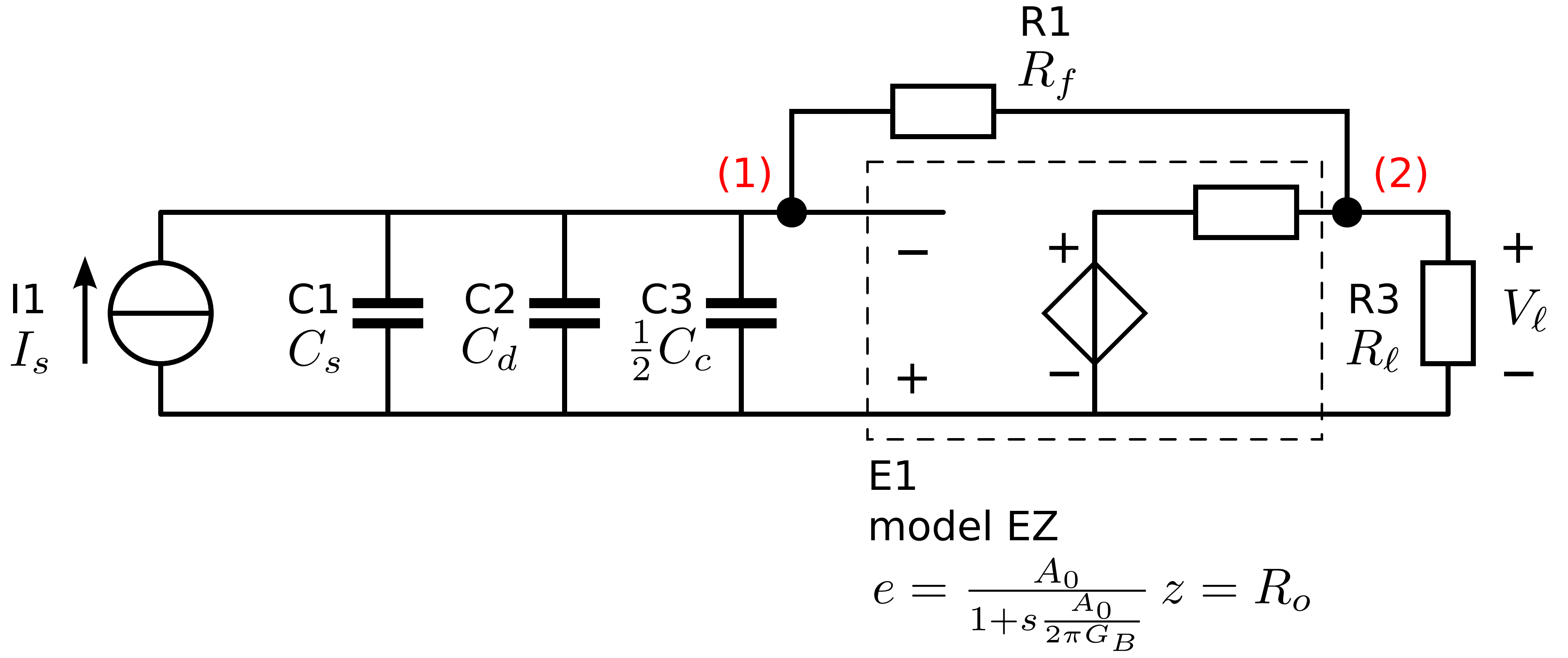
Transimpedance Amplifier



OpAmp small-signal model



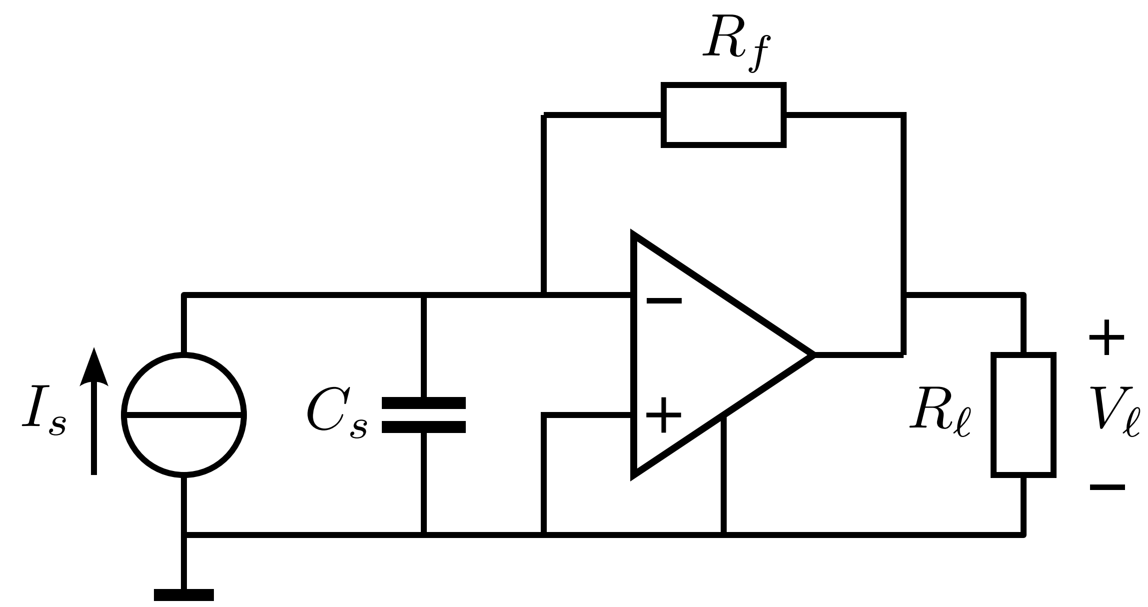
Complete small-signal model



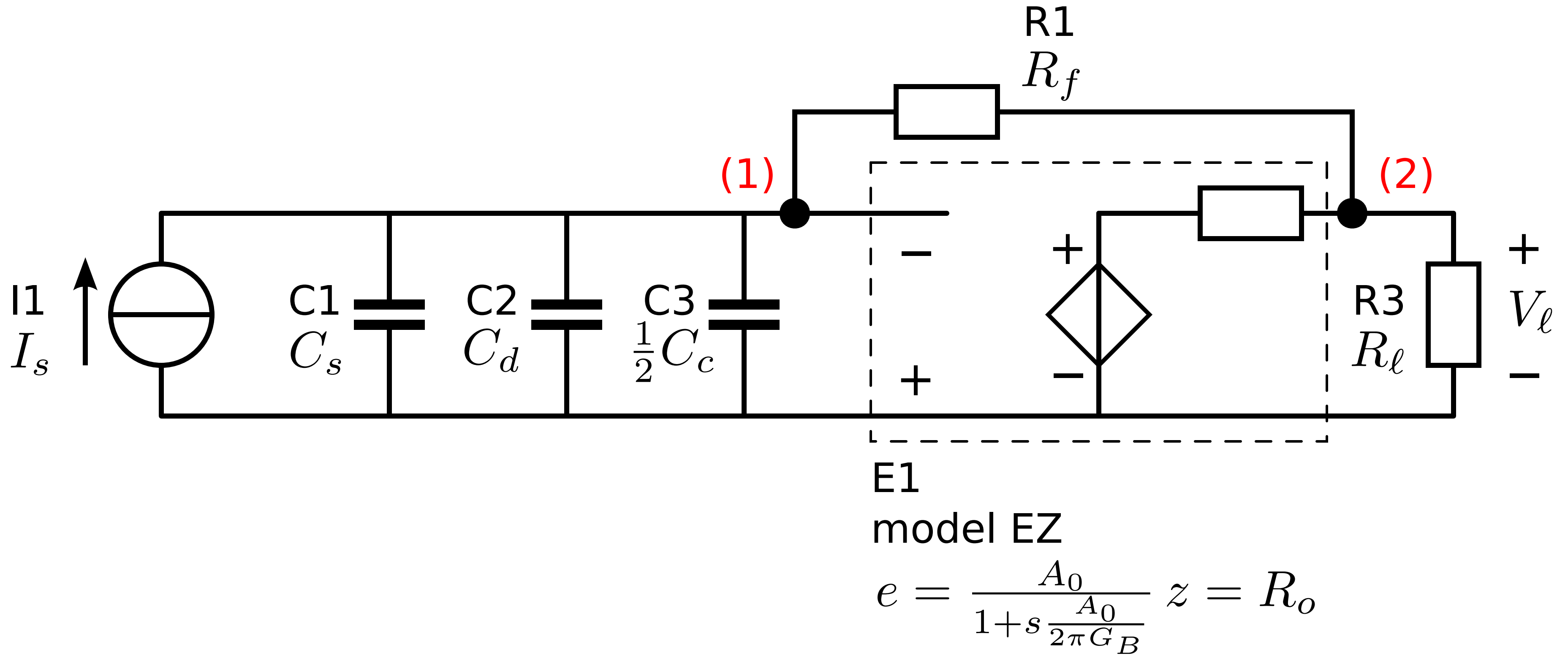
Design equation GB product (found from LP product):

Example 11.1-11.3

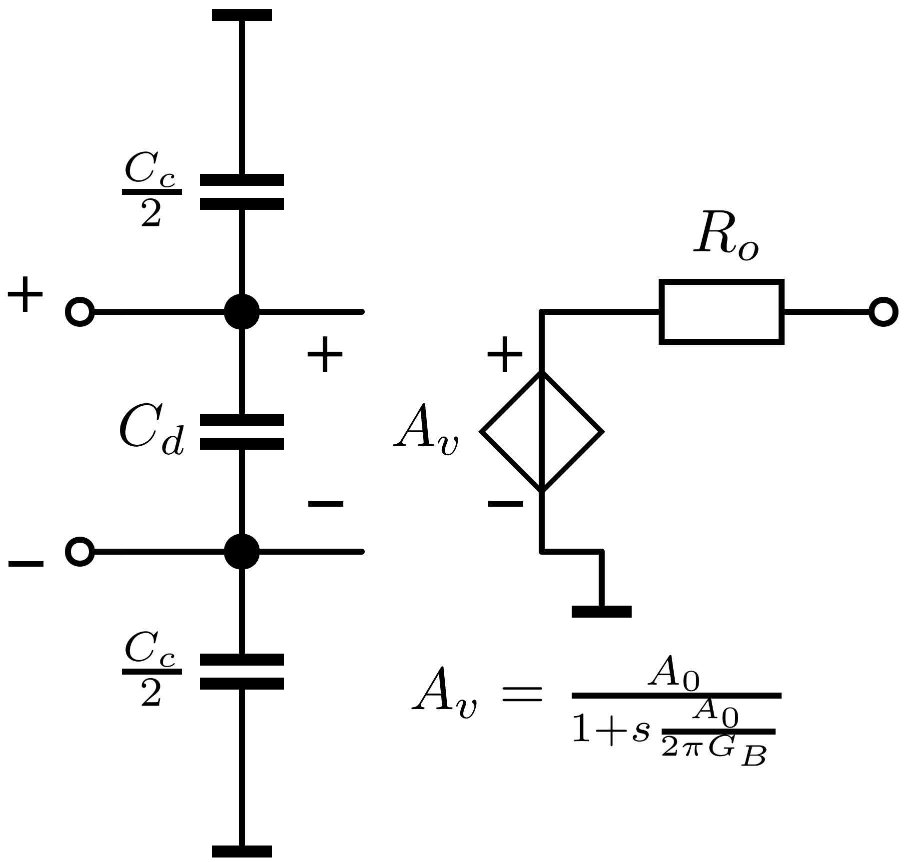
Transimpedance Amplifier



Complete small-signal model



OpAmp small-signal model

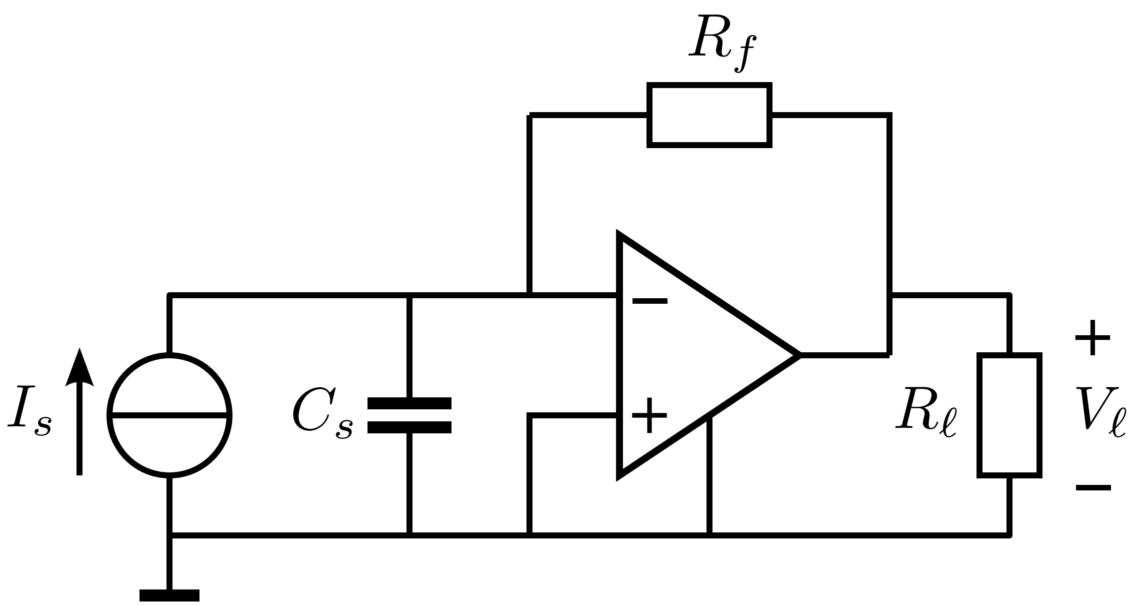


Design equation GB product (found from LP product):

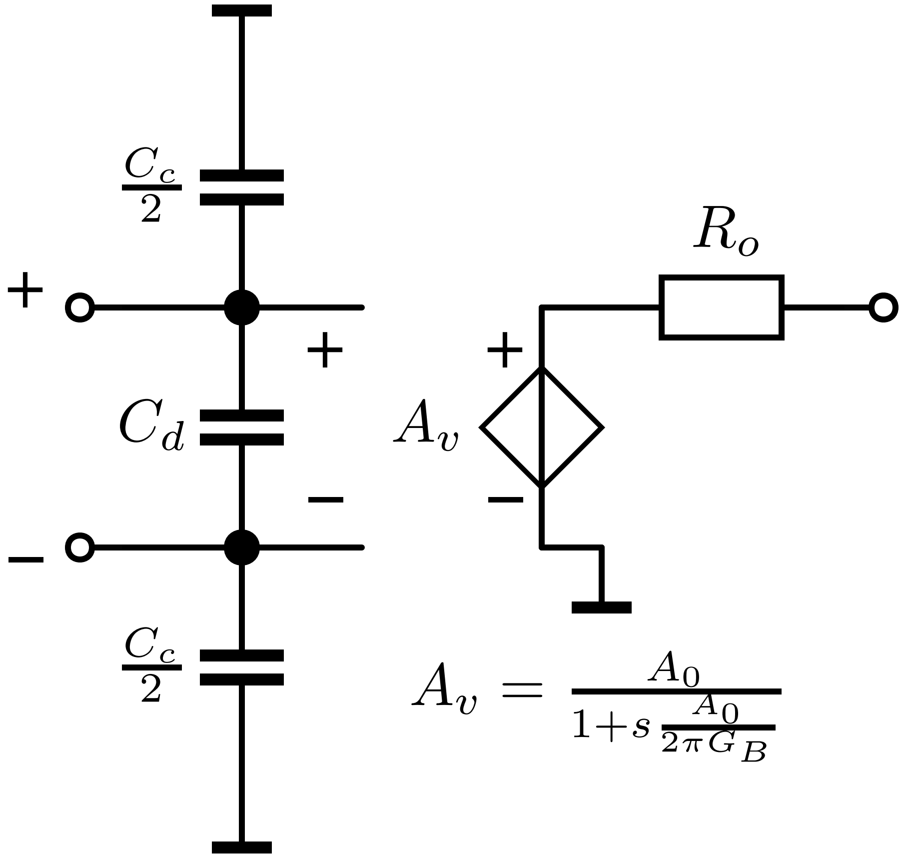
$$G_B \frac{R_\ell}{R_\ell + R_o} \frac{1}{((R_o||R_\ell)+R_f)\left(C_s + C_d + \frac{C_c}{2}\right)} \geq 2\pi B_f^2$$

Example 11.1-11.3

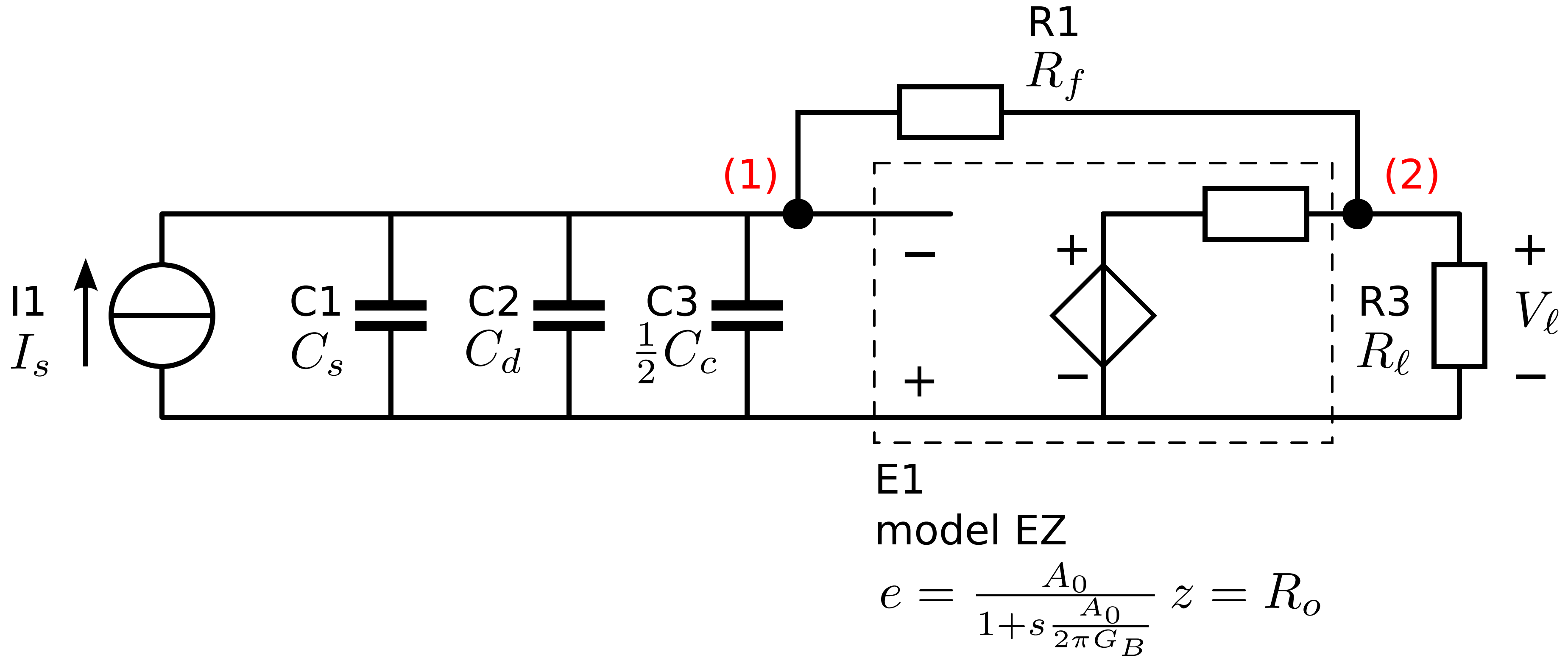
Transimpedance Amplifier



OpAmp small-signal model



Complete small-signal model



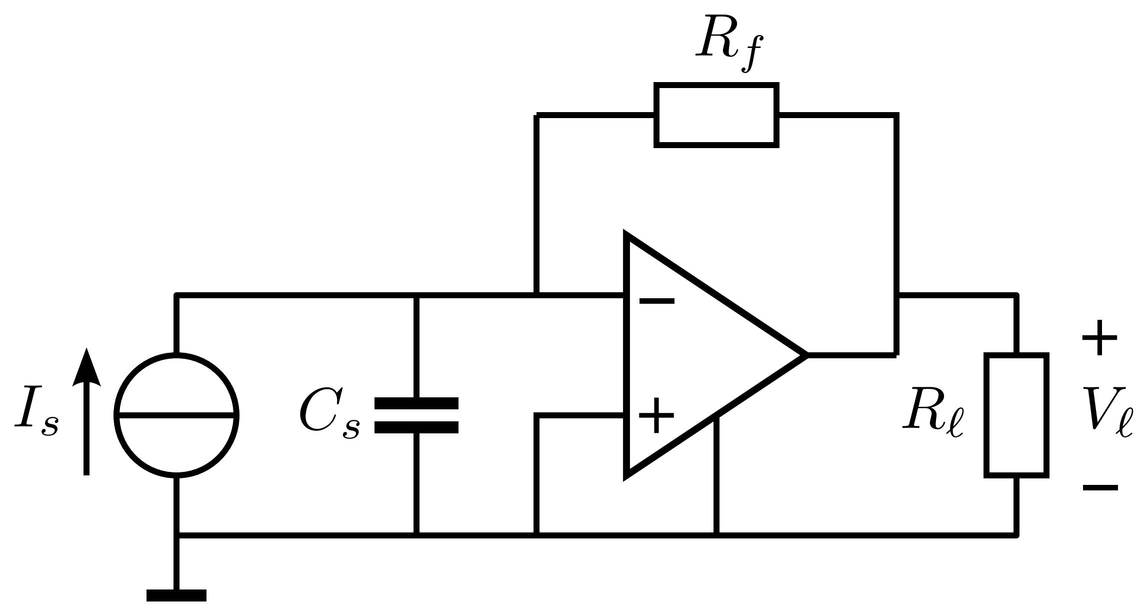
Design equation GB product (found from LP product):

$$G_B \frac{R_\ell}{R_\ell + R_o} \frac{1}{((R_o||R_\ell)+R_f)\left(C_s+C_d+\frac{C_c}{2}\right)} \geq 2\pi B_f^2$$

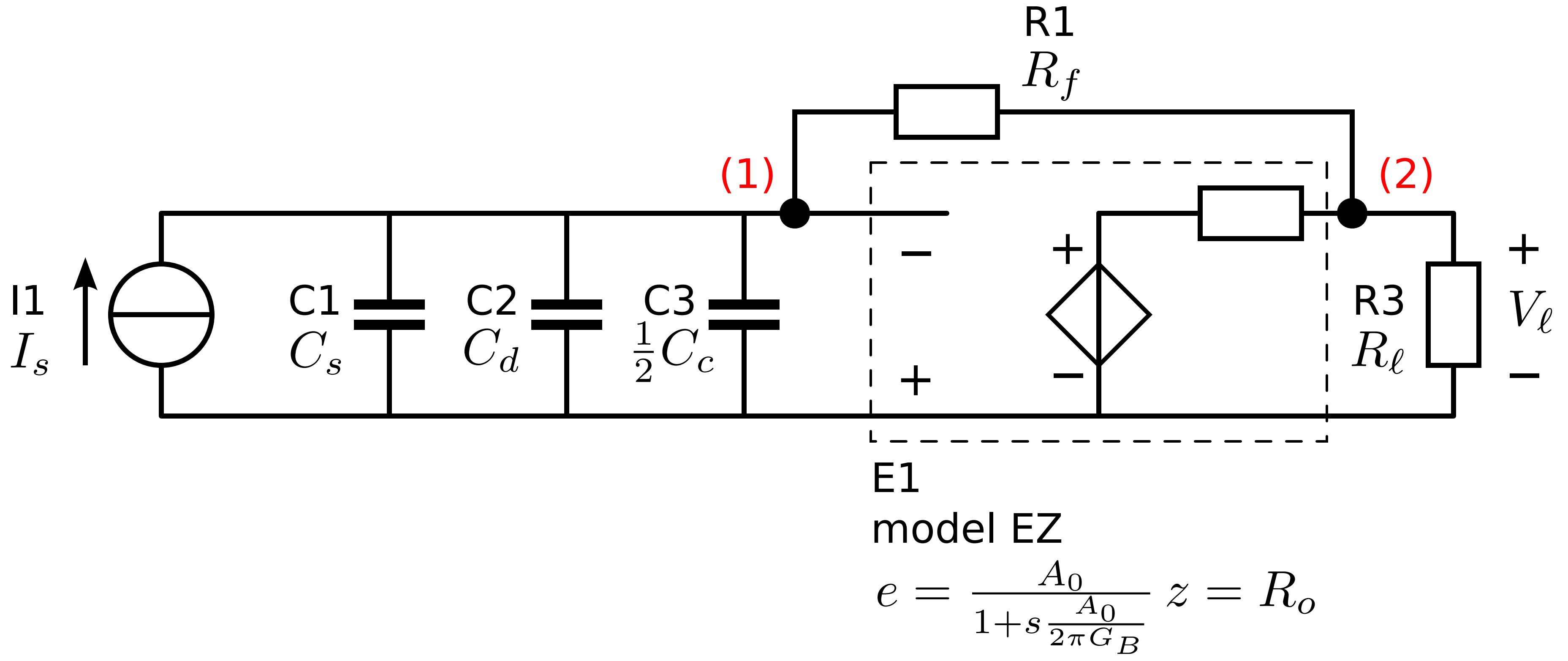
Show stopper value:

Example 11.1-11.3

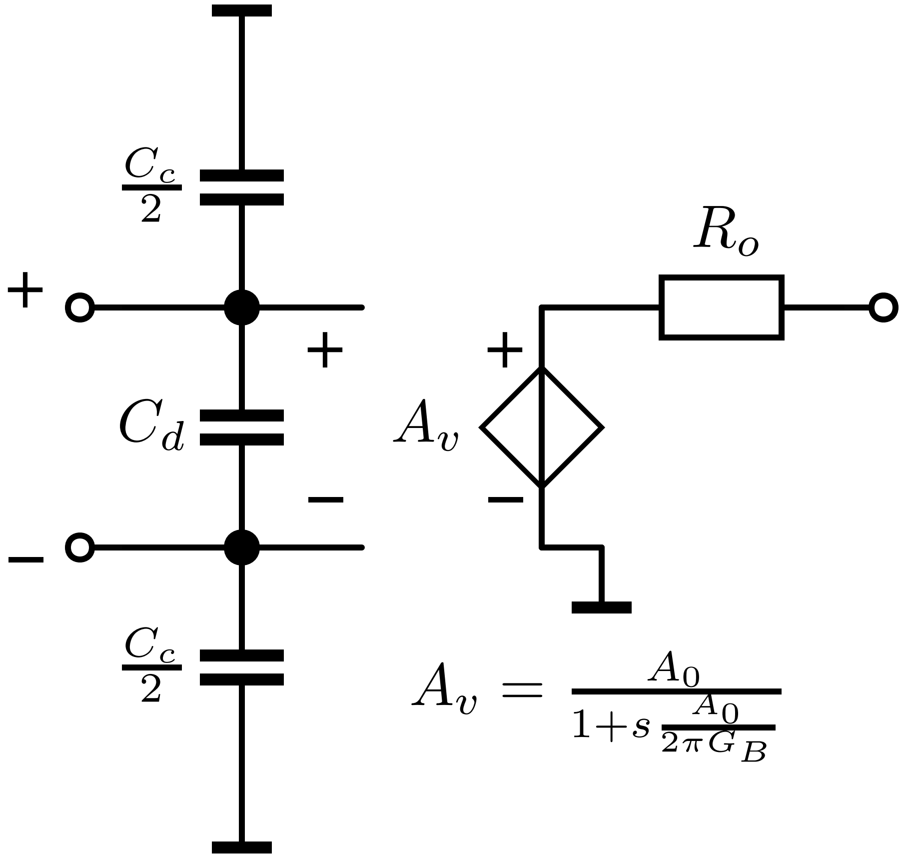
Transimpedance Amplifier



Complete small-signal model



OpAmp small-signal model



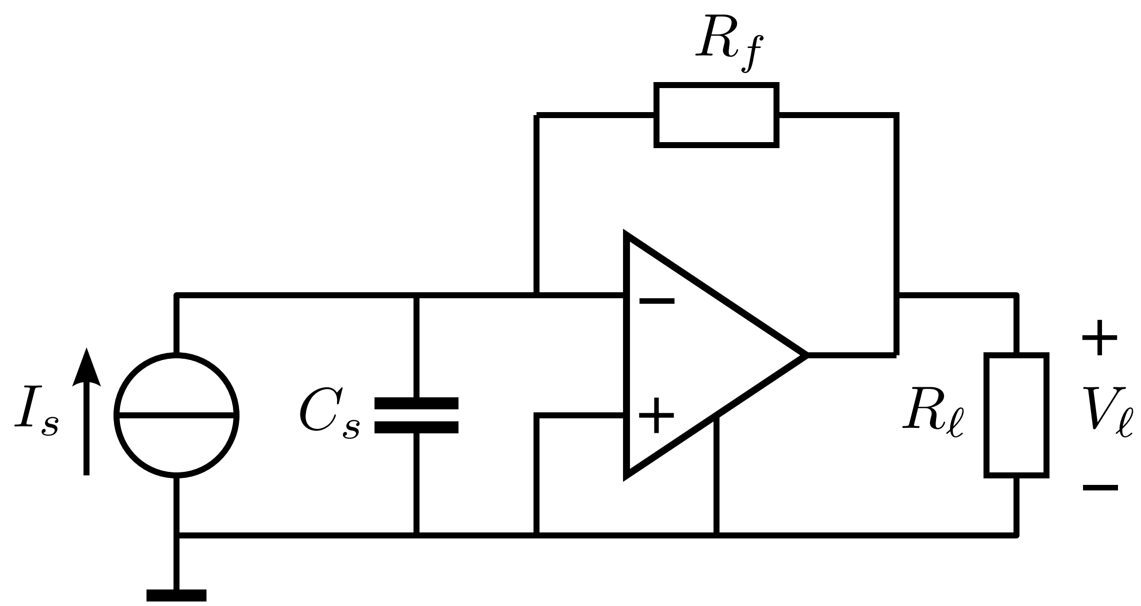
Design equation GB product (found from LP product):

$$G_B \frac{R_\ell}{R_\ell + R_o} \frac{1}{((R_o||R_\ell)+R_f)\left(C_s + C_d + \frac{C_c}{2}\right)} \geq 2\pi B_f^2$$

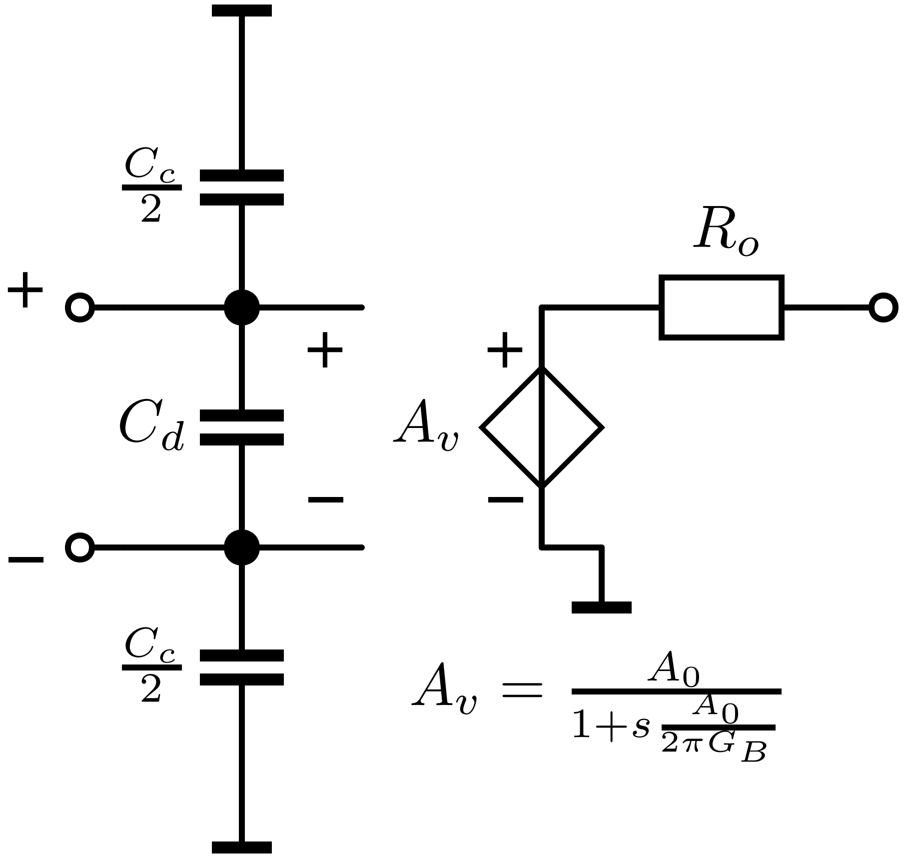
Show stopper value: $G_B \geq 2\pi R_f C_s B_f^2$

Example 11.1-11.3

Transimpedance Amplifier

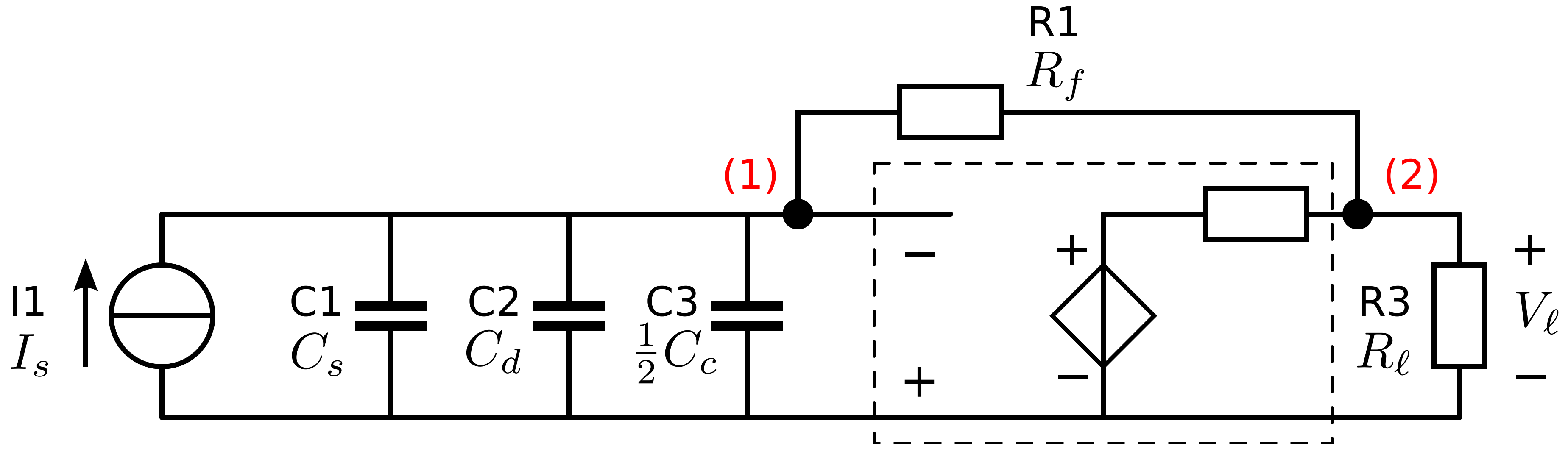


OpAmp small-signal model



$$A_v = \frac{A_0}{1+s\frac{A_0}{2\pi G_B}}$$

Complete small-signal model



$$e = \frac{A_0}{1+s\frac{A_0}{2\pi G_B}} \quad z = R_o$$

Design equation GB product (found from LP product):

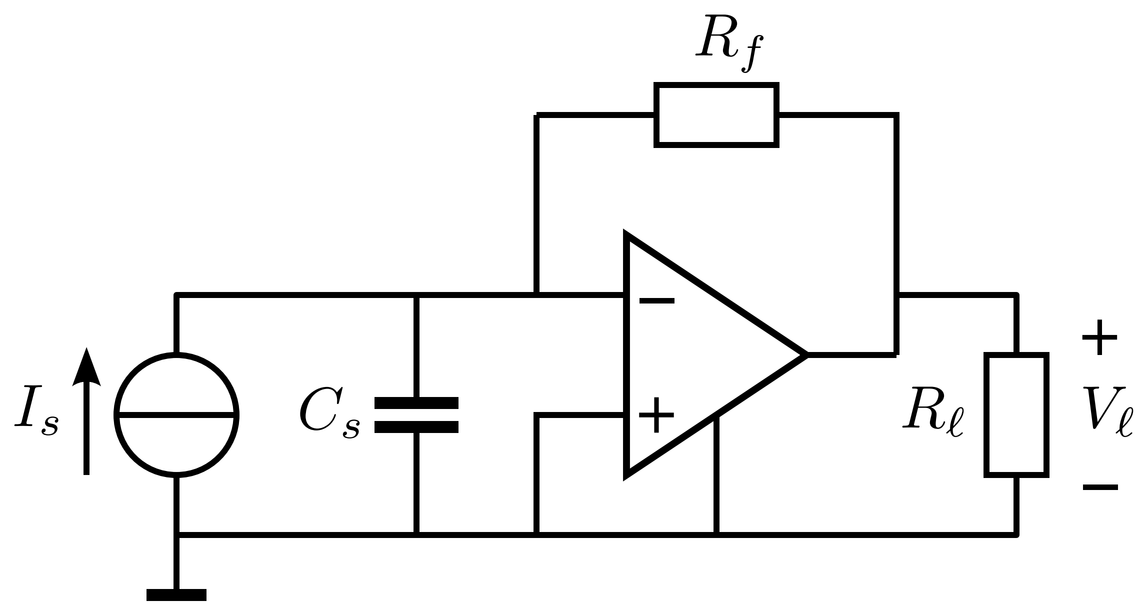
$$G_B \frac{R_\ell}{R_\ell + R_o} \frac{1}{((R_o||R_\ell)+R_f)\left(C_s + C_d + \frac{C_c}{2}\right)} \geq 2\pi B_f^2$$

Show stopper value: $G_B \geq 2\pi R_f C_s B_f^2$

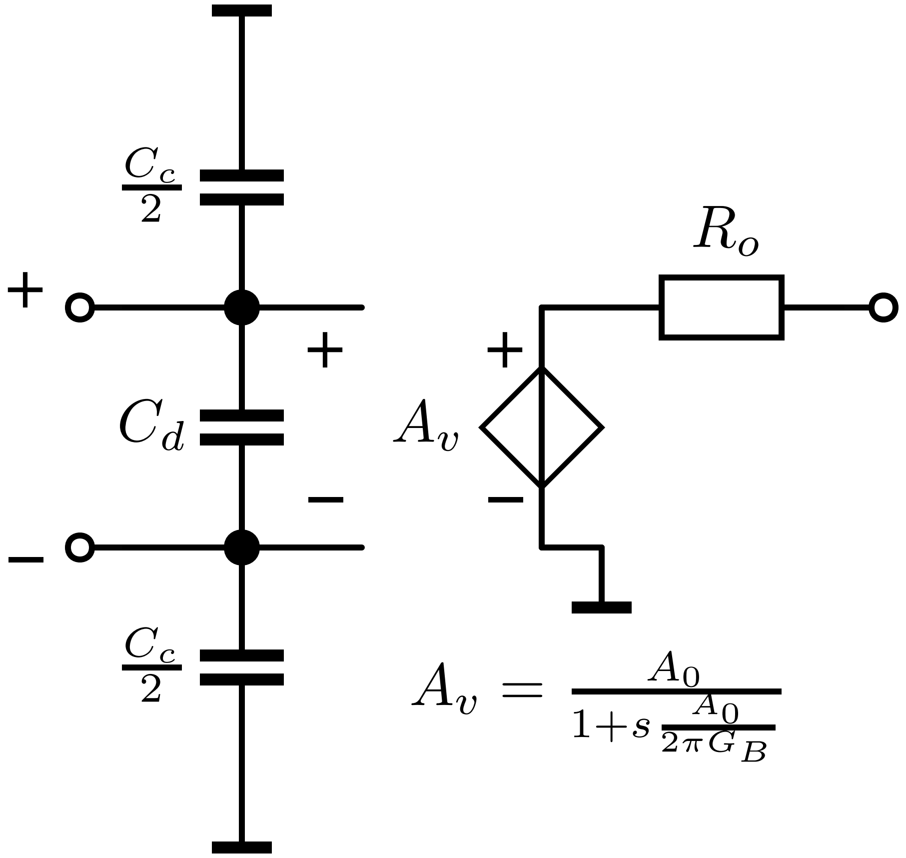
If:

Example 11.1-11.3

Transimpedance Amplifier

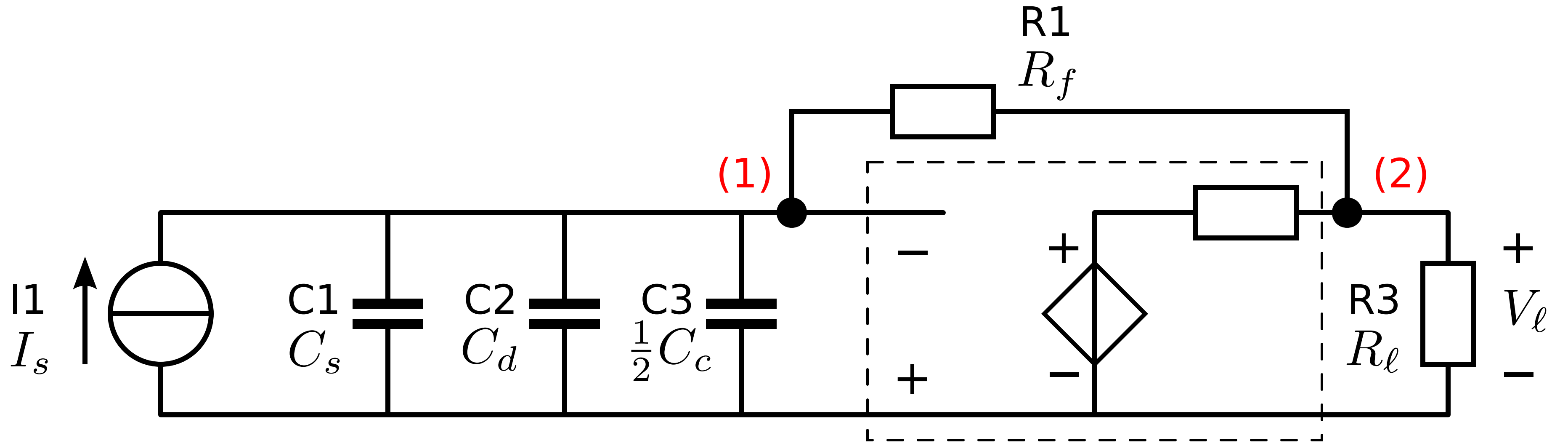


OpAmp small-signal model



$$A_v = \frac{A_0}{1+s\frac{A_0}{2\pi G_B}}$$

Complete small-signal model



$e = \frac{A_0}{1+s\frac{A_0}{2\pi G_B}}$ $z = R_o$

Design equation GB product (found from LP product):

$$G_B \frac{R_\ell}{R_\ell + R_o} \frac{1}{((R_o||R_\ell)+R_f)\left(C_s + C_d + \frac{C_c}{2}\right)} \geq 2\pi B_f^2$$

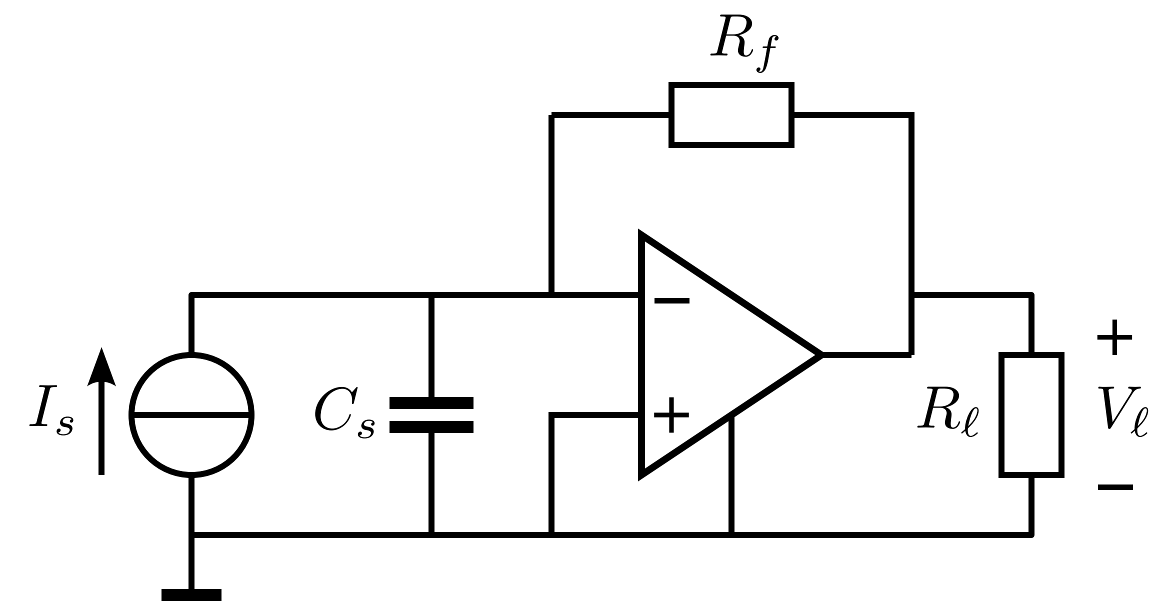
Show stopper value: $G_B \geq 2\pi R_f C_s B_f^2$

If:

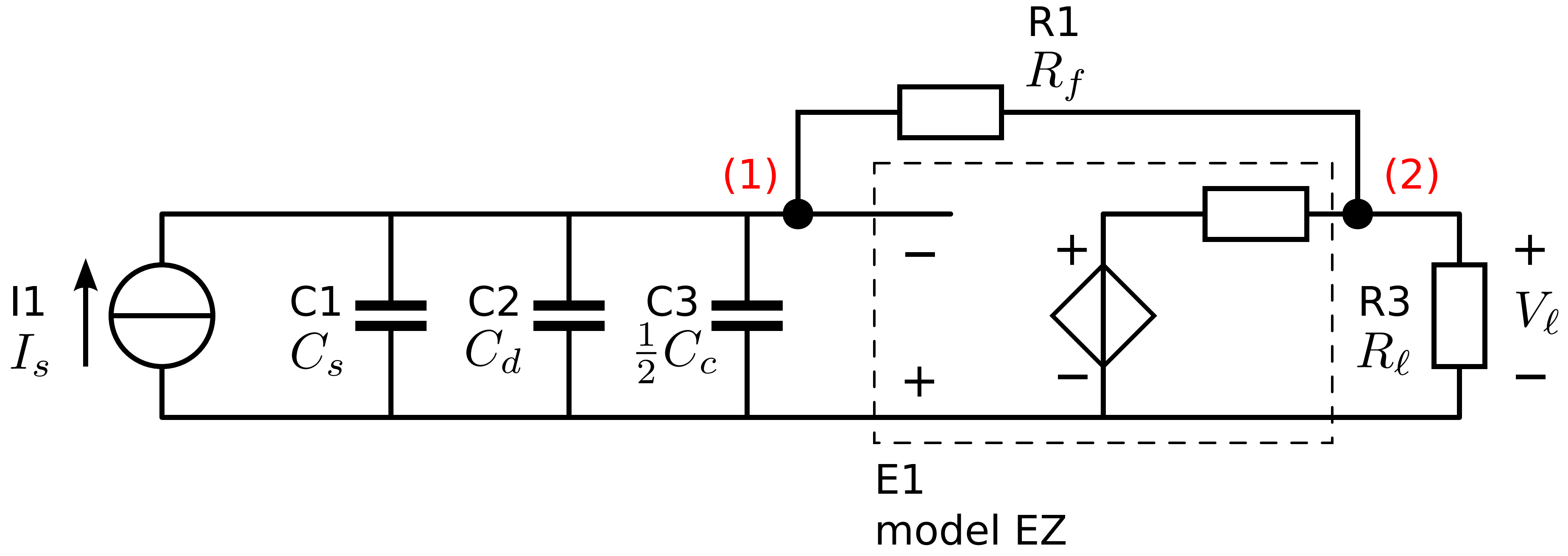
$$\begin{cases} C_d + \frac{C_c}{2} \ll C_s \\ R_o \ll R_\ell \\ R_o \ll R_f \end{cases}$$

Example 11.1-11.3

Transimpedance Amplifier

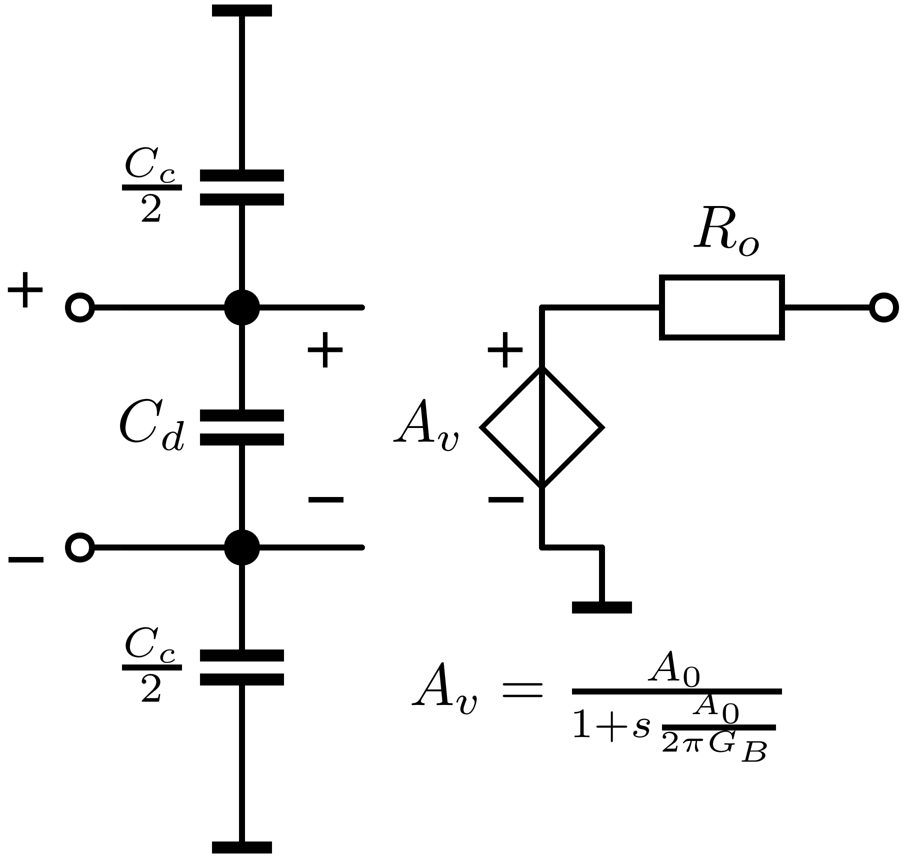


Complete small-signal model



$e = \frac{A_0}{1+s\frac{A_0}{2\pi G_B}}$ $z = R_o$

OpAmp small-signal model



$$A_v = \frac{A_0}{1+s\frac{A_0}{2\pi G_B}}$$

Design equation GB product (found from LP product):

$$G_B \frac{R_\ell}{R_\ell + R_o} \frac{1}{((R_o || R_\ell) + R_f)\left(C_s + C_d + \frac{C_c}{2}\right)} \geq 2\pi B_f^2$$

Show stopper value: $G_B \geq 2\pi R_f C_s B_f^2$

If:

$$\begin{cases} C_d + \frac{C_c}{2} \ll C_s \\ R_o \ll R_\ell \\ R_o \ll R_f \end{cases}$$

Example 11.1-11.3

Target bandwidth: 500kHz

Example 11.1-11.3

Target bandwidth: 500kHz

Show-stopper GB product: 785kHz

Example 11.1-11.3

Target bandwidth: 500kHz

Show-stopper GB product: 785kHz

Selected OpAmp: OPA627:

Example 11.1-11.3

Target bandwidth: 500kHz

Show-stopper GB product: 785kHz

Selected OpAmp: OPA627:

Device selection and verification

The achievable low-pass cut-off frequency f_h with the OPA627 in [MHz] is:

$$f_h = 1.225 \quad (1)$$

List with circuit parameters

name		symbolic		value
C_s	=	$5.0\,10^{-12}$	=	$5.0\,10^{-12}$
R_f	=	$1.0\,10^{5}$	=	$1.0\,10^{5}$
R_ℓ	=	2000.0	=	2000.0
I_s	=	$undefined$	=	$undefined$
C_d	=	$8.0\,10^{-12}$	=	$8.0\,10^{-12}$
C_c	=	$7.0\,10^{-12}$	=	$7.0\,10^{-12}$
A_0	=	$1.0\,10^{6}$	=	$1.0\,10^{6}$
G_B	=	$1.6\,10^{7}$	=	$1.6\,10^{7}$
R_o	=	55	=	55.0

Example 11.1-11.3

Target bandwidth: 500kHz

Show-stopper GB product: 785kHz

Selected OpAmp: OPA627:

Device selection and verification

The achievable low-pass cut-off frequency f_h with the OPA627 in [MHz] is:

$$f_h = 1.225 \tag{1}$$

List with circuit parameters

name		symbolic		value
C_s	=	$5.0\,10^{-12}$	=	$5.0\,10^{-12}$
R_f	=	$1.0\,10^{5}$	=	$1.0\,10^{5}$
R_ℓ	=	2000.0	=	2000.0
I_s	=	$undefined$	=	$undefined$
C_d	=	$8.0\,10^{-12}$	=	$8.0\,10^{-12}$
C_c	=	$7.0\,10^{-12}$	=	$7.0\,10^{-12}$
A_0	=	$1.0\,10^{6}$	=	$1.0\,10^{6}$
G_B	=	$1.6\,10^{7}$	=	$1.6\,10^{7}$
R_o	=	55	=	55.0

Contribution of input capacitance on LP product could not be ignored!

Example 11.1-11.3

Target bandwidth: 500kHz

Show-stopper GB product: 785kHz

Selected OpAmp: OPA627:

Device selection and verification

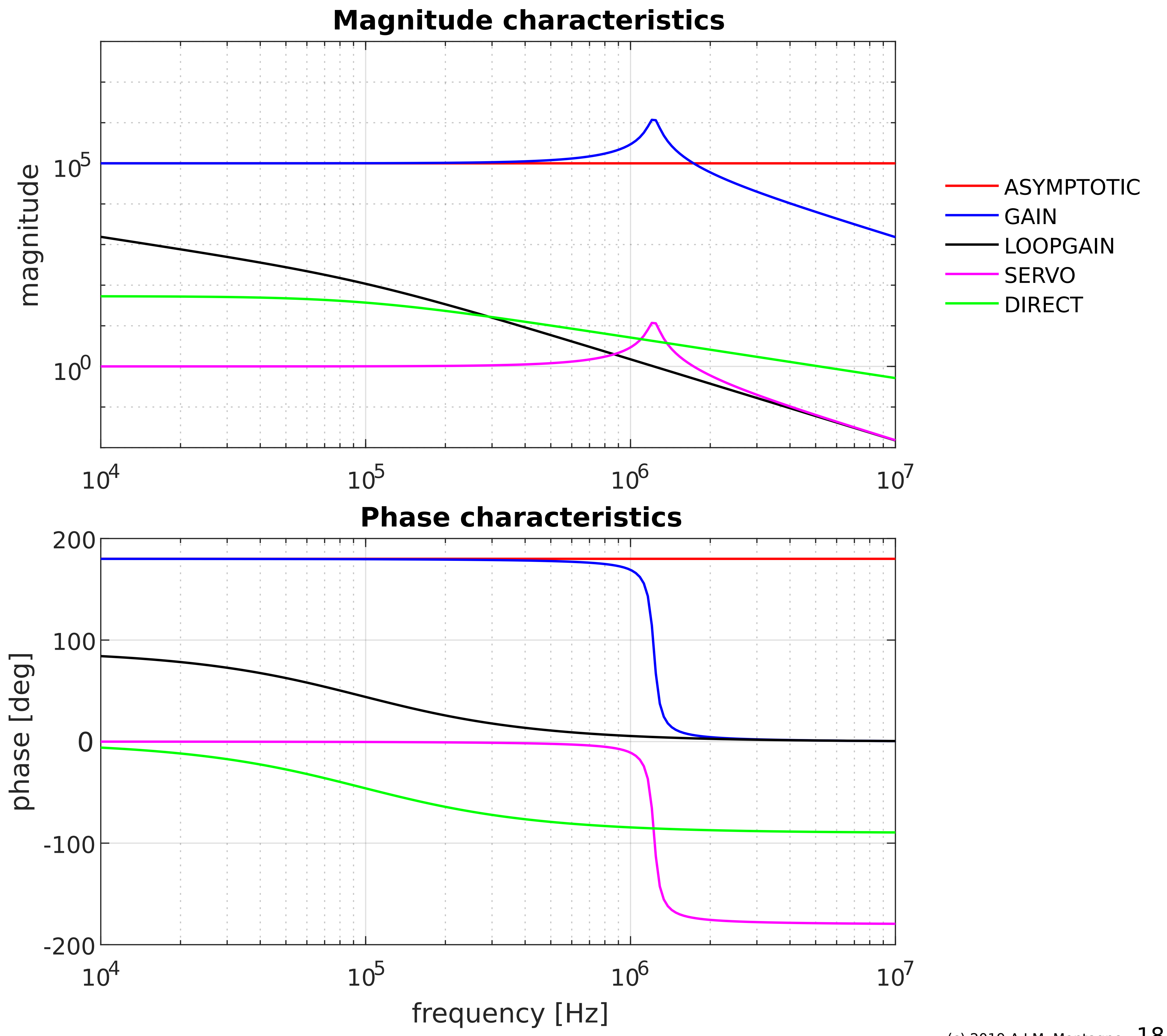
The achievable low-pass cut-off frequency f_h with the OPA627 in [MHz] is:

$$f_h = 1.225 \tag{1}$$

List with circuit parameters

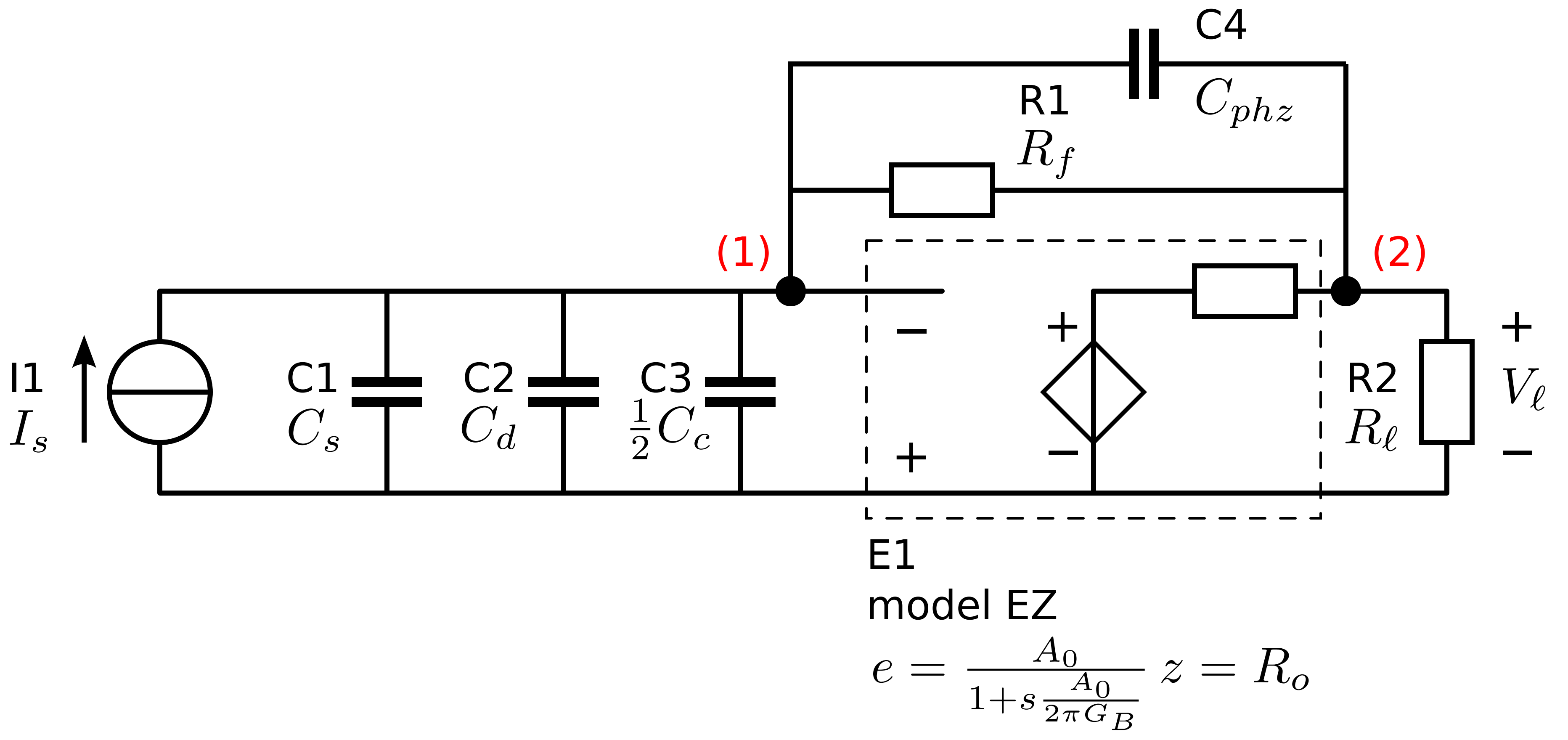
name		symbolic		value
C_s	=	$5.0\,10^{-12}$	=	$5.0\,10^{-12}$
R_f	=	$1.0\,10^{5}$	=	$1.0\,10^{5}$
R_ℓ	=	2000.0	=	2000.0
I_s	=	$undefined$	=	$undefined$
C_d	=	$8.0\,10^{-12}$	=	$8.0\,10^{-12}$
C_c	=	$7.0\,10^{-12}$	=	$7.0\,10^{-12}$
A_0	=	$1.0\,10^{6}$	=	$1.0\,10^{6}$
G_B	=	$1.6\,10^{7}$	=	$1.6\,10^{7}$
R_o	=	55	=	55.0

Contribution of input capacitance on LP product could not be ignored!



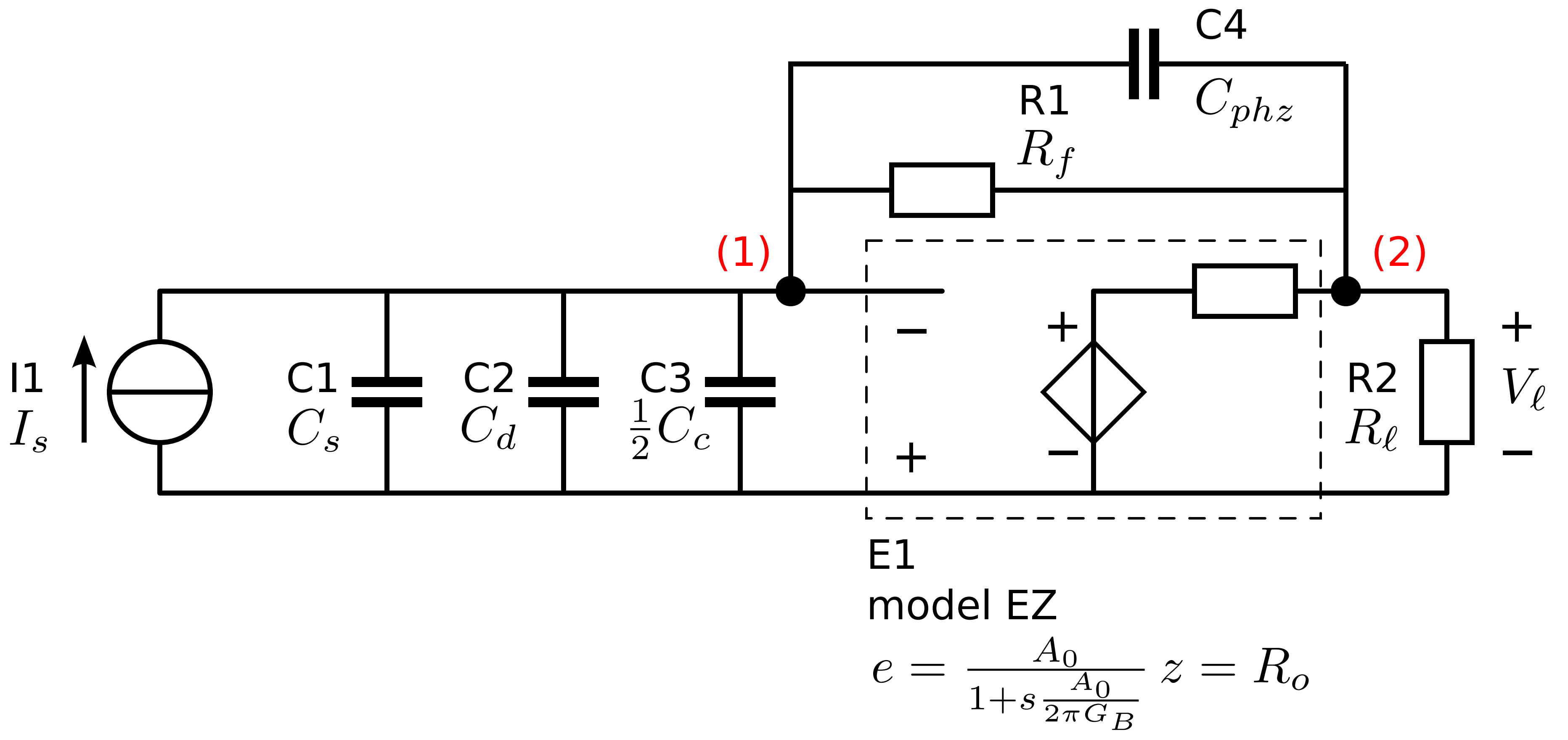
Example 12.8

Transimpedance with phantom zero in feedback network:



Example 12.8

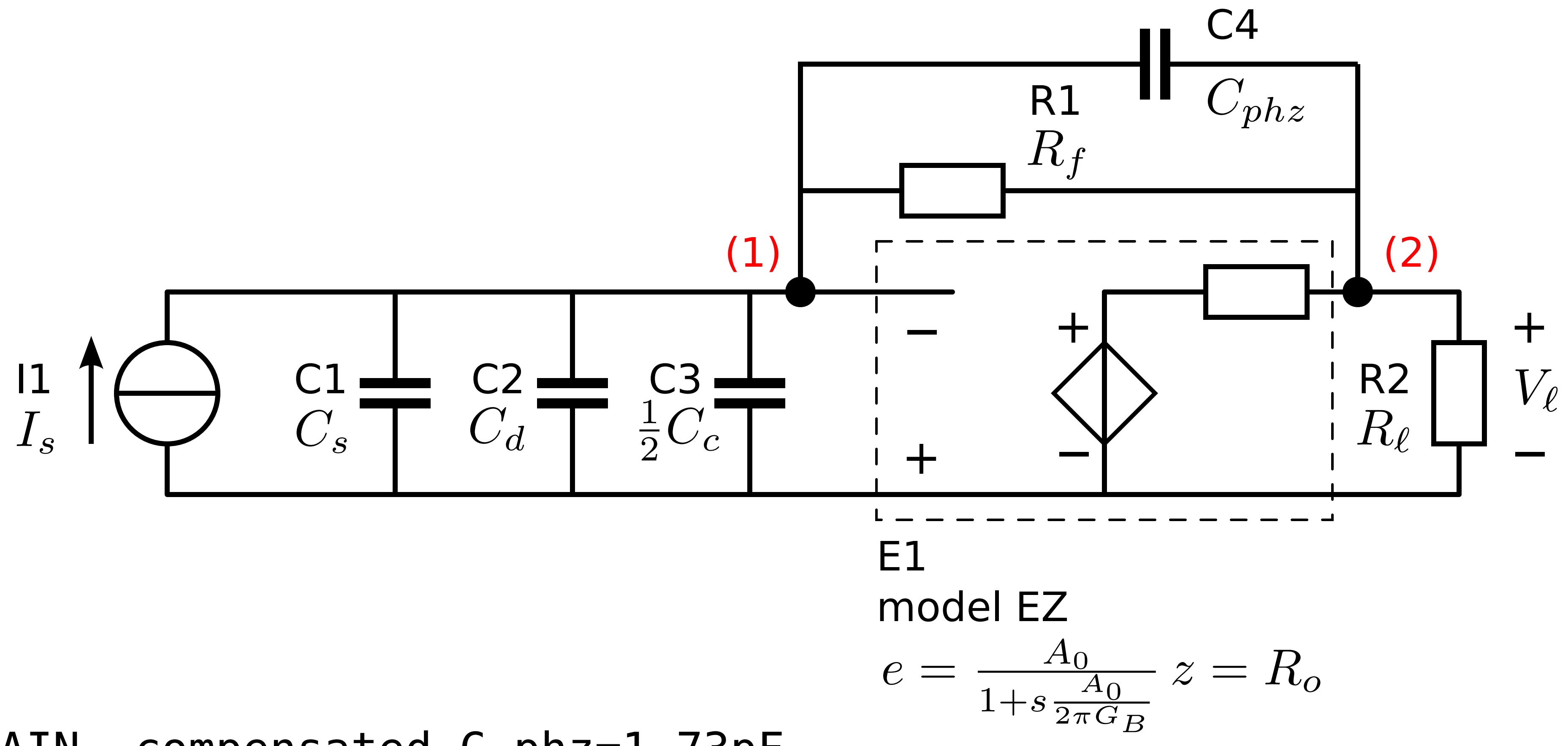
Transimpedance with phantom zero in feedback network:




```
LOOPGAIN, compensated C_phz=1.73pF
DC value = -9.732e+05
Poles:
          RealPart      ImagPart     Frequency     Q
         __________     ________     _________     _

p_1             -16     0                   16     0
p_2          -87243     0                87243     0
p_3      -1.895e+09     0            1.895e+09     0

Zeros:
          RealPart       ImagPart     Frequency      Q
         ___________     ________     __________     _

z_1      -9.1743e+05     0            9.1743e+05     0
```

Example 12.8

Transimpedance with phantom zero in feedback network:



LOOPGAIN, compensated C_phz=1.73pF
DC value = -9.732e+05
Poles:

	RealPart	ImagPart	Frequency	Q
p_1	-16	0	16	0
p_2	-87243	0	87243	0
p_3	-1.895e+09	0	1.895e+09	0

Zeros:

	RealPart	ImagPart	Frequency	Q
z_1	-9.1743e+05	0	9.1743e+05	0

GAIN, compensated C_phz=1.73pF
DC value = -1.000e+05
Poles:

	RealPart	ImagPart	Frequency	Q
p_1	-7.8428e+05	-8.6284e+05	1.166e+06	0.74336
p_2	-7.8428e+05	8.6284e+05	1.166e+06	0.74336
p_3	-1.8935e+09	0	1.8935e+09	0

Zeros:

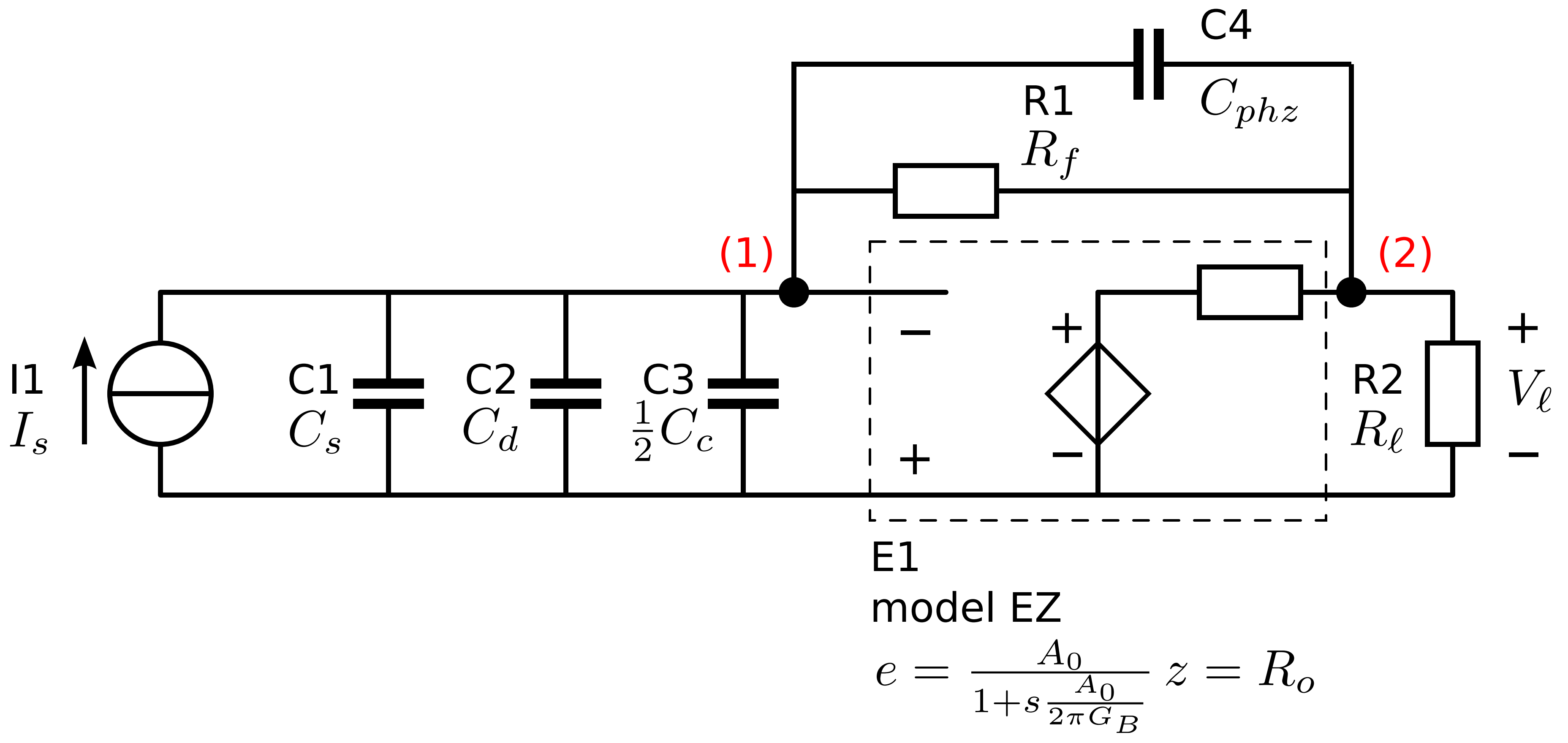
	RealPart	ImagPart	Frequency	Q
z_1	1.6291e+08	0	1.6291e+08	0
z_2	-1.6383e+08	0	1.6383e+08	0

Example 12.8

Transimpedance with phantom zero
in feedback network:

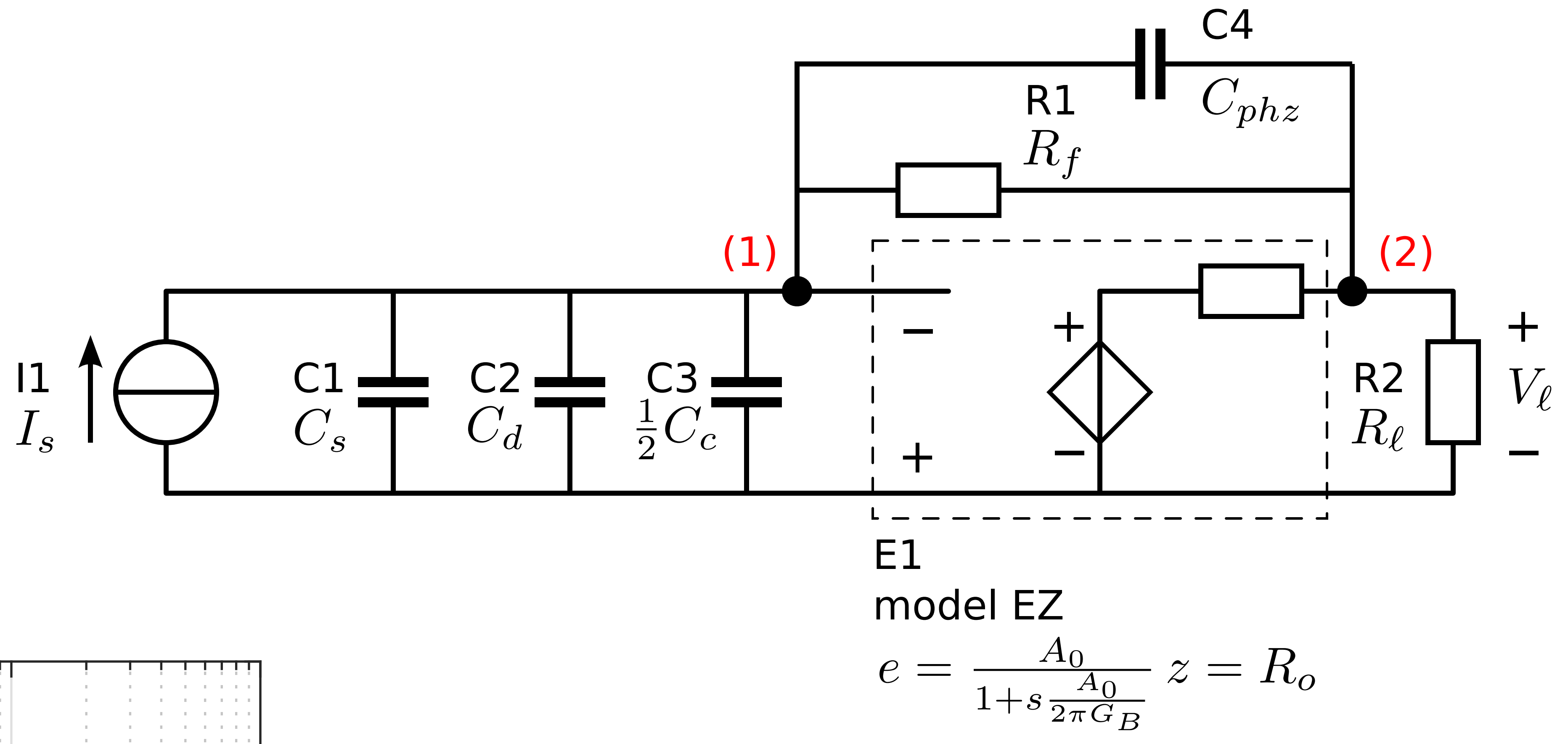
Example 12.8

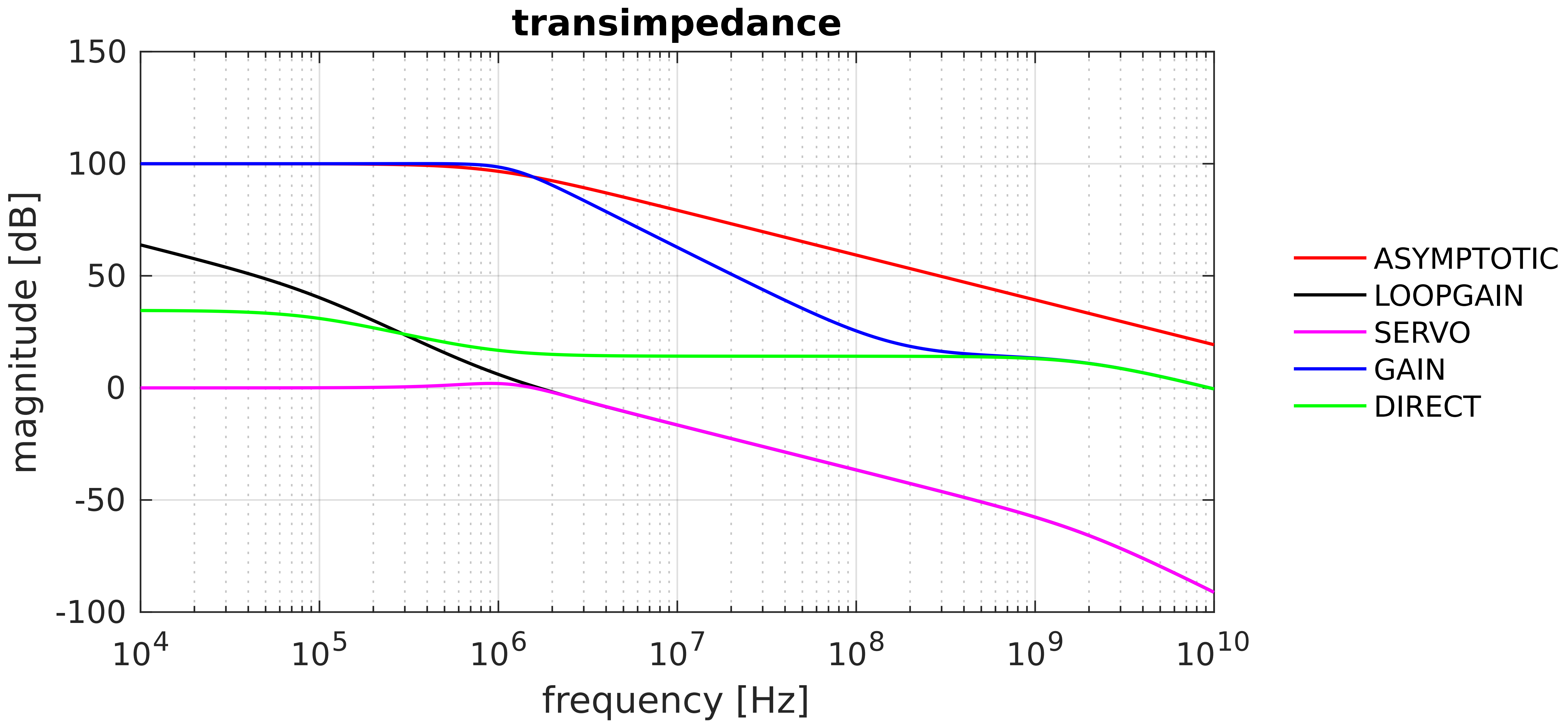
Transimpedance with phantom zero in feedback network:



Example 12.8

Transimpedance with phantom zero in feedback network:



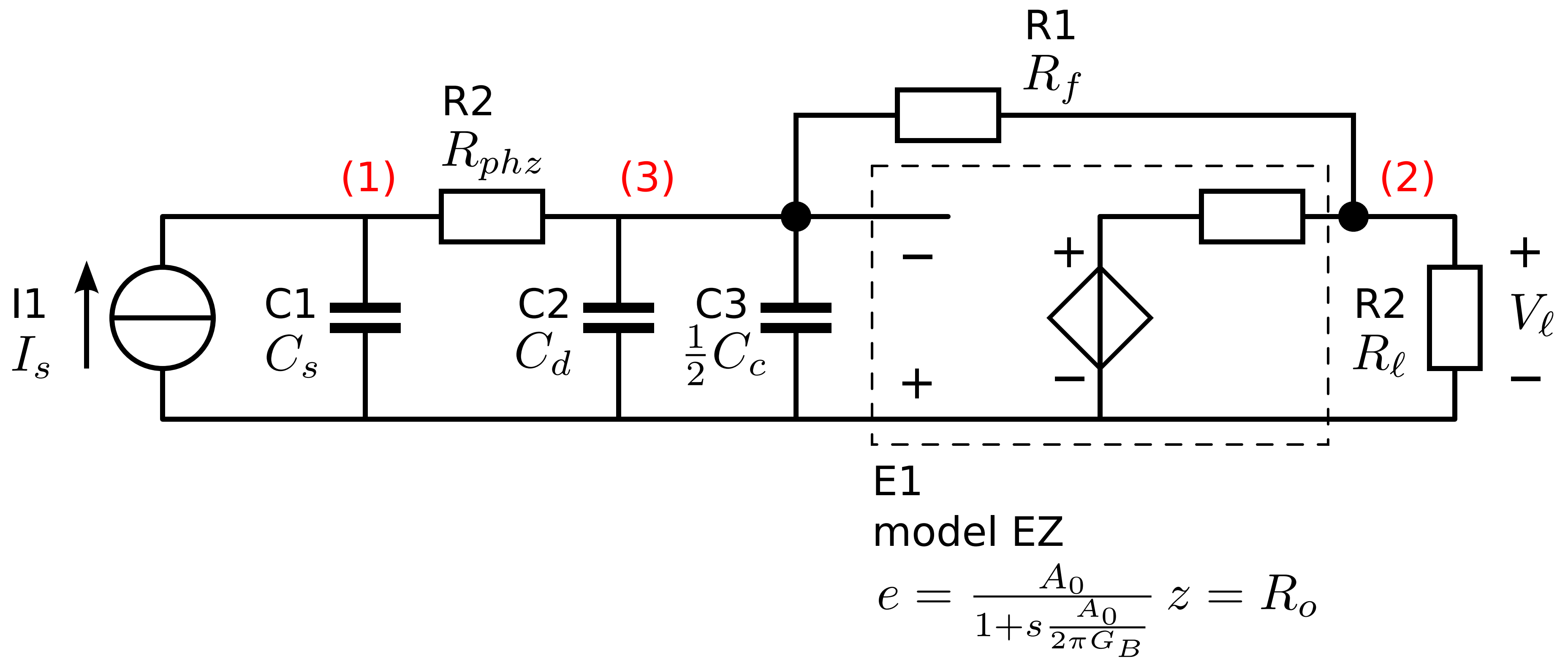


Example 12.9

Transimpedance with phantom zero
at the source:

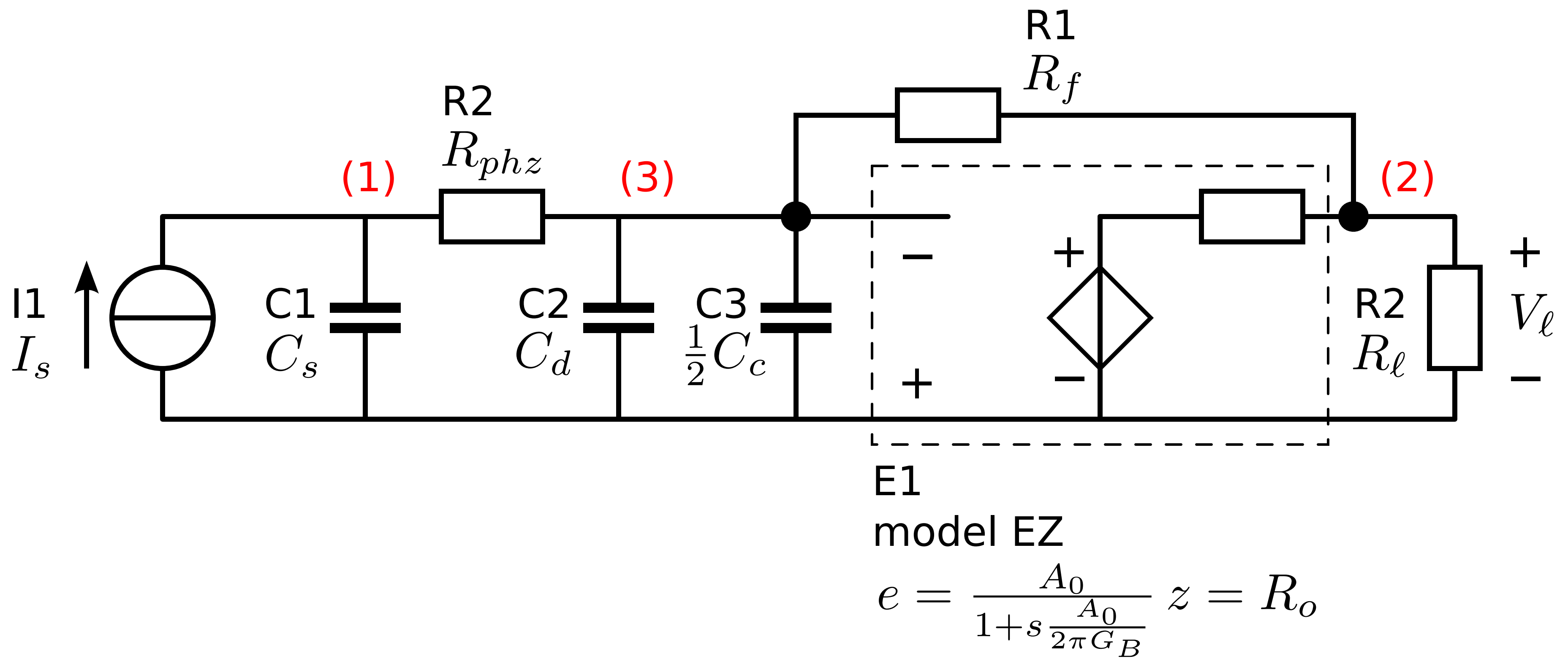
Example 12.9

Transimpedance with phantom zero at the source:



Example 12.9

Transimpedance with phantom zero at the source:




```
LOOPGAIN, R_phz=34.7k
DC value = -9.732e+05
Poles:
```

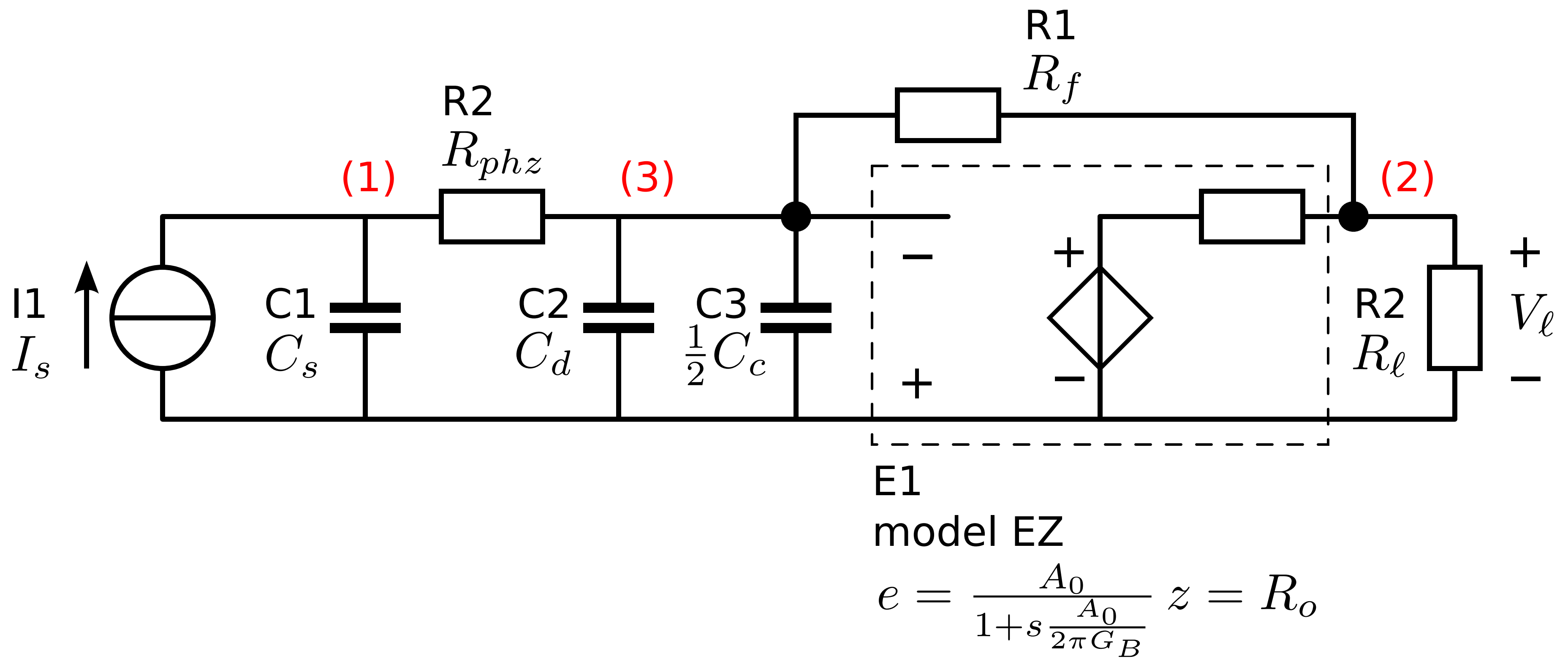
	RealPart	ImagPart	Frequency	Q
p_1	-16	0	16	0
p_2	-93212	0	93212	0
p_3	-1.3614e+06	0	1.3614e+06	0

```
Zeros:
```

	RealPart	ImagPart	Frequency	Q
z_1	-9.1743e+05	0	9.1743e+05	0

Example 12.9

Transimpedance with phantom zero at the source:



LOOPGAIN, R_phz=34.7k
DC value = -9.732e+05
Poles:

	RealPart	ImagPart	Frequency	Q
p_1	-16	0	16	0
p_2	-93212	0	93212	0
p_3	-1.3614e+06	0	1.3614e+06	0

Zeros:

	RealPart	ImagPart	Frequency	Q
z_1	-9.1743e+05	0	9.1743e+05	0

GAIN, R_phz=34.7k
DC value = -1.000e+05
Poles:

	RealPart	ImagPart	Frequency	Q
p_1	-1.9697e+05	1.3506e+06	1.3649e+06	3.4647
p_2	-1.9697e+05	-1.3506e+06	1.3649e+06	3.4647
p_3	-1.0607e+06	0	1.0607e+06	0

Zeros:

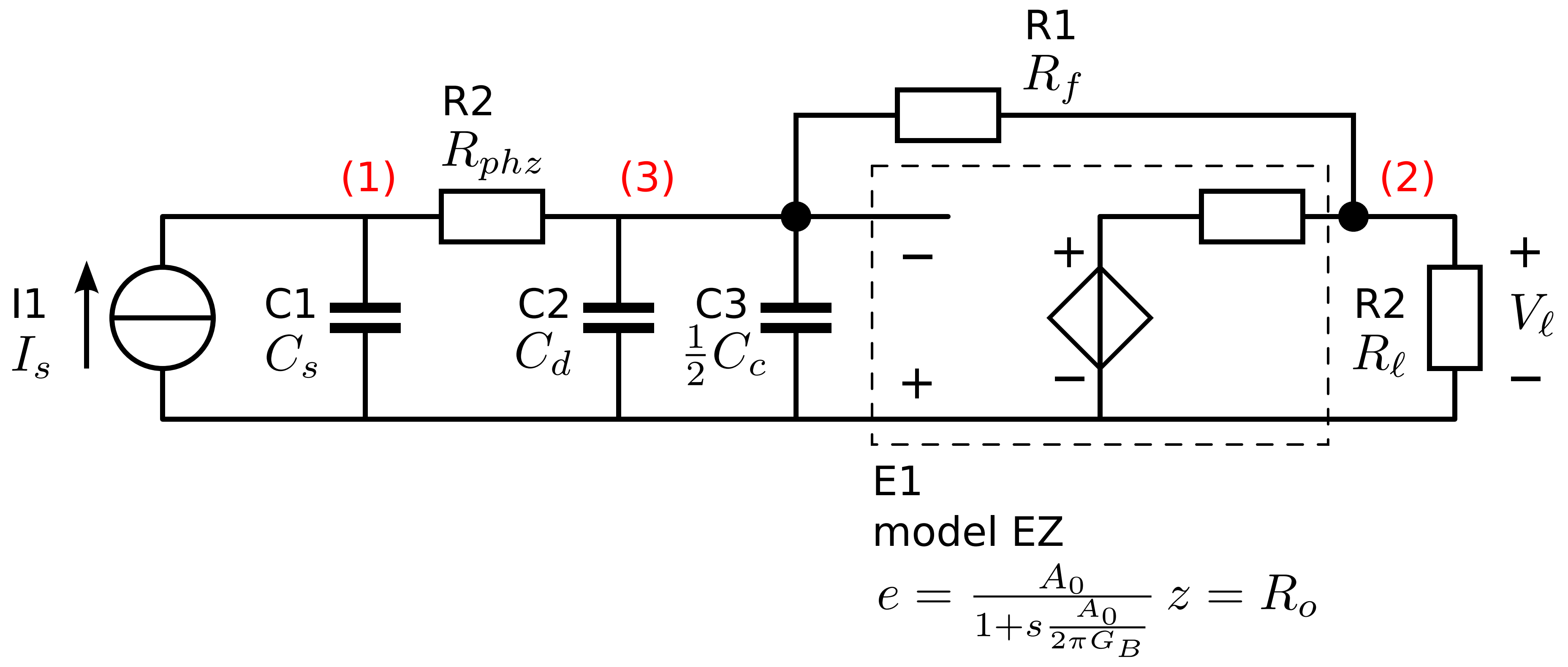
	RealPart	ImagPart	Frequency	Q
z_1	2.9091e+10	0	2.9091e+10	0

Example 12.9

Transimpedance with phantom zero at the source:

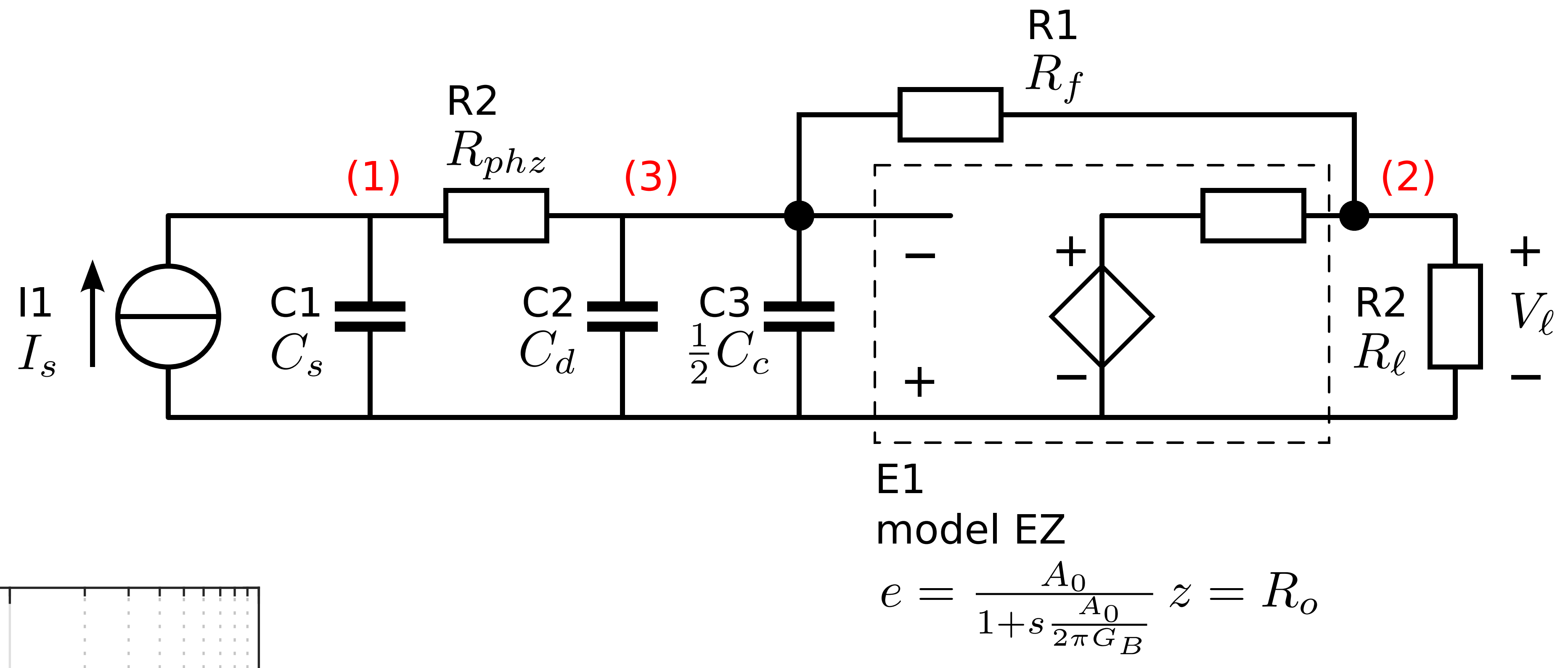
Example 12.9

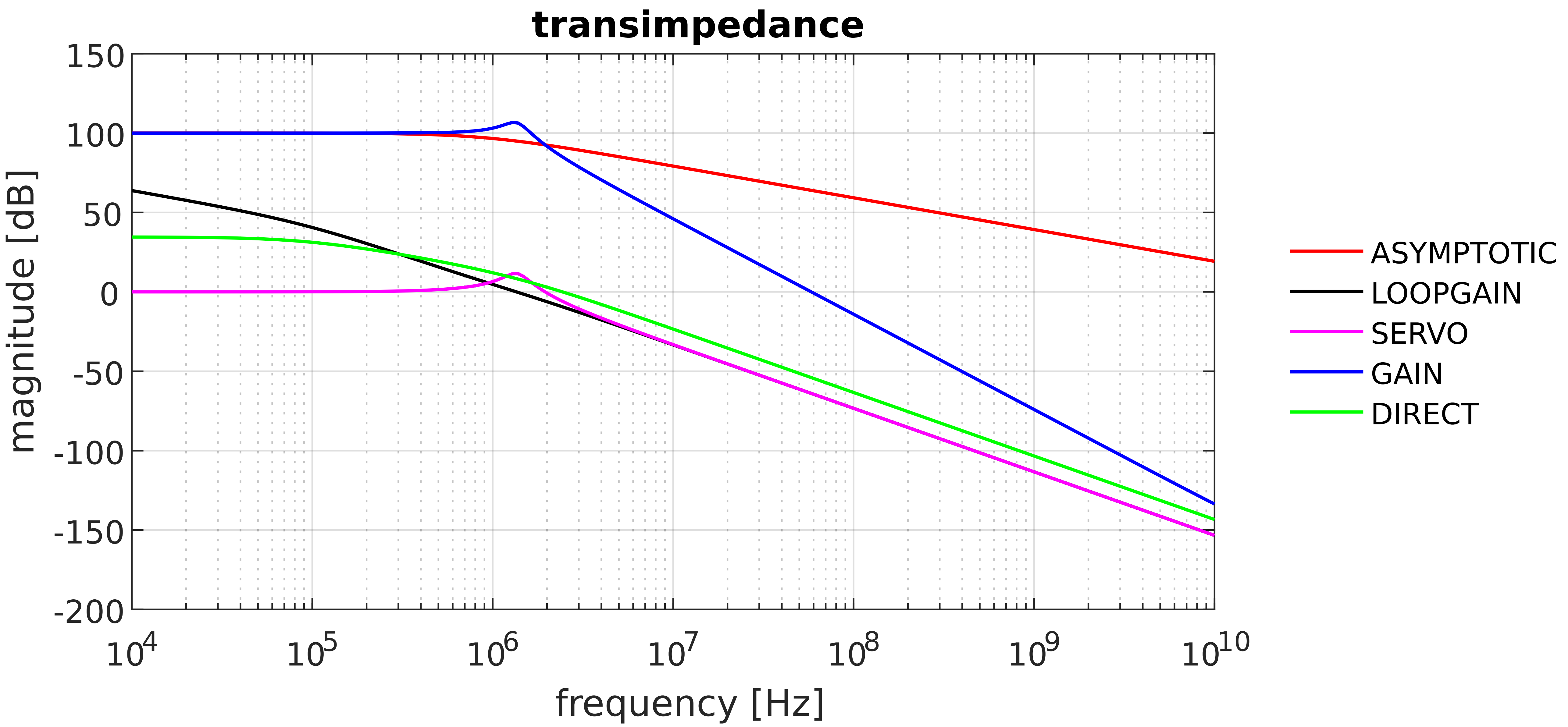
Transimpedance with phantom zero at the source:



Example 12.9

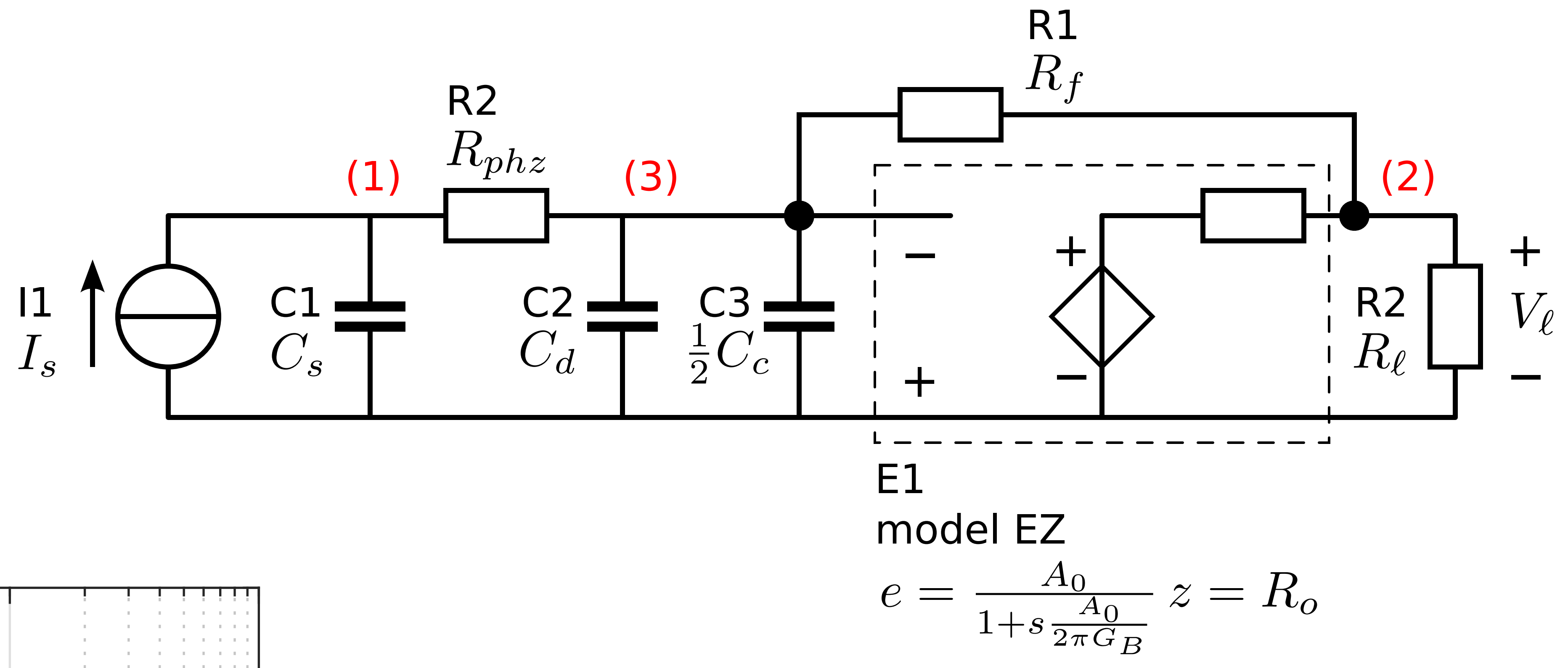
Transimpedance with phantom zero at the source:

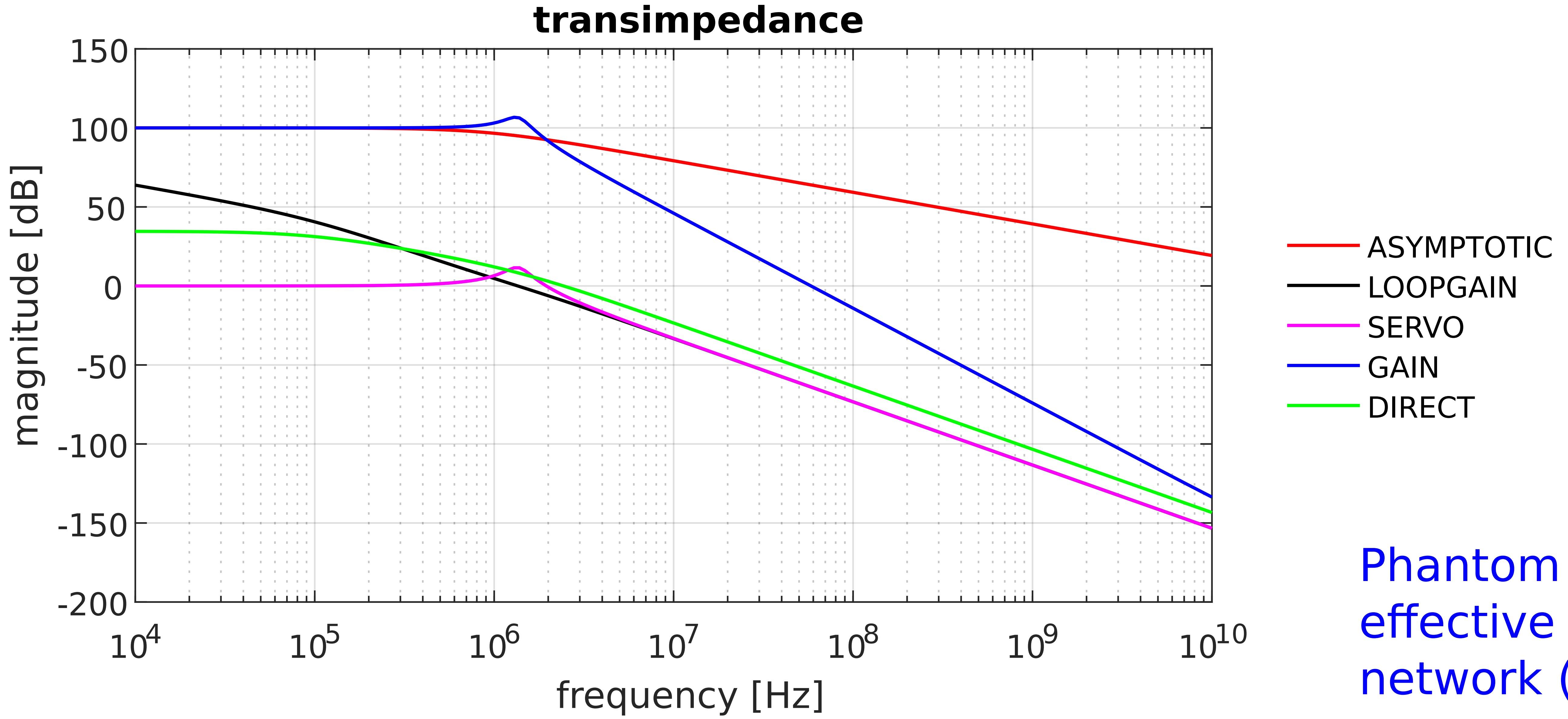




Example 12.9

Transimpedance with phantom zero at the source:

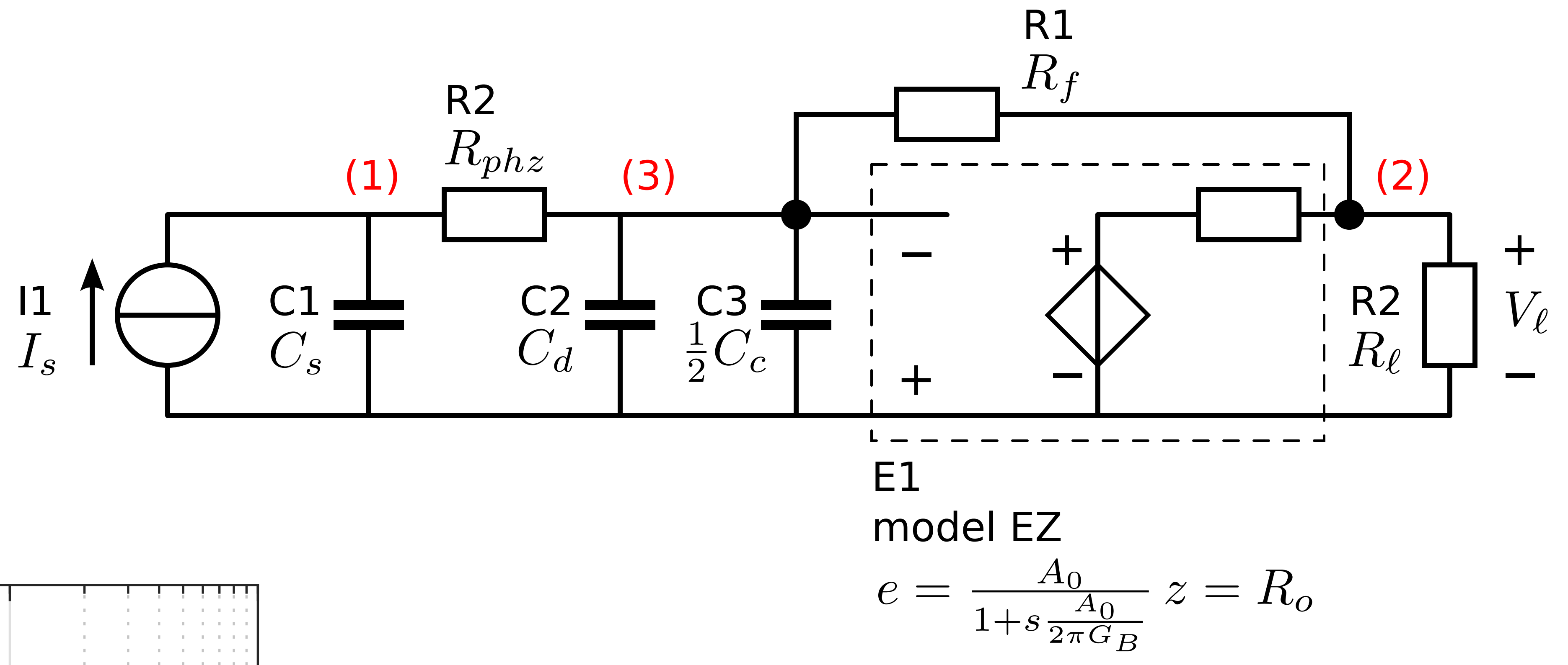


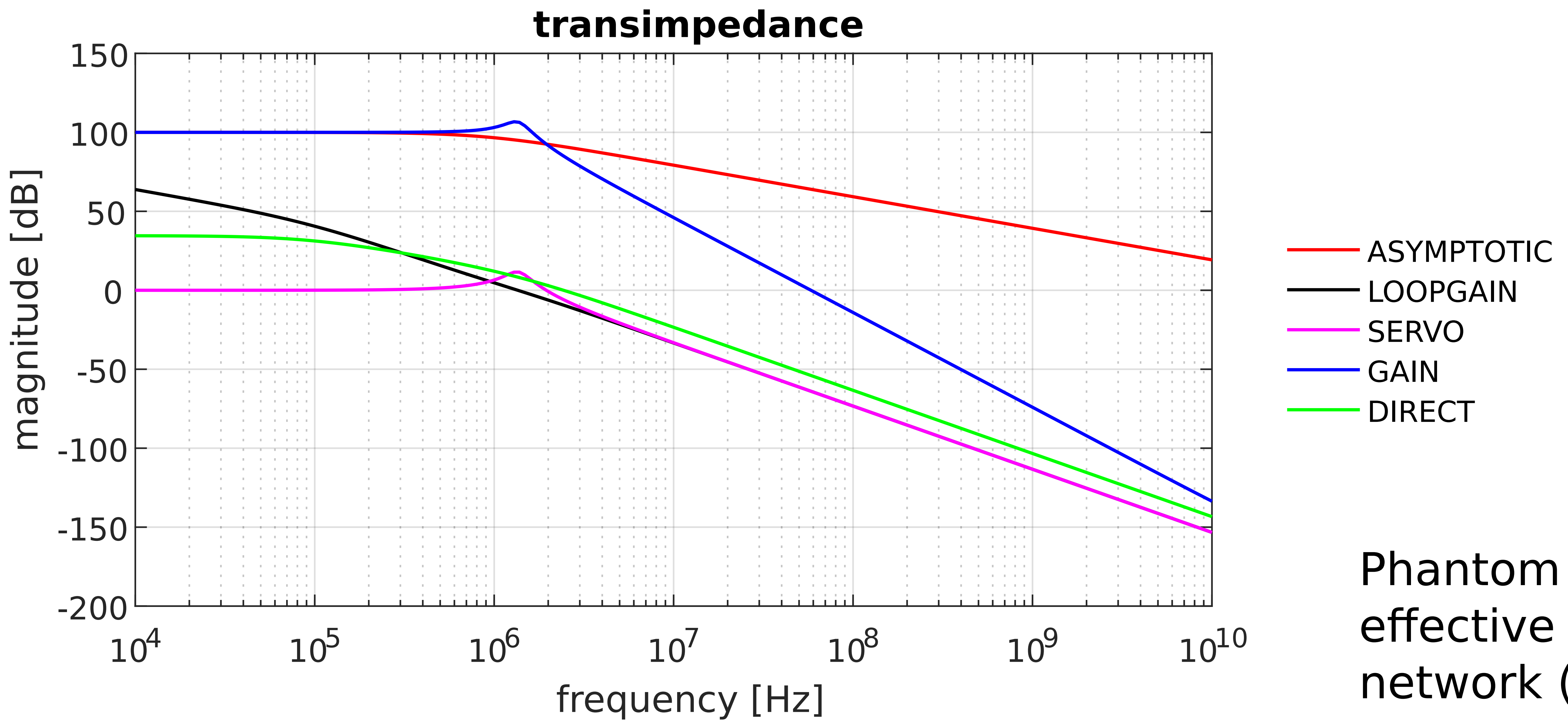


Phantom zero at the source less effective than in the feedback network (not a rule!)

Example 12.9

Transimpedance with phantom zero at the source:





Phantom zero at the source less effective than in the feedback network (not a rule!)