

Structured Electronic Design

Design of low-noise feedback amplifier configurations

Negative feedback: a powerful error reduction technique

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Study the noise behavior of nonenergetic and passive feedback amplifiers

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- Find rules for low-noise design

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- Model the controller as a noisy nullor

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This enables orthogonal design of the noise behavior
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Negative feedback: a powerful error reduction technique

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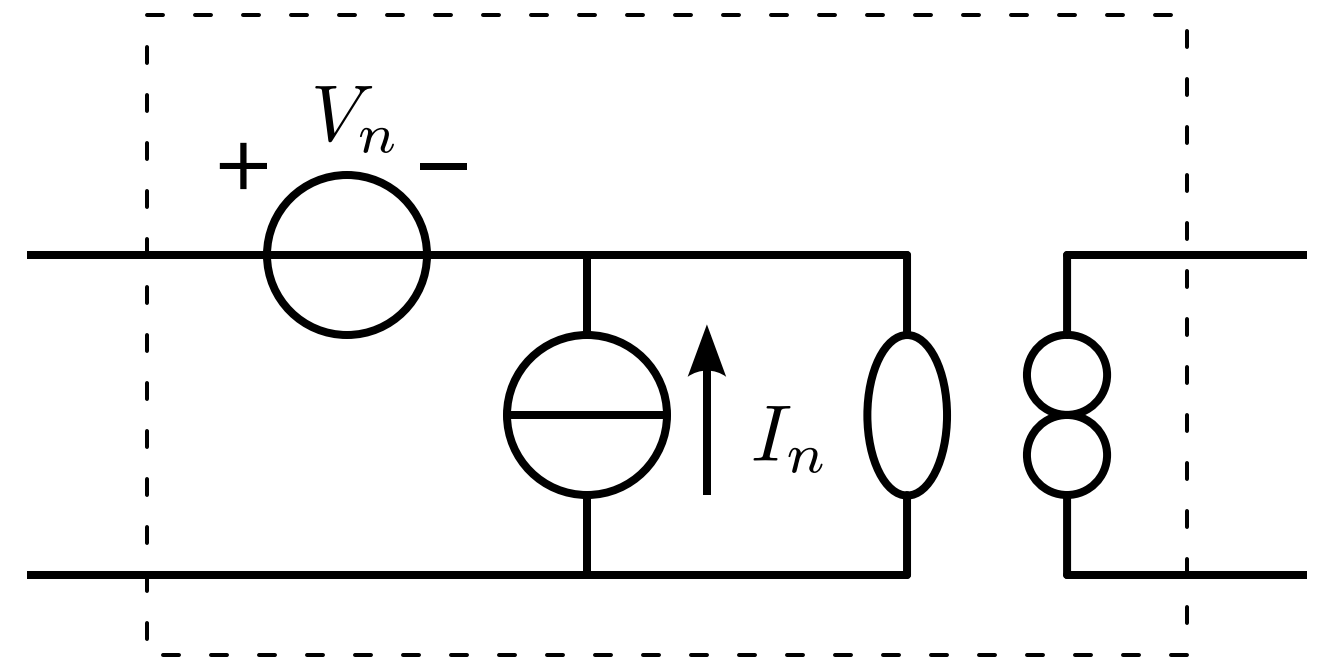
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Study the noise behavior of nonenergetic and passive feedback amplifiers

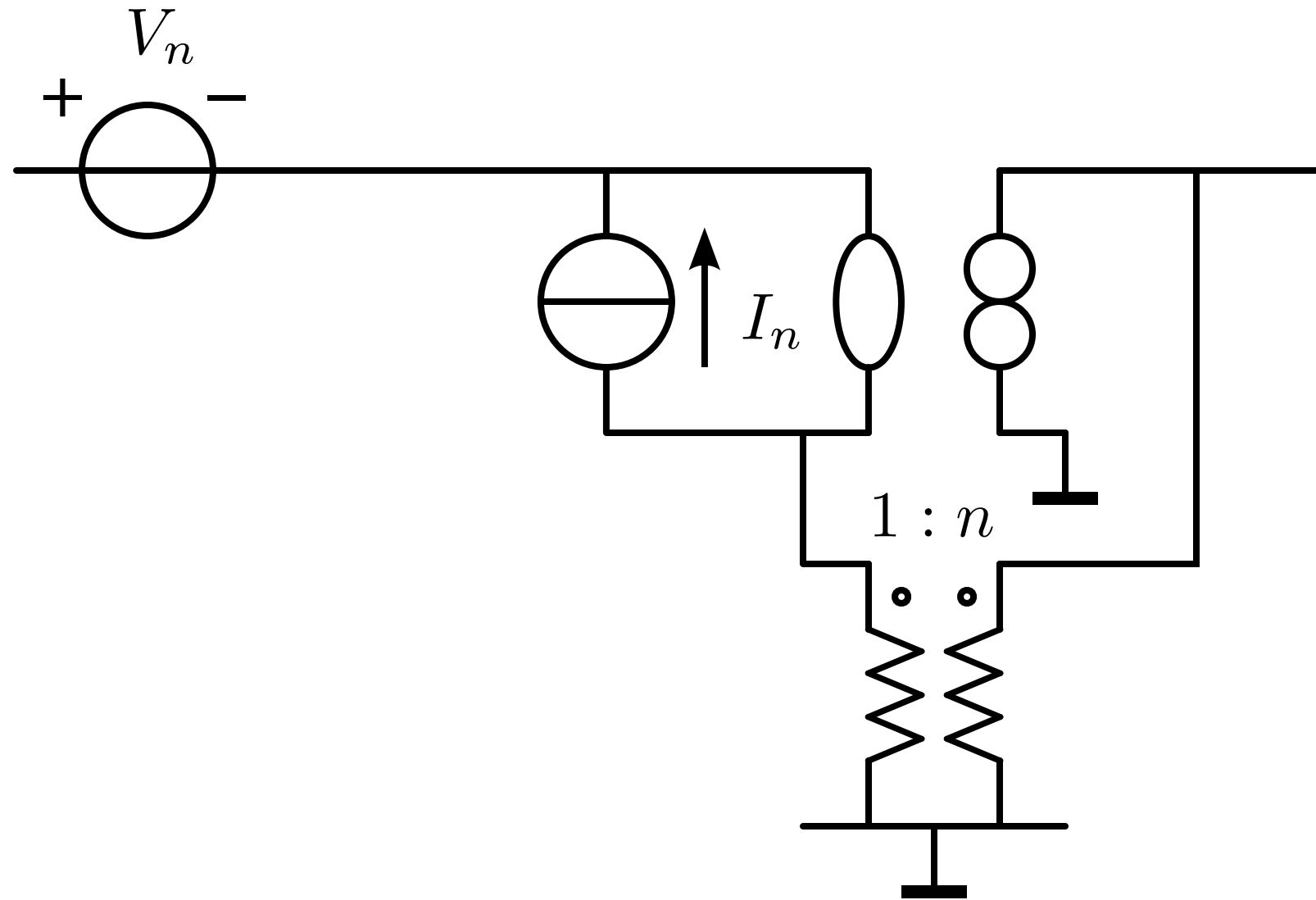
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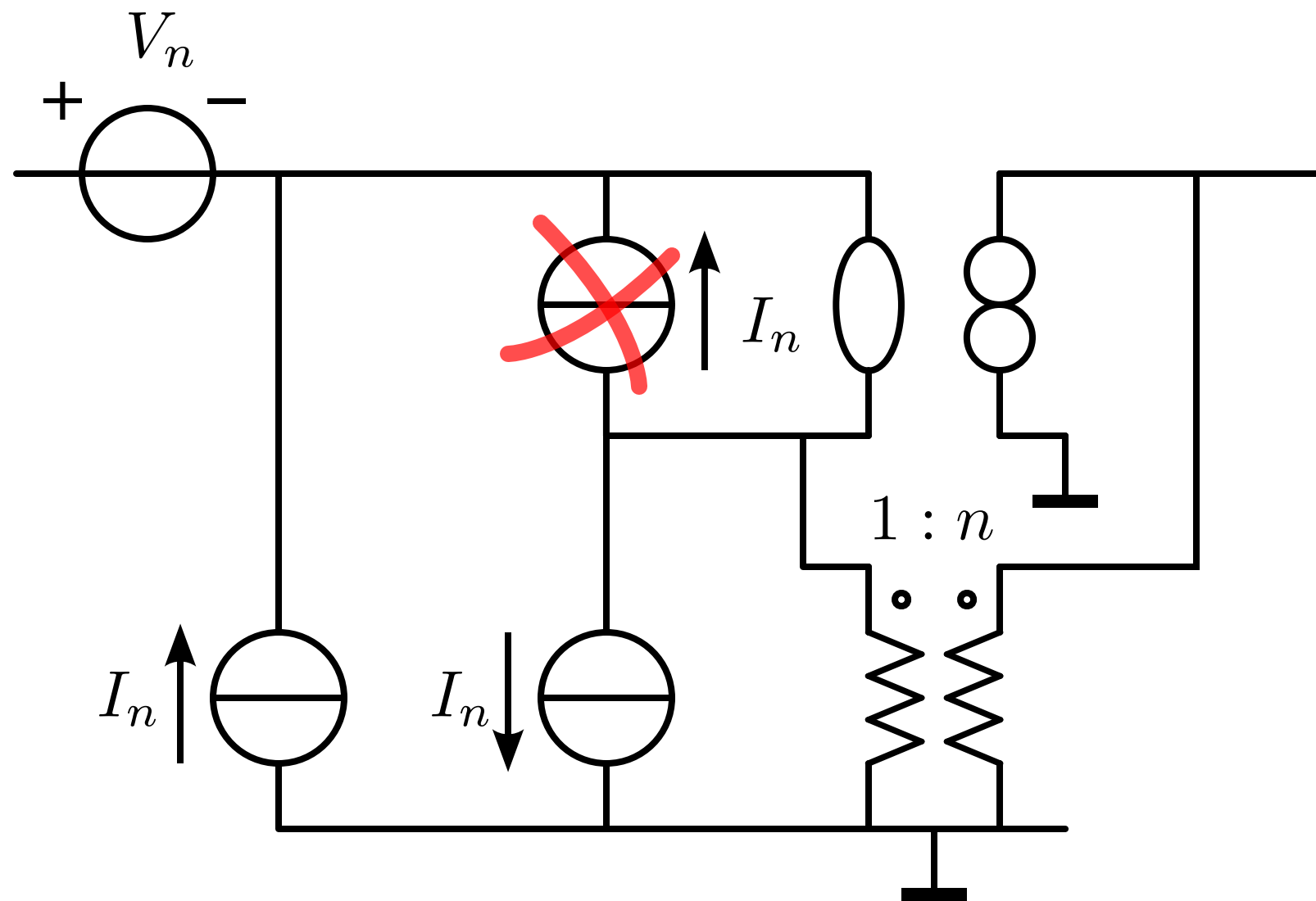


Noise performance of nonenergetic feedback amplifiers

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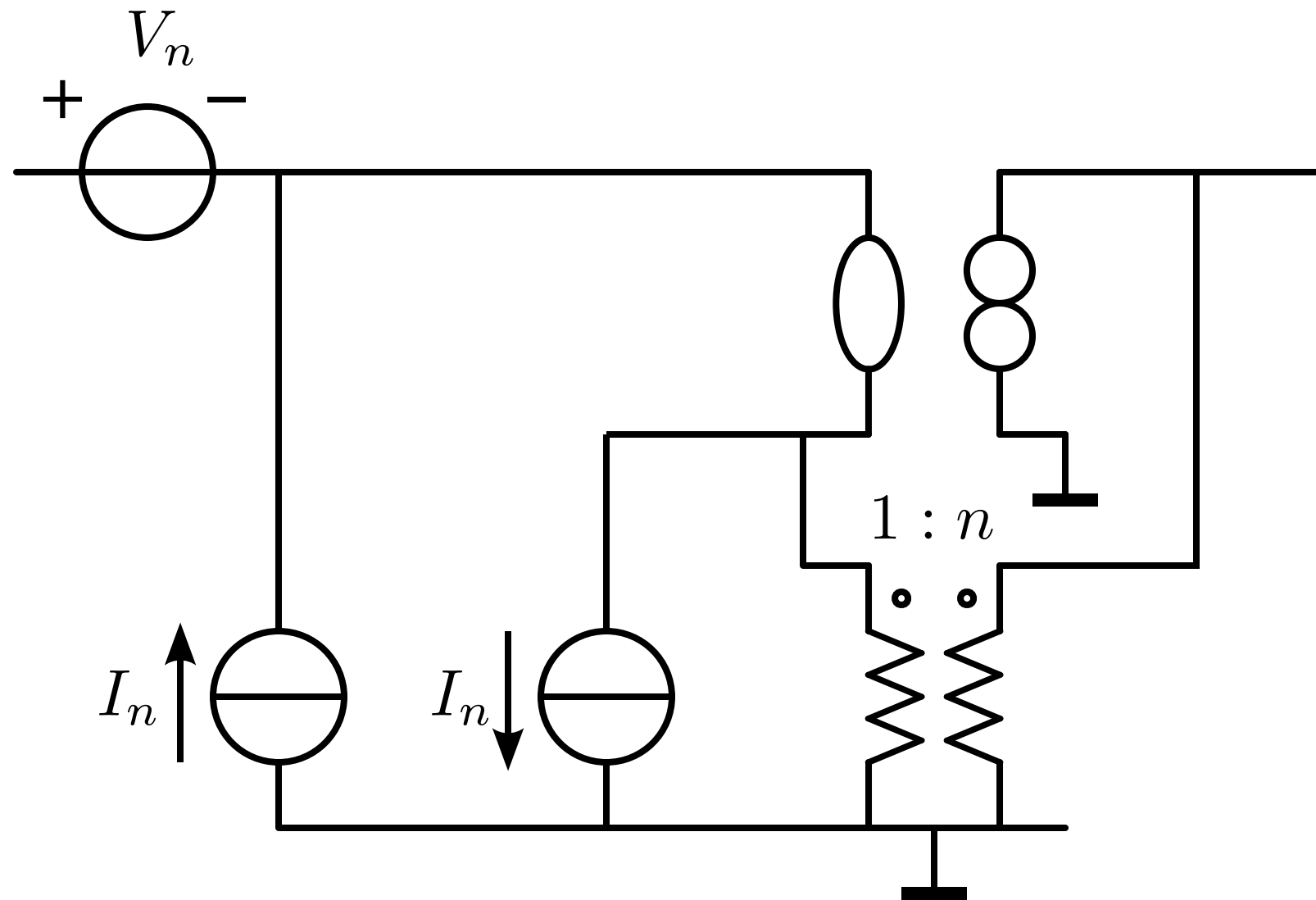


Noise performance of nonenergetic feedback amplifiers



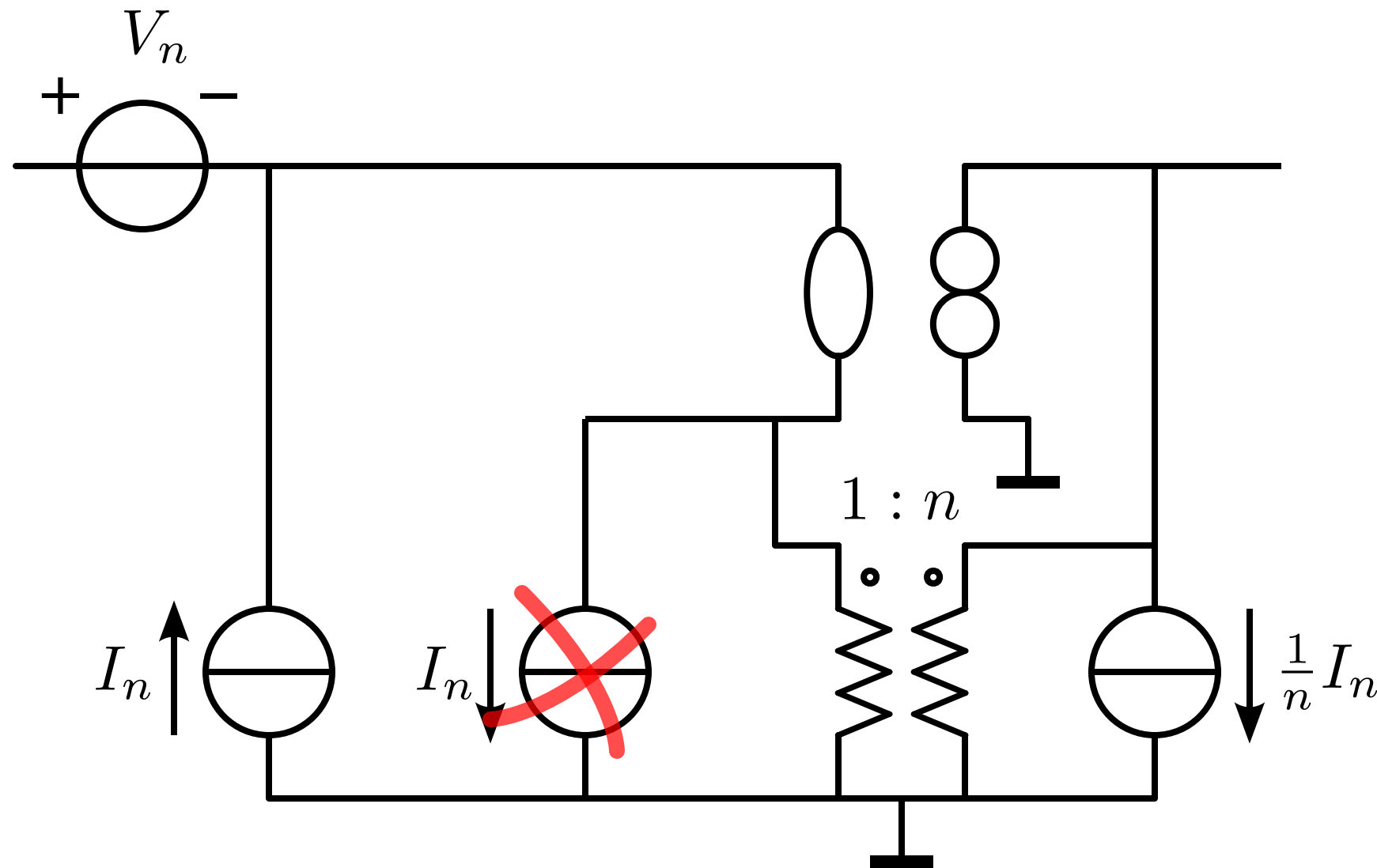
Redirect the current noise
source via ground

Noise performance of nonenergetic feedback amplifiers



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Noise performance of nonenergic feedback amplifiers

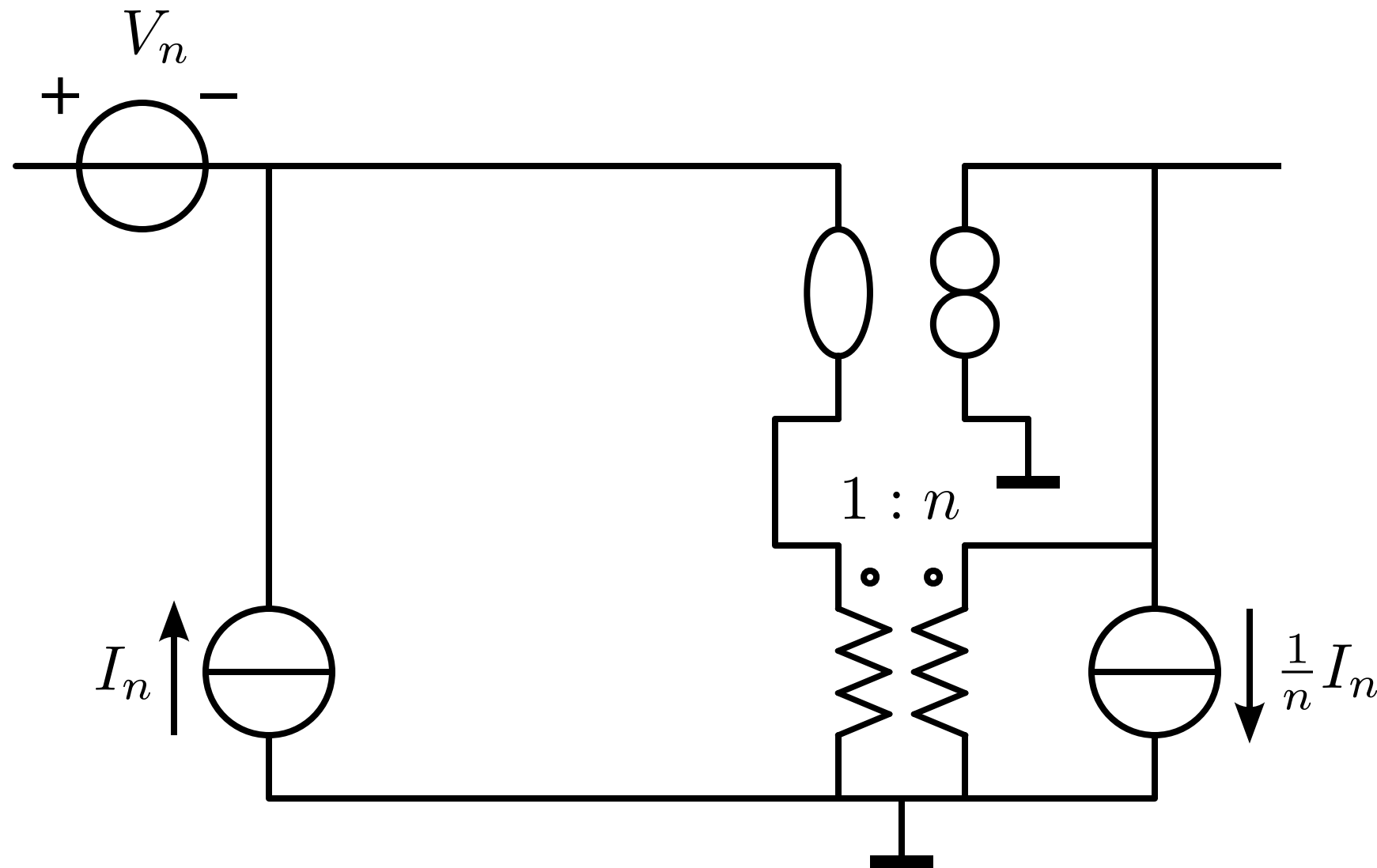


Redirect the current noise source via ground

Replace the equivalent input current noise source of the transformer with an equivalent output current noise source; use:

$$AD = 1, B = C = 0$$

Noise performance of nonenergic feedback amplifiers

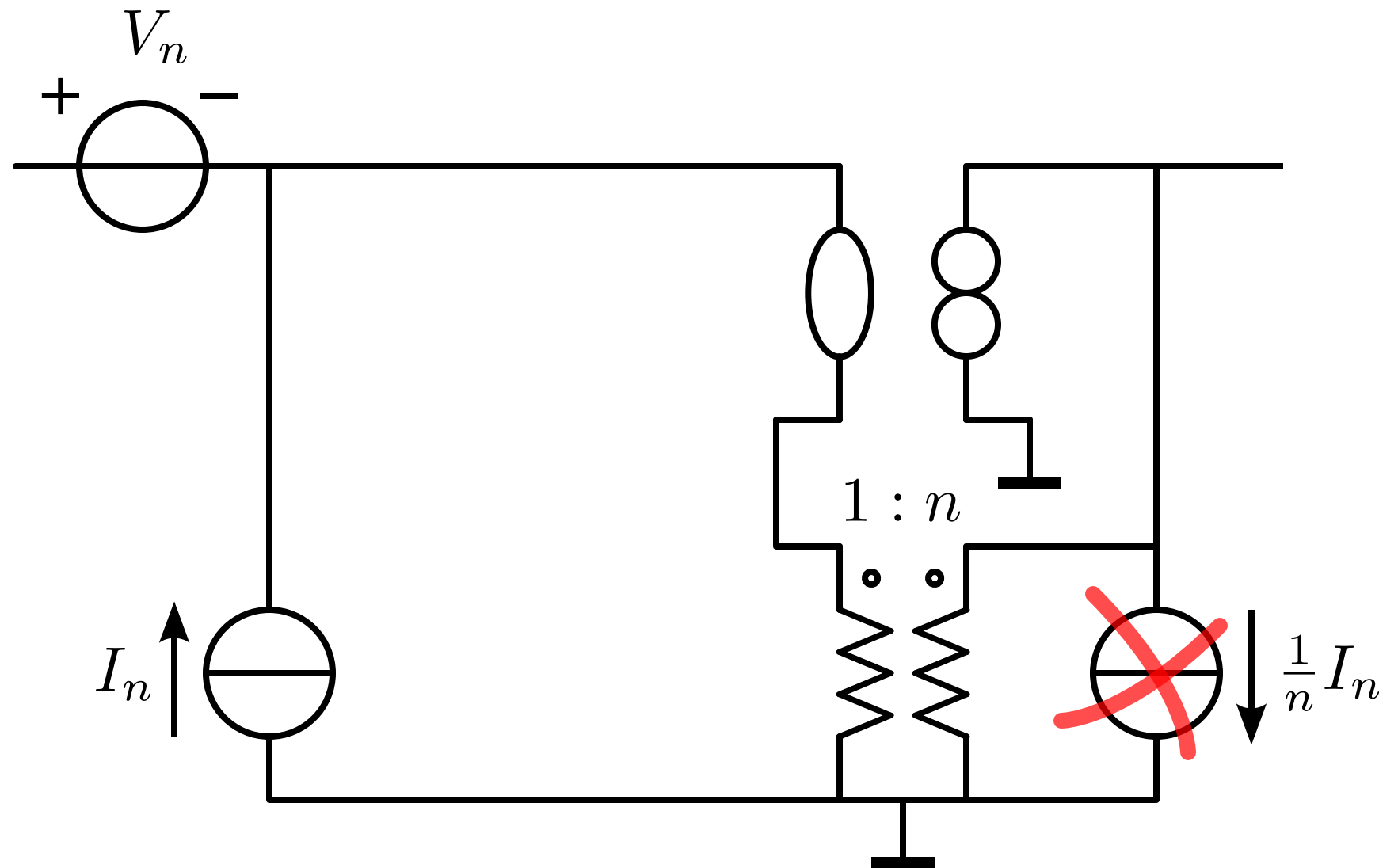


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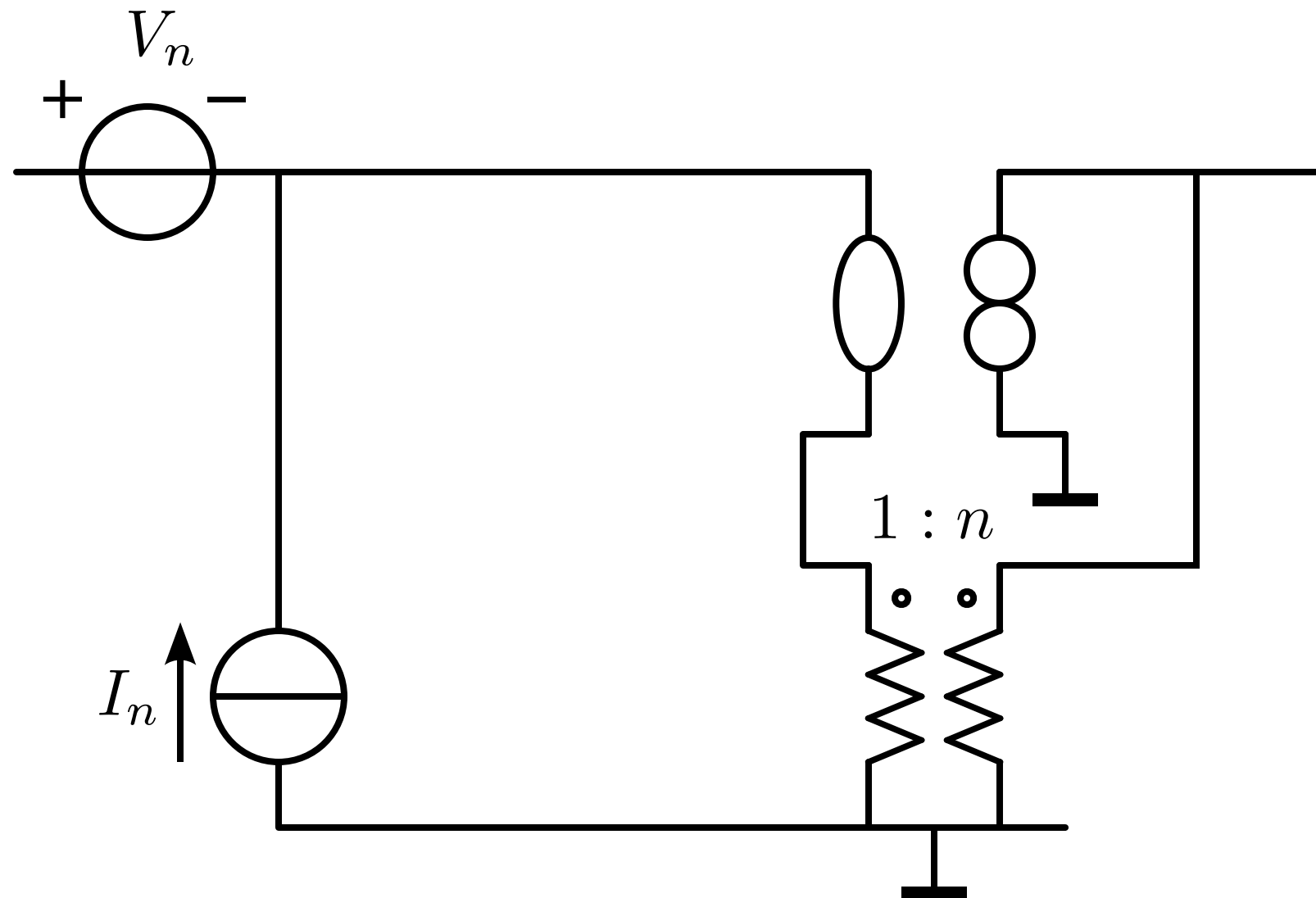
Replace the equivalent input current noise source of the transformer with an equivalent output current noise source; use:

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The current source in parallel with the output of the nullor can be ignored. Replacing it with equivalent input sources yields zero because:

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Noise performance of nonenergetic feedback amplifiers



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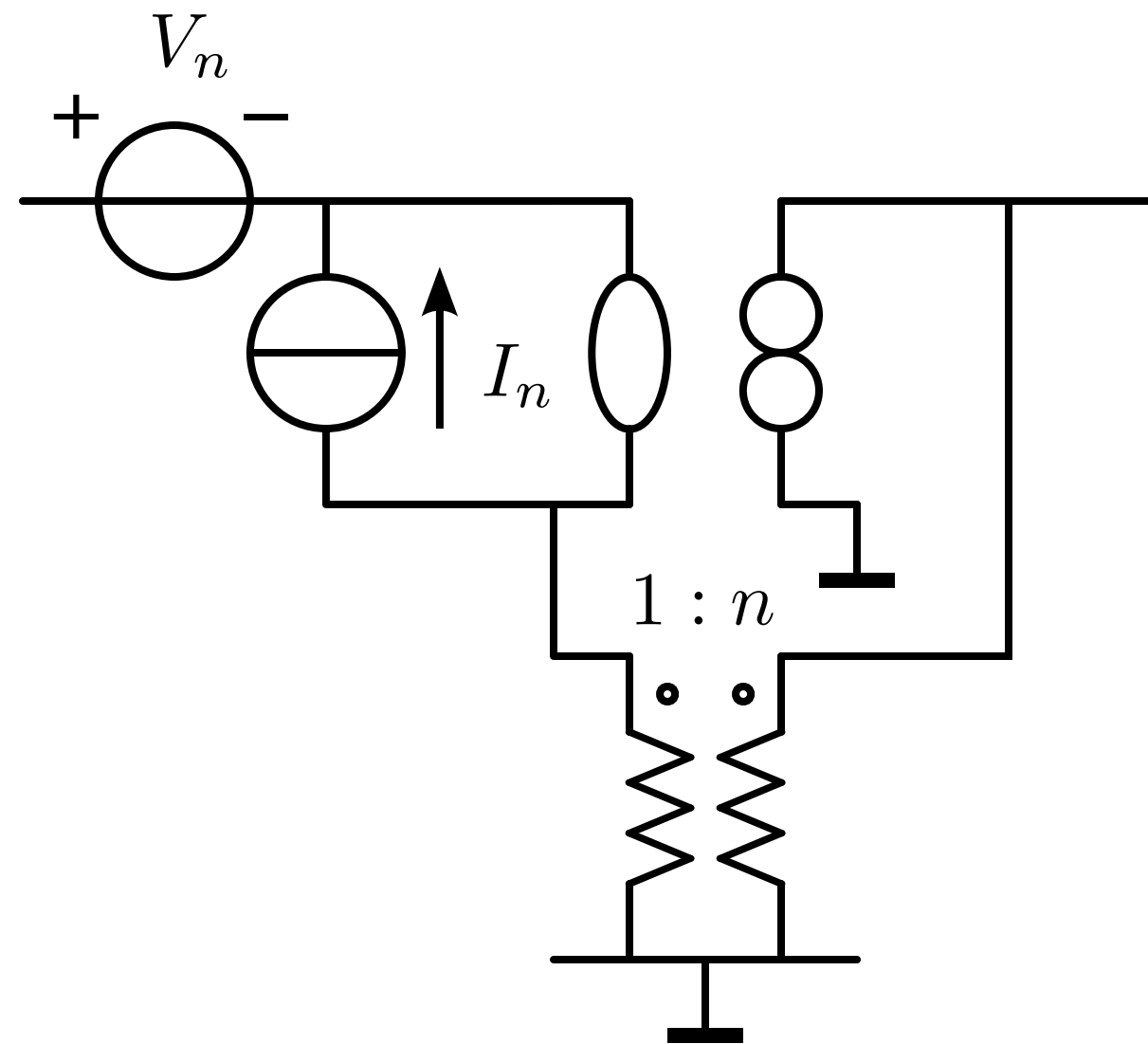
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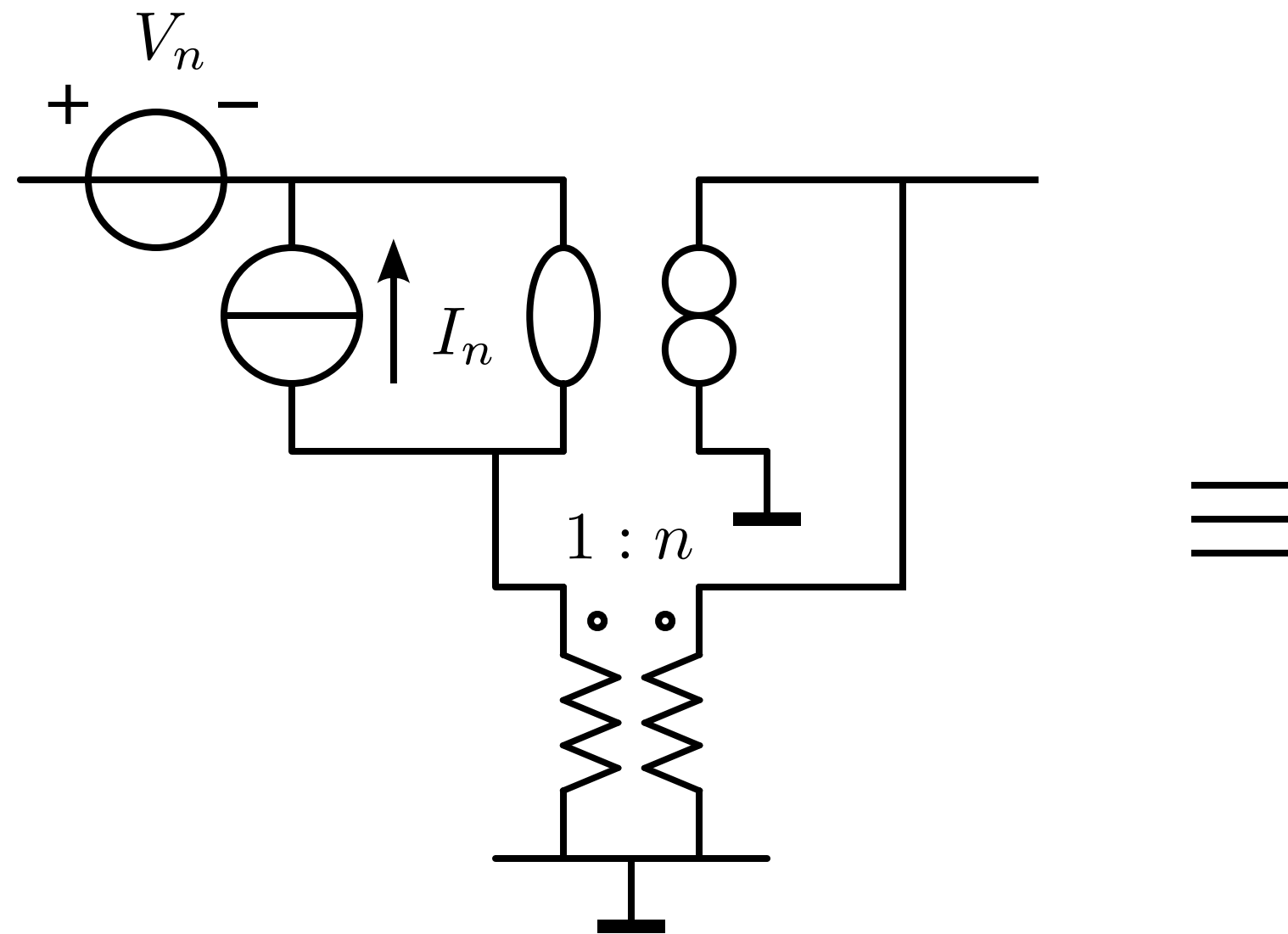
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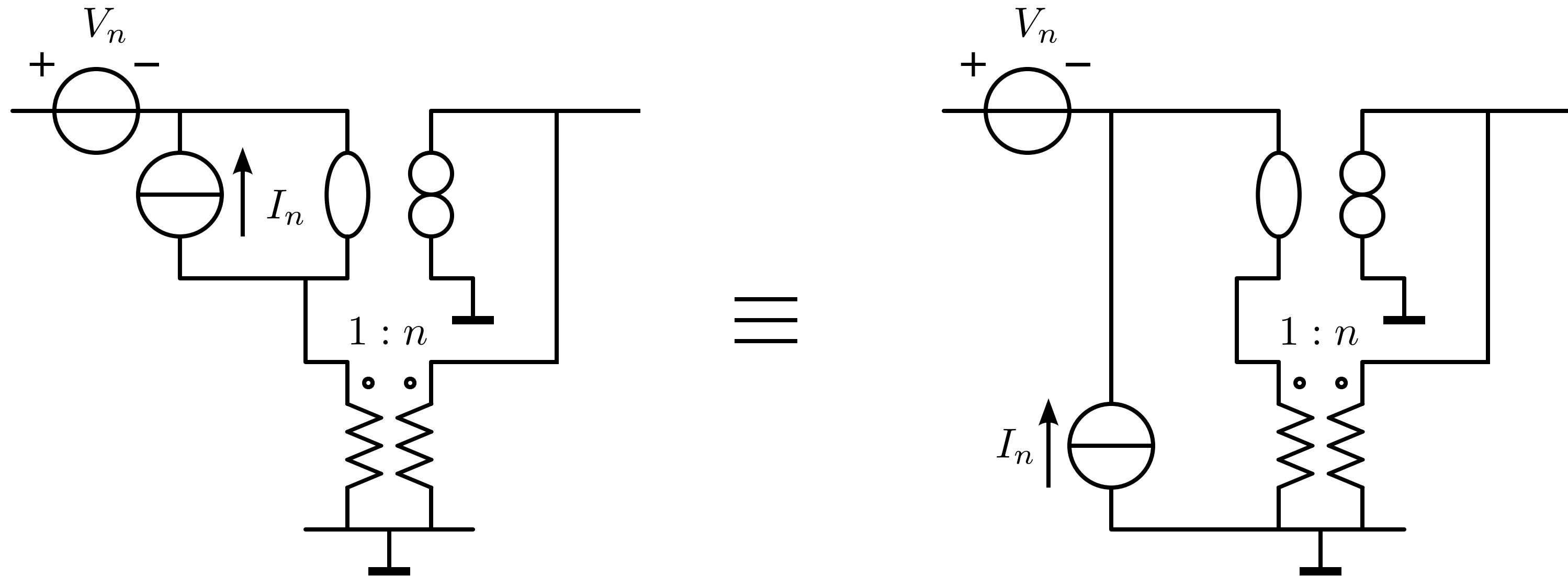
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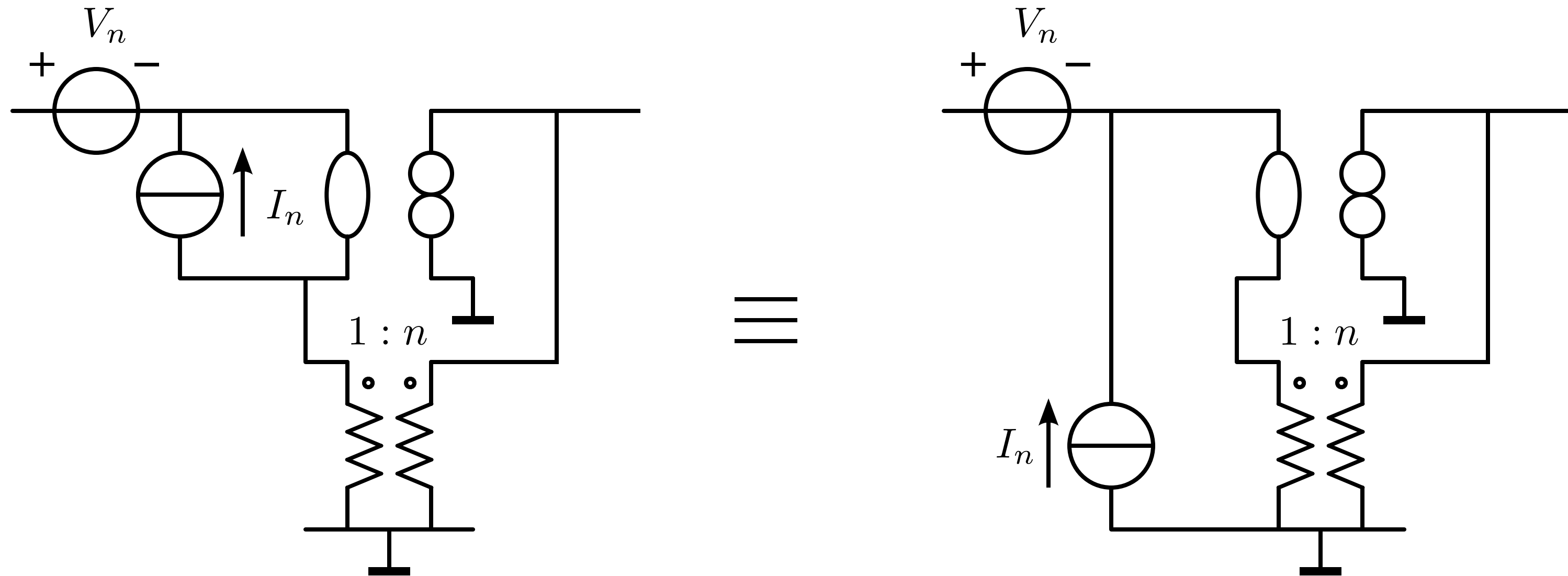
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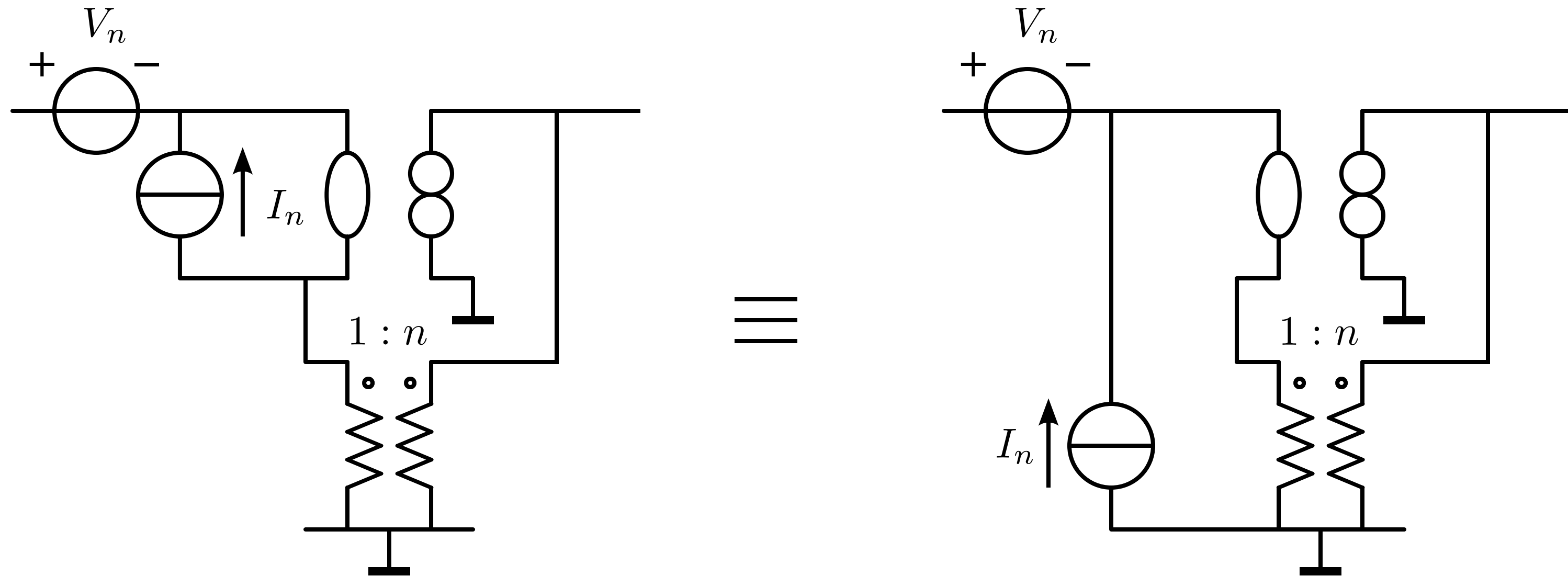


Noise performance of nonenergetic feedback amplifiers



The equivalent input noise sources of a nonenergetic feedback amplifier are equal to those of its controller

Noise performance of nonenergetic feedback amplifiers



The equivalent input noise sources of a nonenergetic feedback amplifier are equal to those of its controller

Noise performance of passive feedback amplifiers

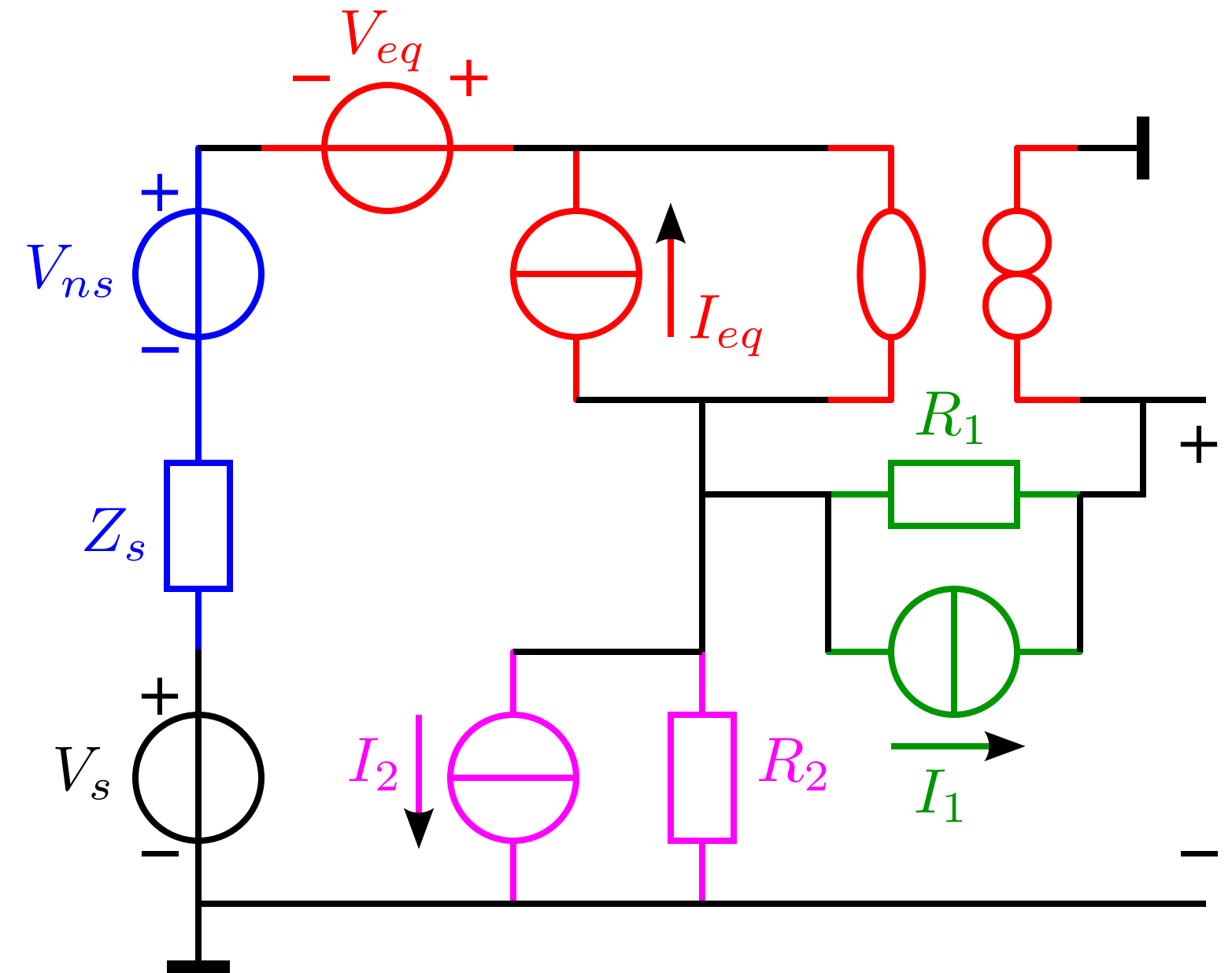
Noise performance of passive feedback amplifiers

Study the noise performance of
passive feedback voltage amplifier

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Use an alternative method:

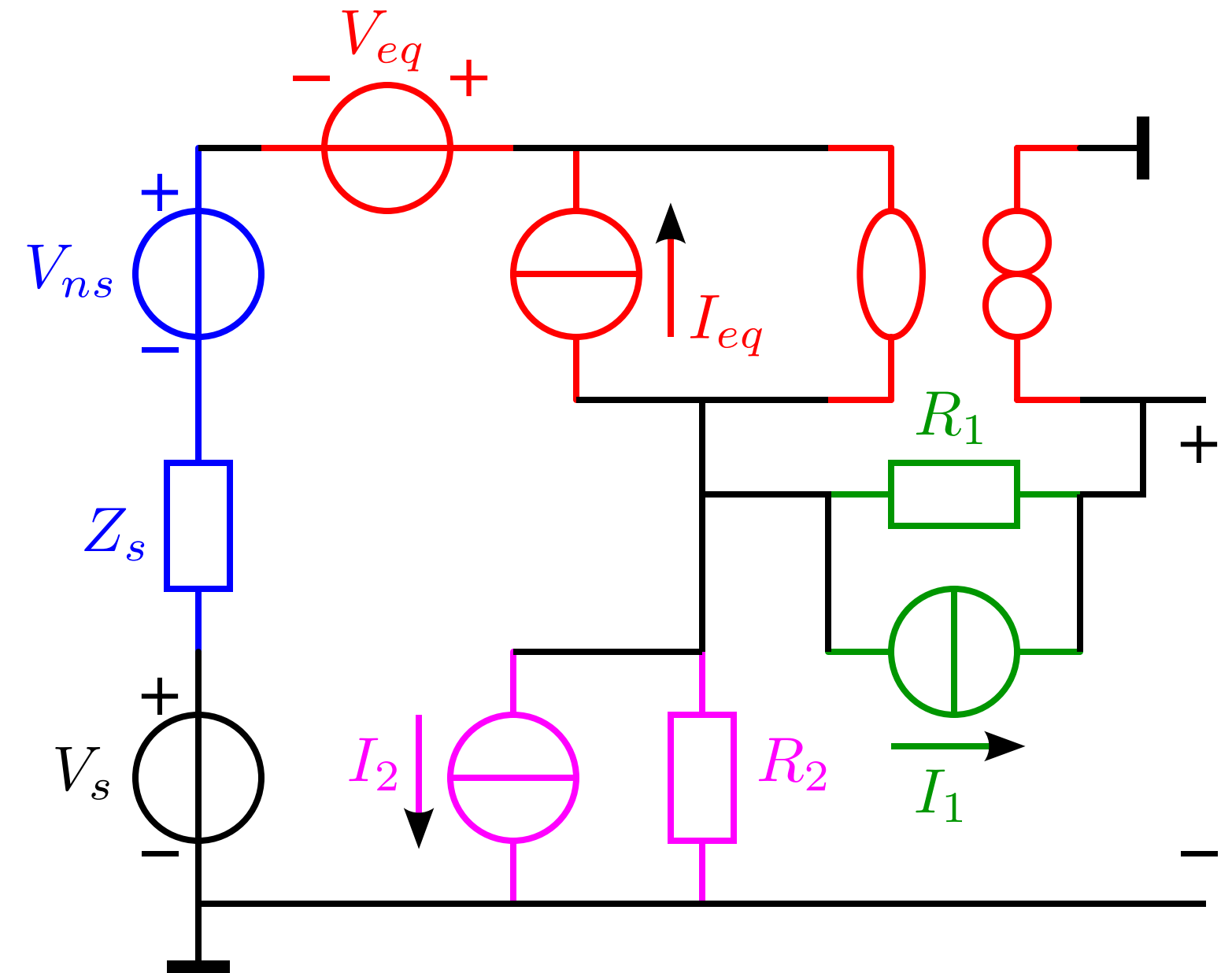


Noise performance of passive feedback amplifiers

Study the noise performance of passive feedback voltage amplifier

Use an alternative method:

1. Determine contribution of each noise source to output noise spectral density

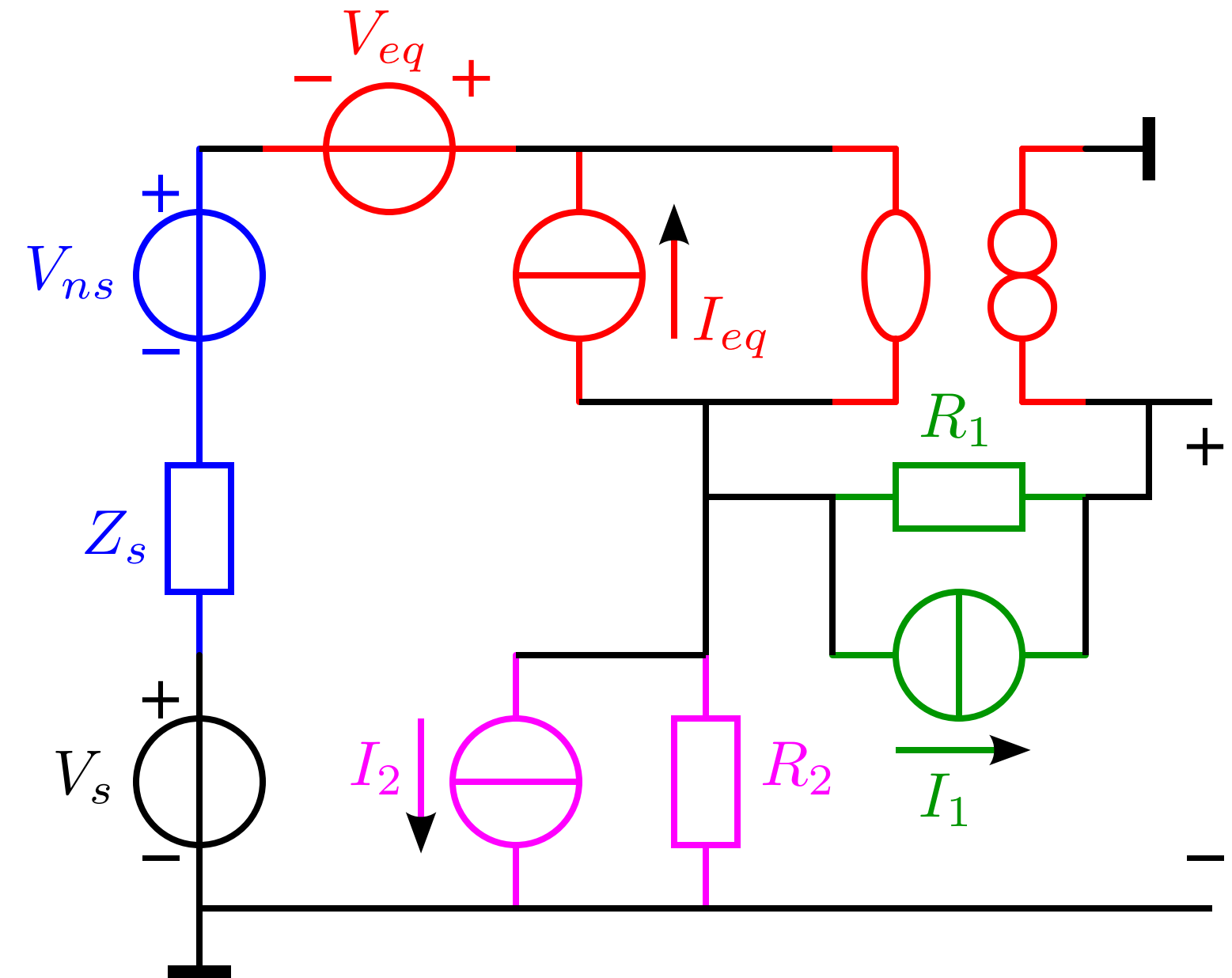


Noise performance of passive feedback amplifiers

Study the noise performance of passive feedback voltage amplifier

Use an alternative method:

1. Determine contribution of each noise source to output noise spectral density
2. Multiply this with the reciprocal value of the source-to-load transfer to obtain the contribution to the source-referred noise spectral density

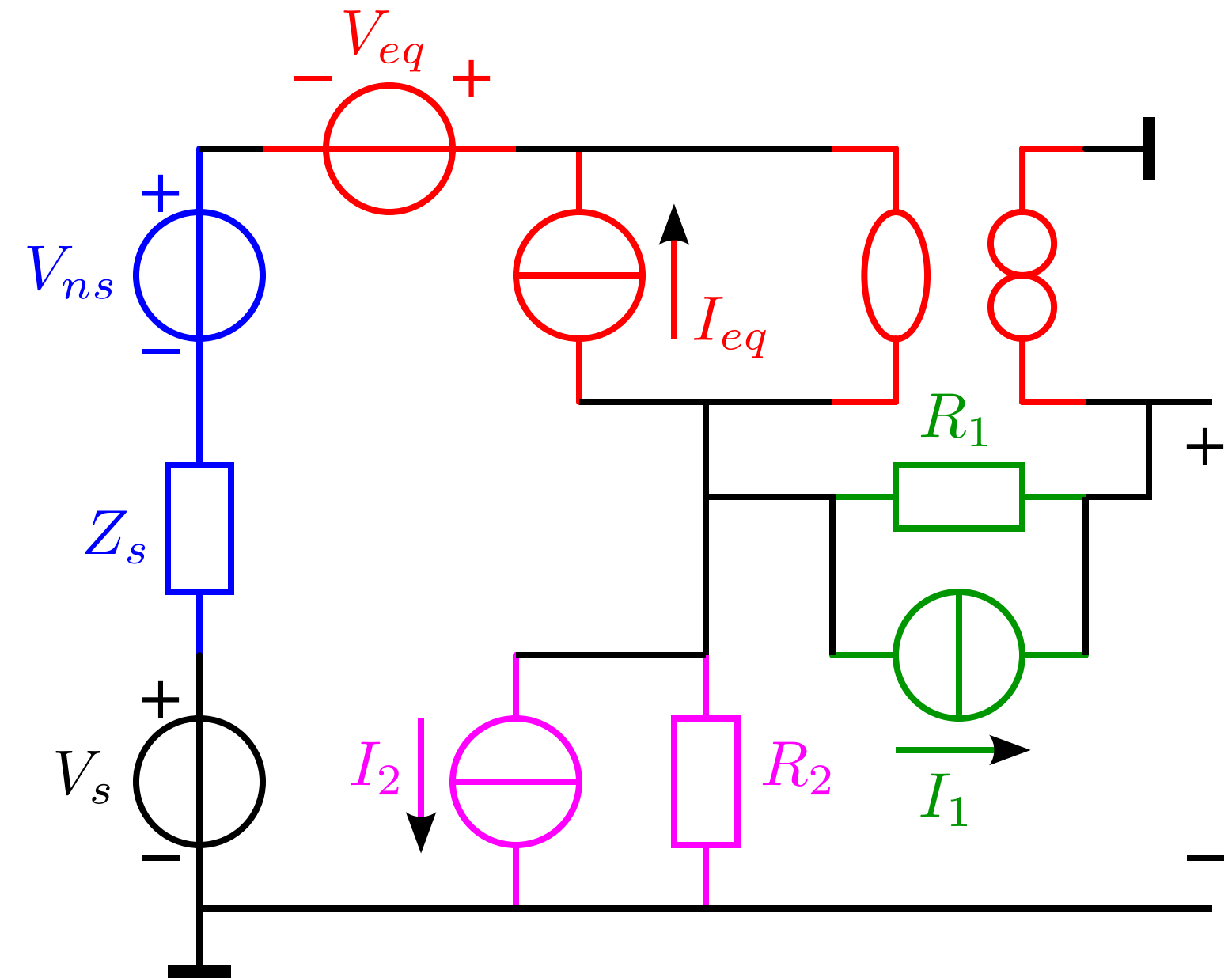


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3. Sum all contributions to these spectral densities to obtain the total source-referred and the total detector-referred noise spectra

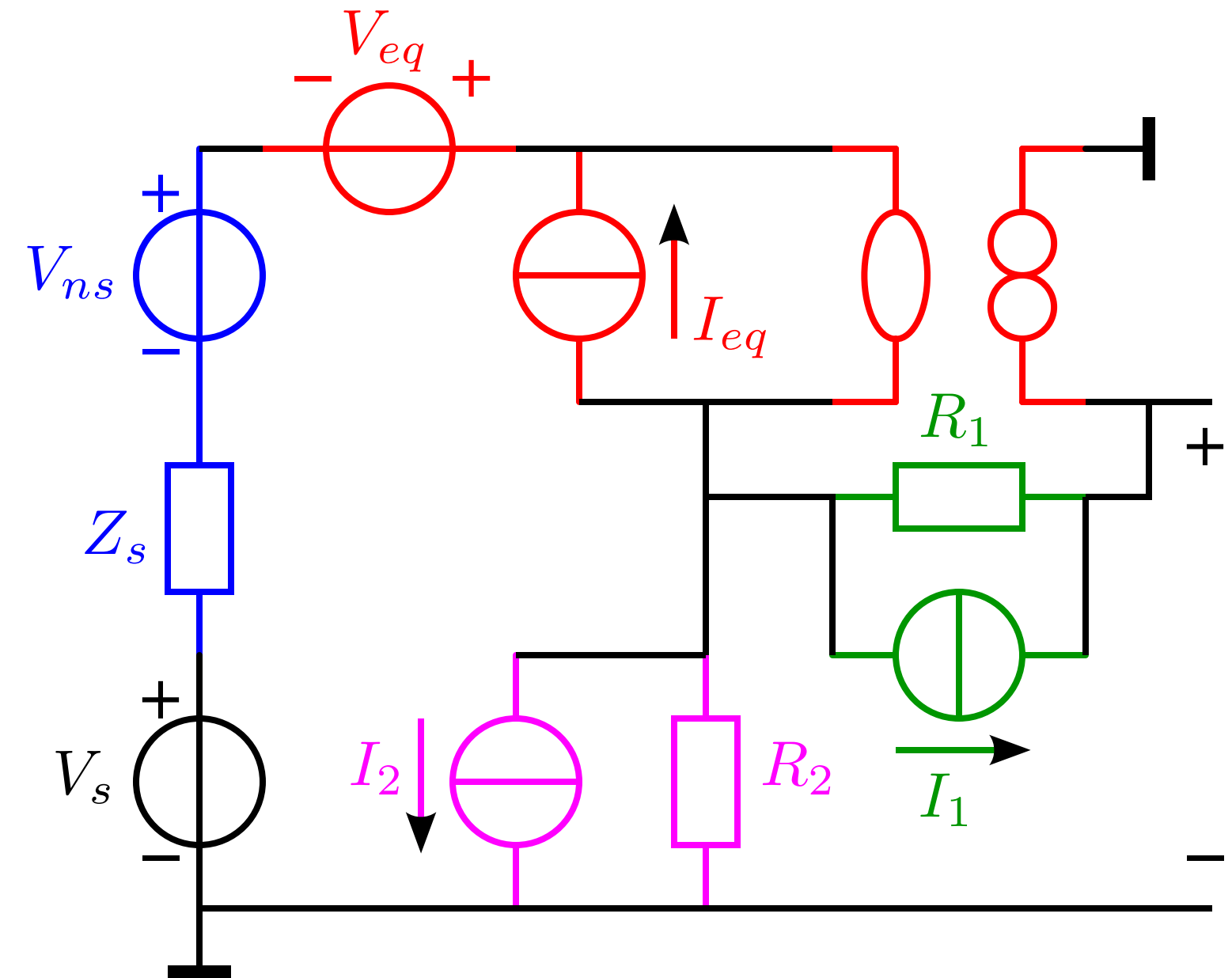


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Noise performance of passive feedback amplifiers

Contribution of

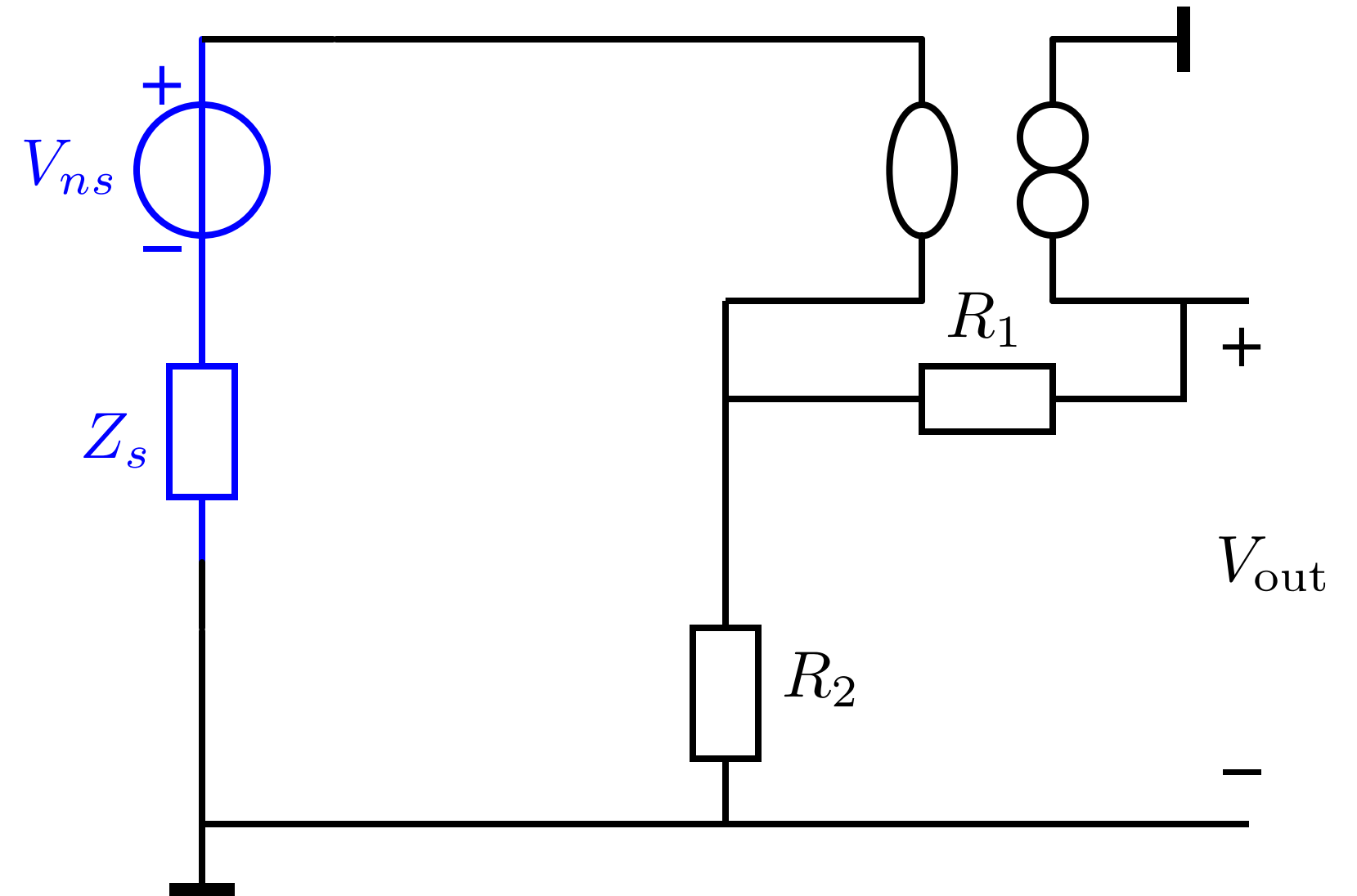
$$V_{ns}$$

Source spectral density:

$$4kT\text{Re}(Z_s)$$

Voltage transfer to output:

$$\frac{R_1 + R_2}{R_2}$$



$$S_{V_{out}} = 4kT\text{Re}(Z_s) \left(\frac{R_1 + R_2}{R_2} \right)^2$$

$$S_{V_s} = 4kT\text{Re}(Z_s)$$

Noise performance of passive feedback amplifiers

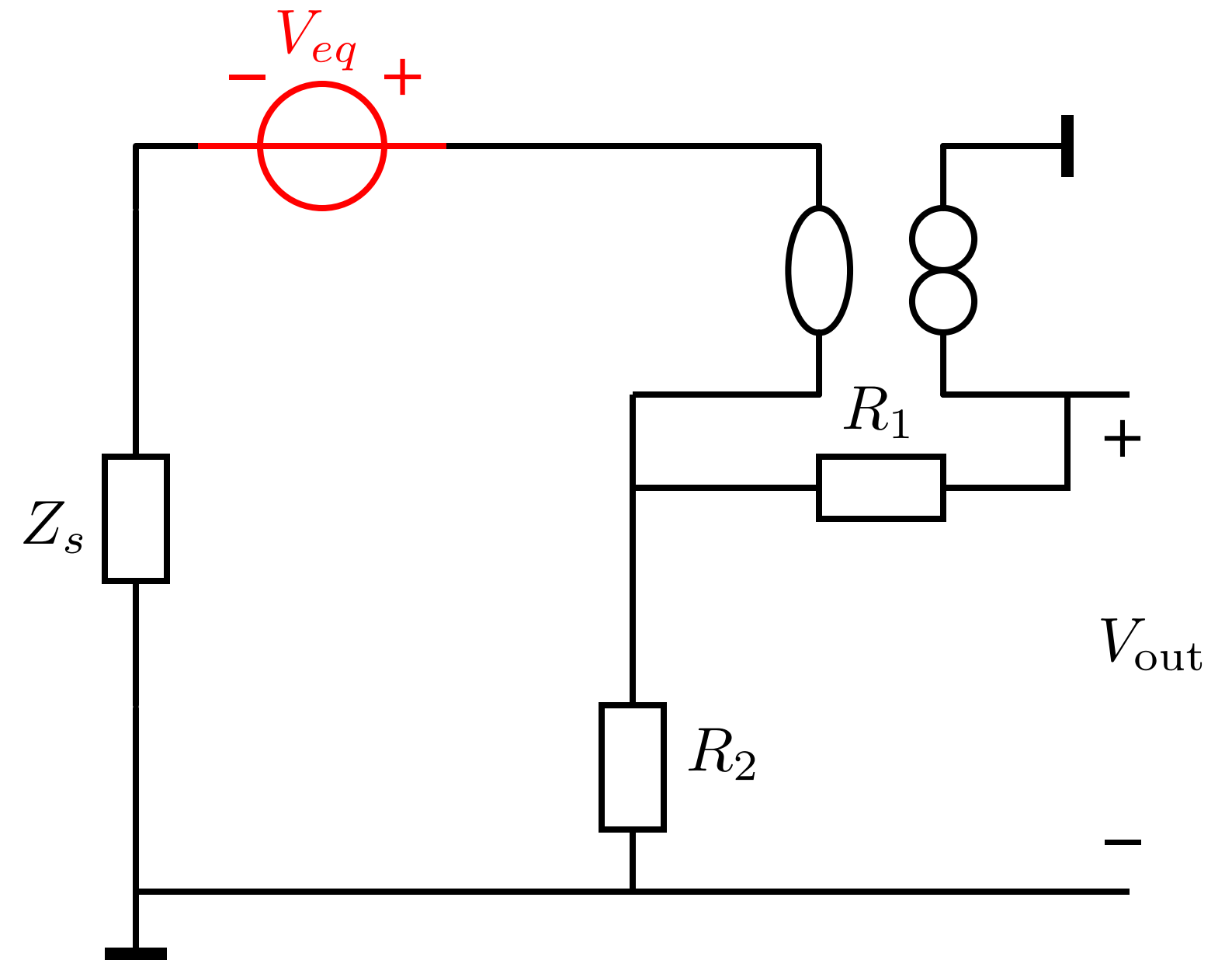
Contribution of:

V_{eq}

Source spectral density:

$S_{V_{eq}}$

Voltage transfer to output: $\frac{R_1+R_2}{R_2}$



$$S_{V_{out}} = 4kT\text{Re}(Z_s) \left(\frac{R_1+R_2}{R_2} \right)^2 + S_{V_{eq}} \left(\frac{R_1+R_2}{R_2} \right)^2$$

$$S_{V_s} = 4kT\text{Re}(Z_s) + S_{V_{eq}}$$

Noise performance of passive feedback amplifiers

Contribution of:

I_{eq}

Source spectral density:

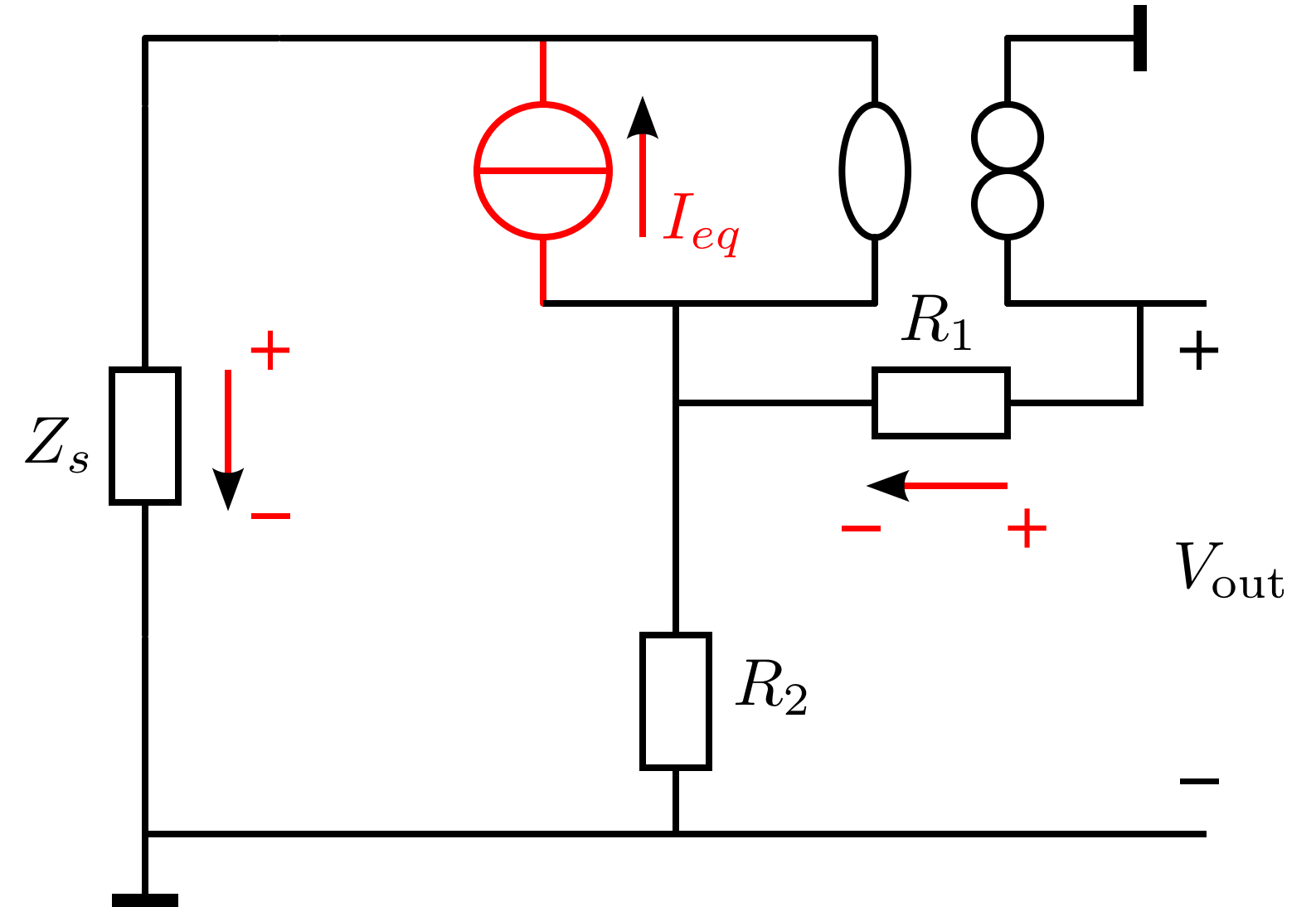
$S_{I_{eq}}$

Transfer to output:

$Z_s \frac{R_1+R_2}{R_2} + R_1$

Can be written as:

$\frac{R_1+R_2}{R_2} \left(Z_s + \frac{R_1 R_2}{R_1+R_2} \right)$



$$S_{V_{out}} = 4kT\text{Re}(Z_s) \left(\frac{R_1+R_2}{R_2} \right)^2 + S_{V_{eq}} \left(\frac{R_1+R_2}{R_2} \right)^2 + S_{I_{eq}} \left(\frac{R_1+R_2}{R_2} \right)^2 \left(Z_s + \frac{R_1 R_2}{R_1+R_2} \right)^2$$

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Noise performance of passive feedback amplifiers

Contribution of:

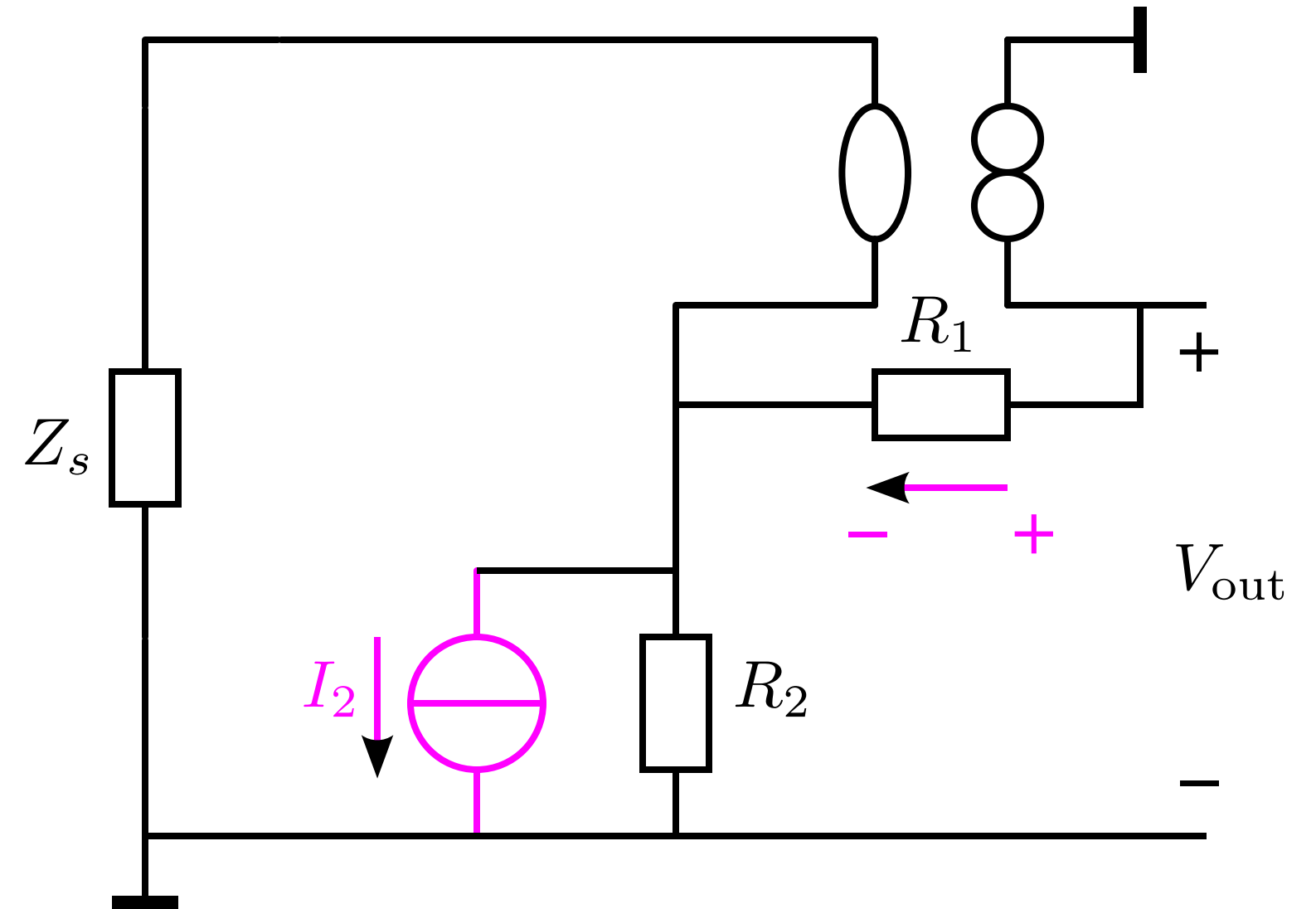
I_2

Source spectral density:

$\frac{4kT}{R_2}$

Transfer to output:

R_1



$$S_{V_{out}} = 4kT \operatorname{Re}(Z_s) \left(\frac{R_1 + R_2}{R_2} \right)^2 + S_{V_{eq}} \left(\frac{R_1 + R_2}{R_2} \right)^2 + S_{I_{eq}} \left(\frac{R_1 + R_2}{R_2} \right)^2 \left(Z_s + \frac{R_1 R_2}{R_1 + R_2} \right)^2 + 4kT \frac{R_1^2}{R_2}$$

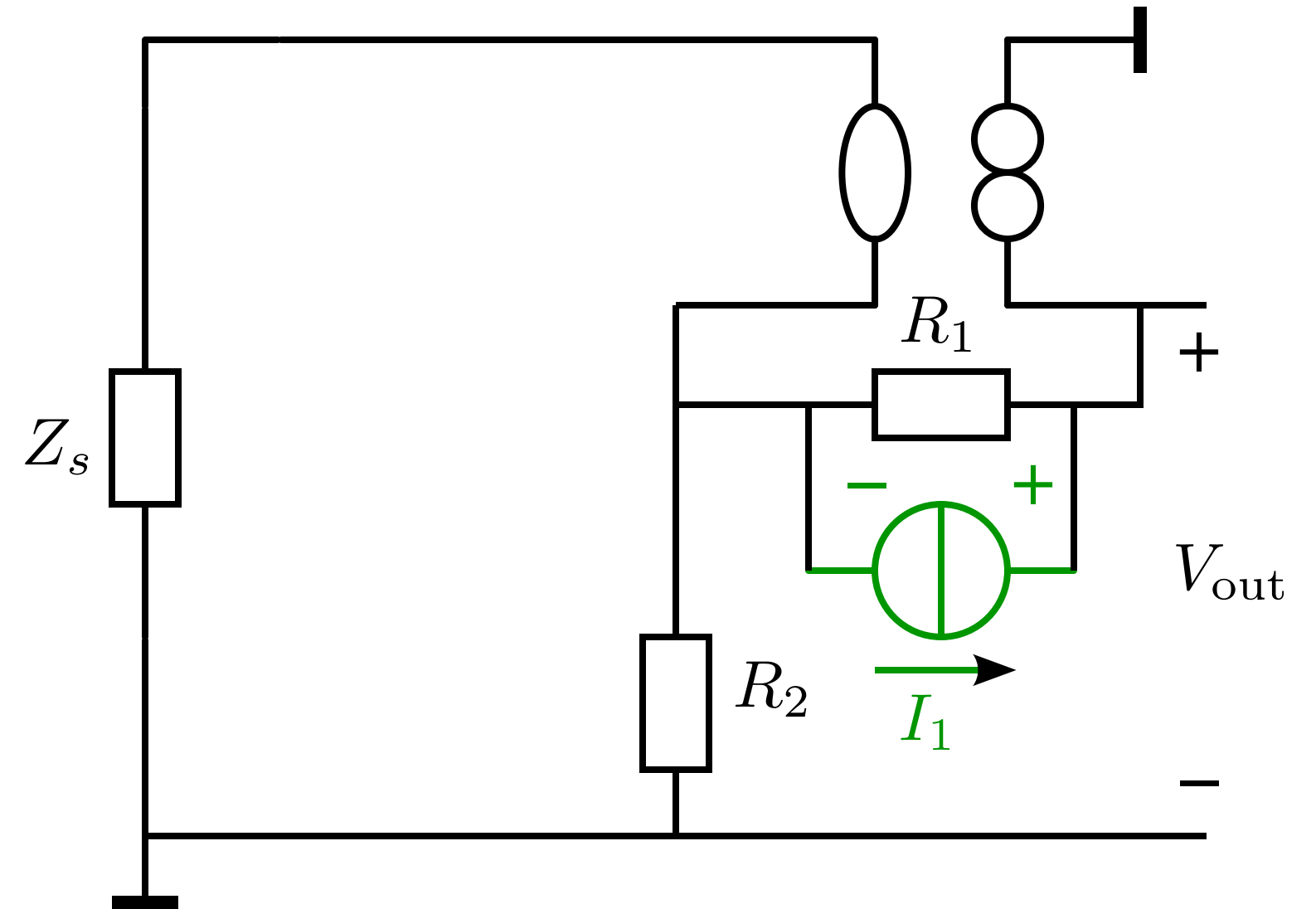
$$S_{V_s} = 4kT \operatorname{Re}(Z_s) + S_{V_{eq}} + S_{I_{eq}} \left(Z_s + \frac{R_1 R_2}{R_1 + R_2} \right)^2 + 4kT \frac{R_1^2 R_2}{(R_1 + R_2)^2}$$

Noise performance of passive feedback amplifiers

Contribution of: I_1

Source spectral density: $\frac{4kT}{R_1}$

Transfer to output: R_1



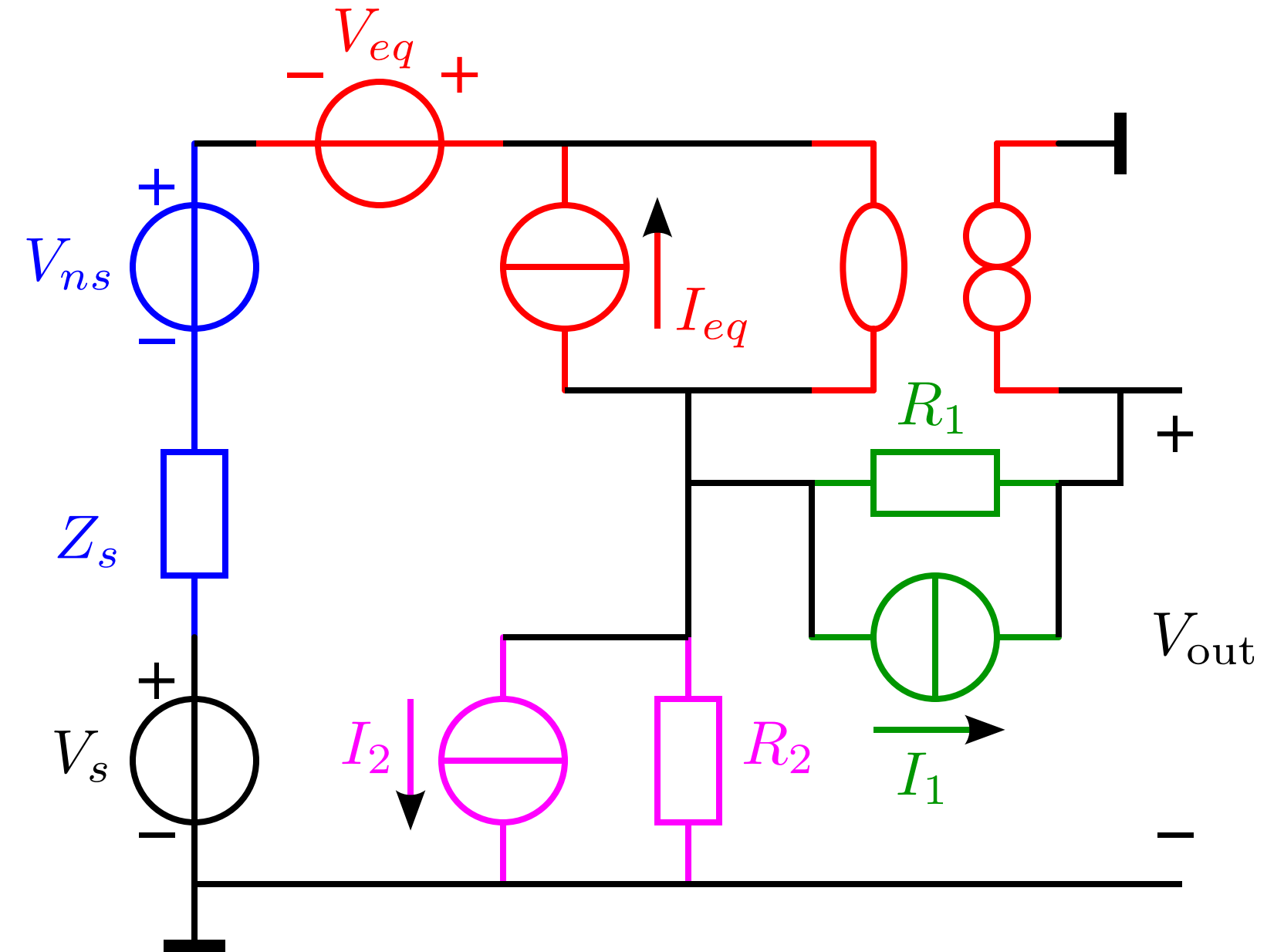
$$S_{V_{out}} = 4kT \operatorname{Re}(Z_s) \left(\frac{R_1 + R_2}{R_2} \right)^2 + S_{V_{eq}} \left(\frac{R_1 + R_2}{R_2} \right)^2 + S_{I_{eq}} \left(\frac{R_1 + R_2}{R_2} \right)^2 \left(Z_s + \frac{R_1 R_2}{R_1 + R_2} \right)^2 + 4kT \frac{R_1^2}{R_2} + 4kT R_1$$

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Noise performance of passive feedback amplifiers

Conclusion:

The influence of the feedback resistors in the passive feedback voltage amplifier can be accounted for as if their parallel connection is in series with the source.



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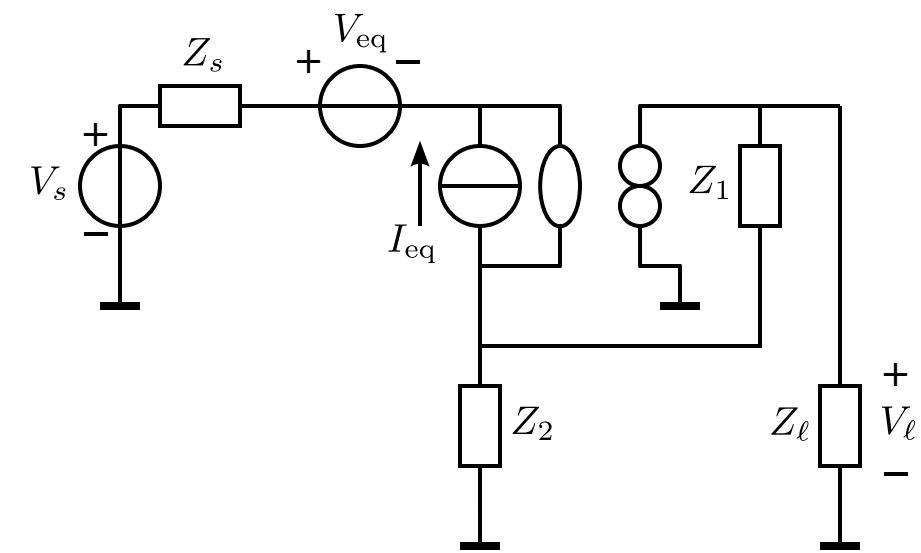
$$S_{V_s} = 4kT \operatorname{Re}(Z_s) + S_{V_{eq}} + S_{I_{eq}} \left(Z_s + \frac{R_1 R_2}{R_1 + R_2} \right)^2 \left(4kT \frac{R_1^2 R_2}{(R_1 + R_2)^2} + 4kT \frac{R_1 R_2^2}{(R_1 + R_2)^2} \right) \rightarrow +4kT \frac{R_1 R_2}{R_1 + R_2}$$

Conclusions noise performance of passive feedback amplifiers

Conclusions noise performance of passive feedback amplifiers

A

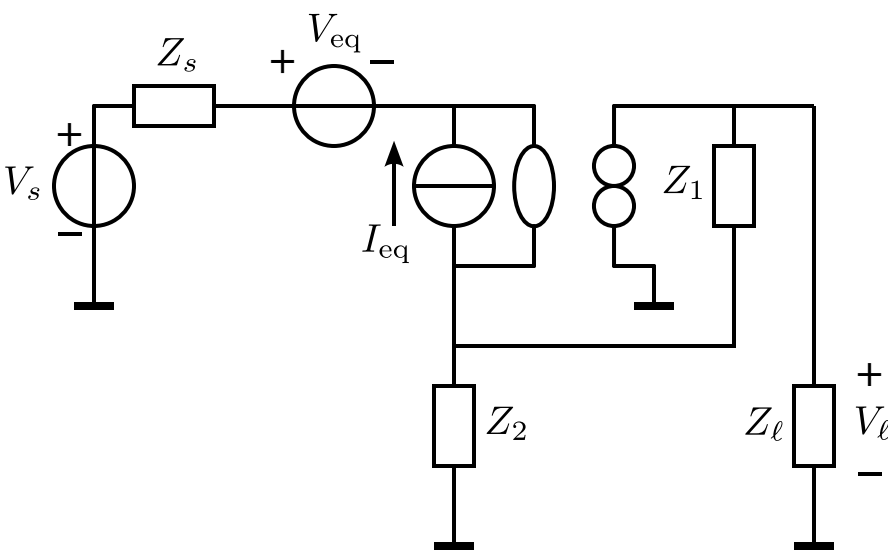
Voltage amplifier



Conclusions noise performance of passive feedback amplifiers

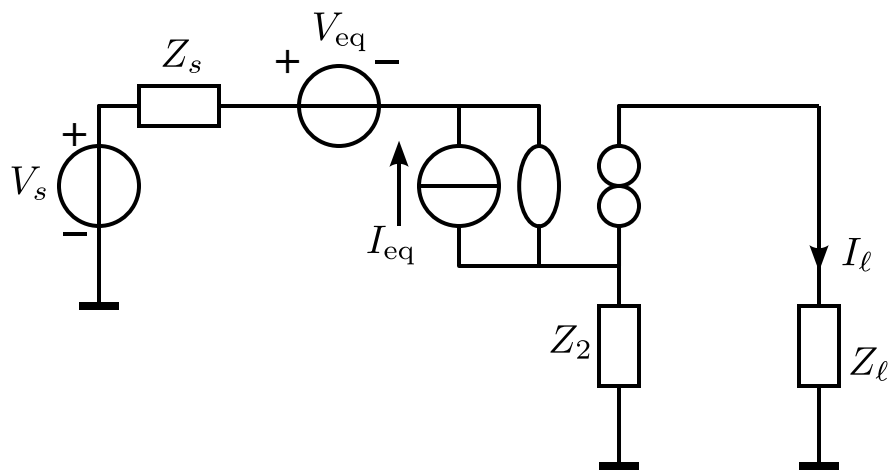
A

Voltage amplifier



B

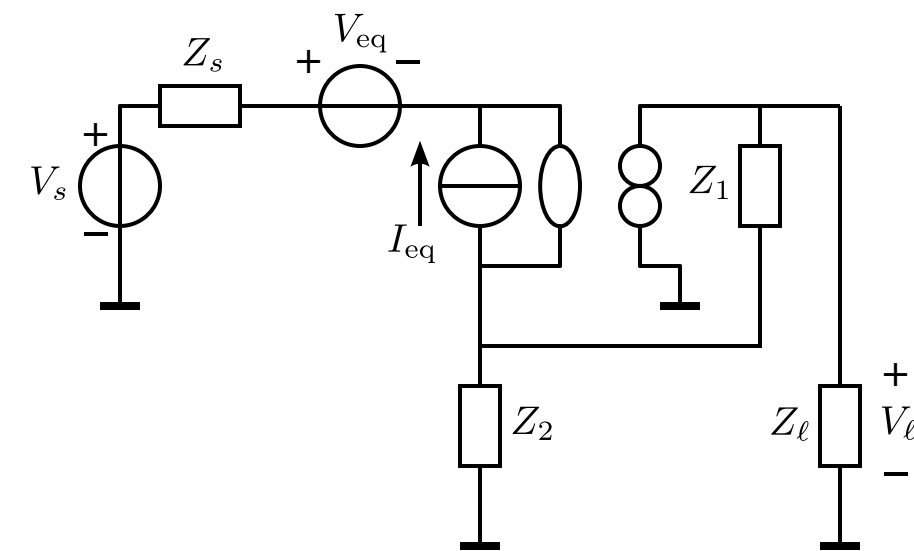
Transadmittance



Conclusions noise performance of passive feedback amplifiers

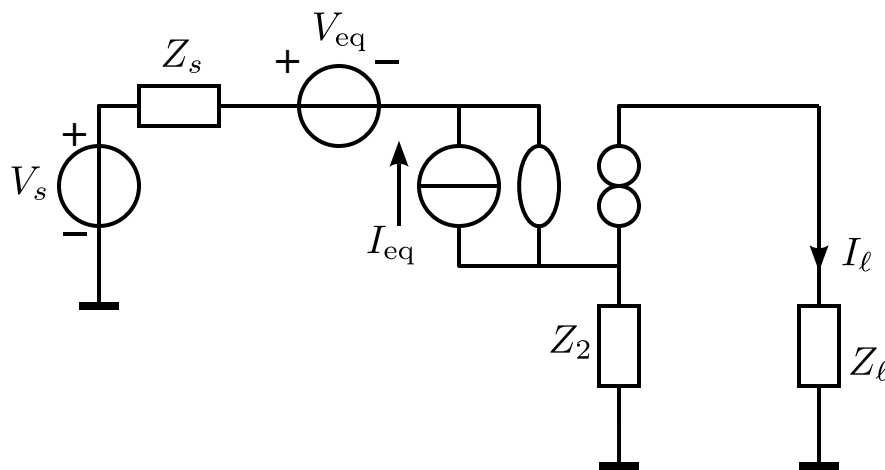
A

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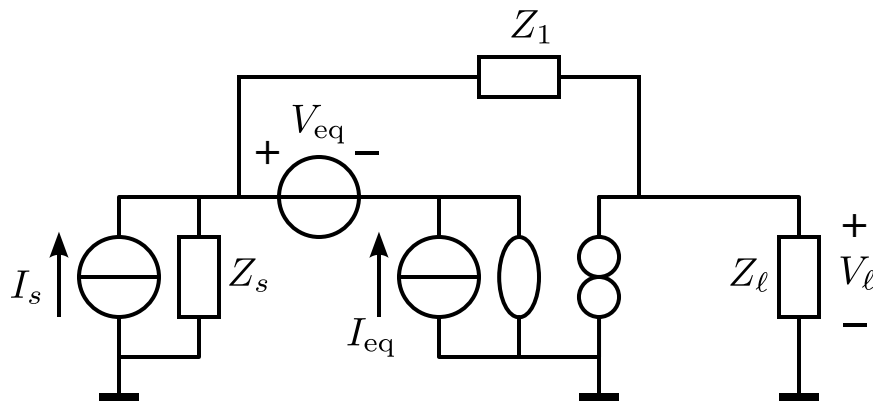
B

Transadmittance



C

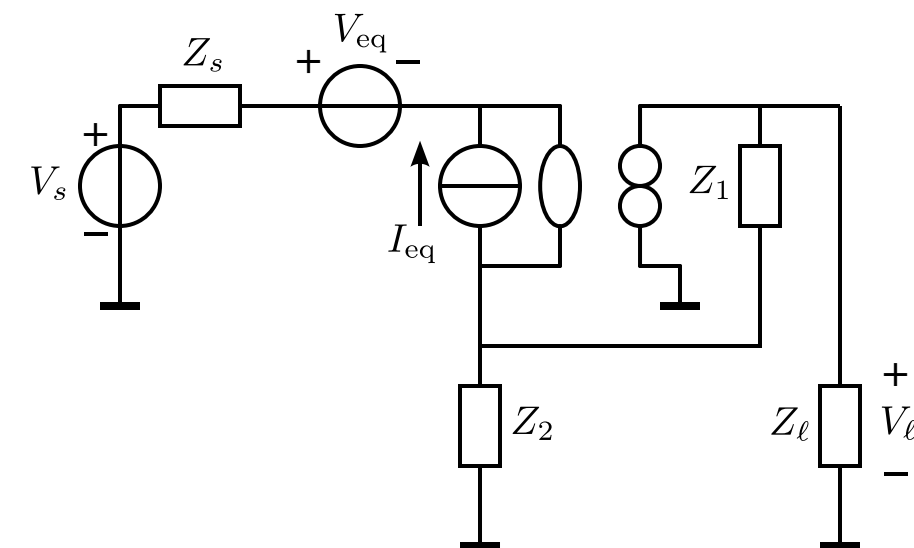
Transimpedance



Conclusions noise performance of passive feedback amplifiers

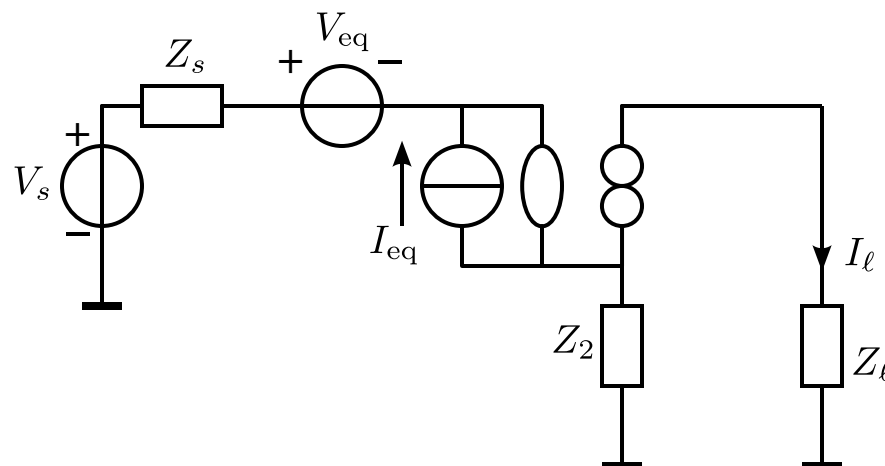
A

Voltage amplifier



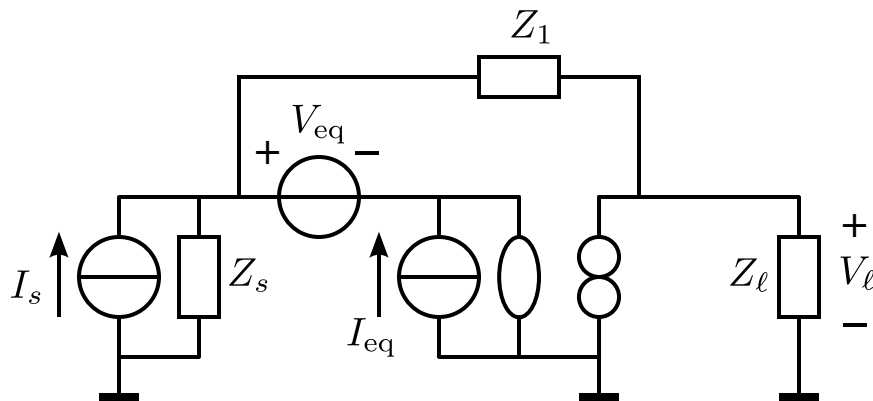
B

Transadmittance



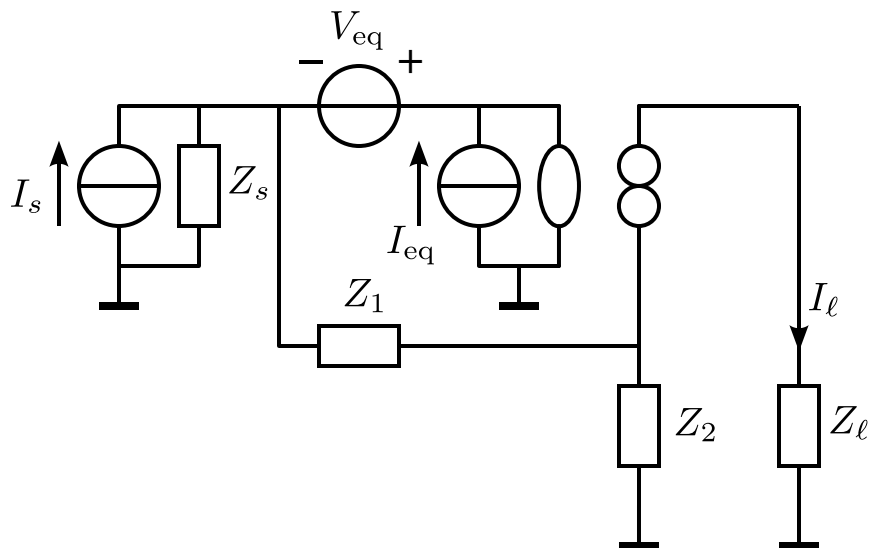
C

Transimpedance



D

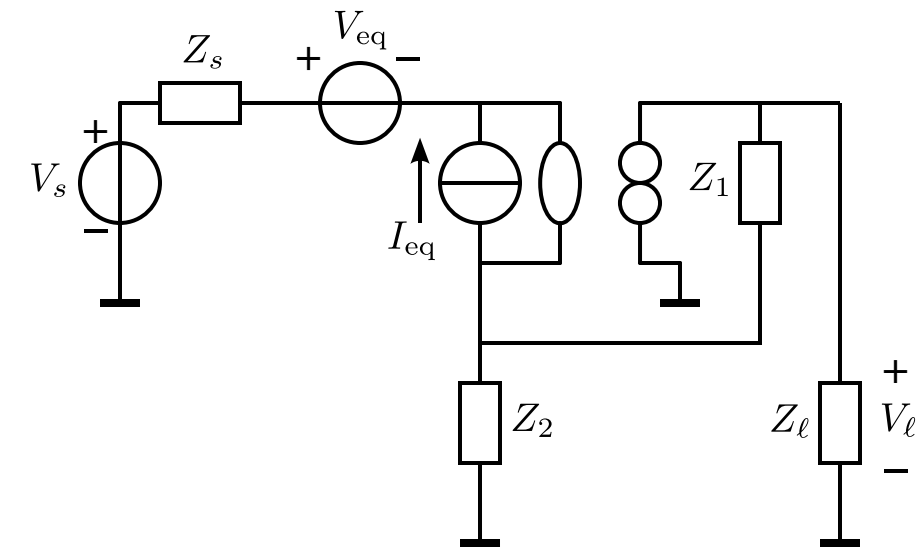
Current amplifier



Conclusions noise performance of passive feedback amplifiers

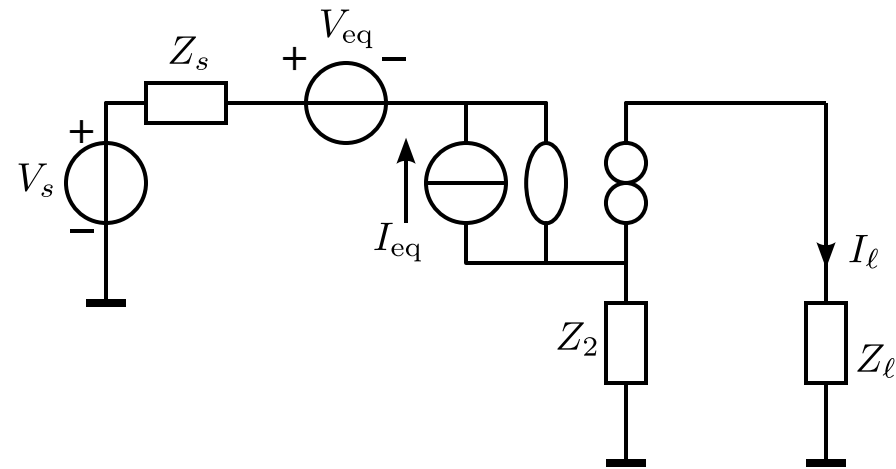
A

Voltage amplifier



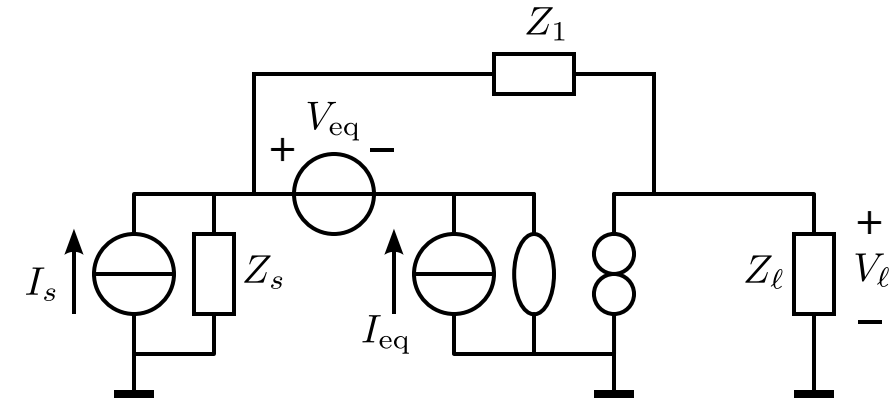
B

Transadmittance



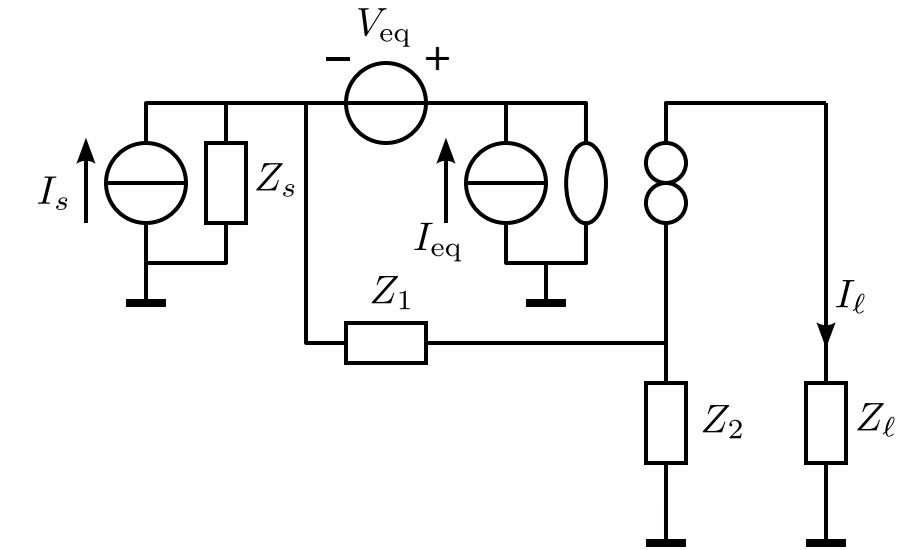
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Current amplifier

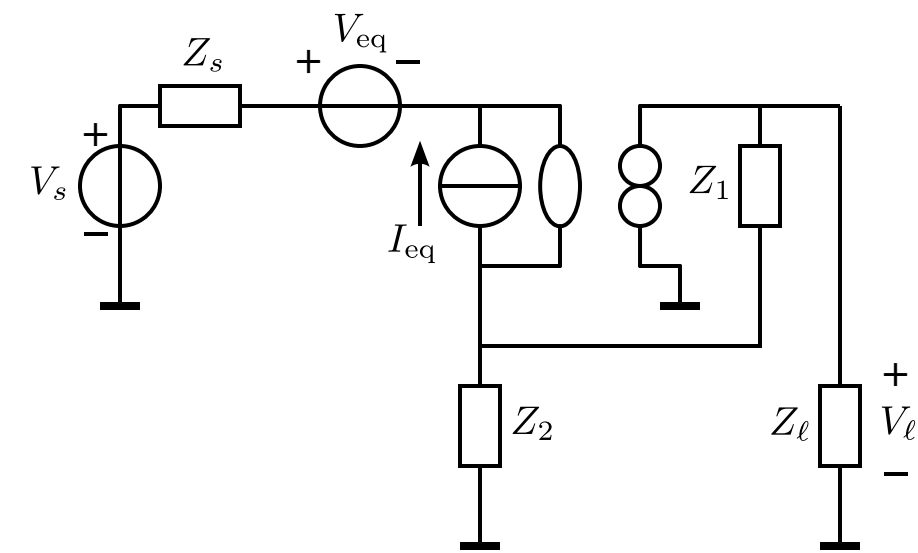


The noise contribution of the feedback impedances and their influence on the contribution of the equivalent input noise sources of the controller can be found:

Conclusions noise performance of passive feedback amplifiers

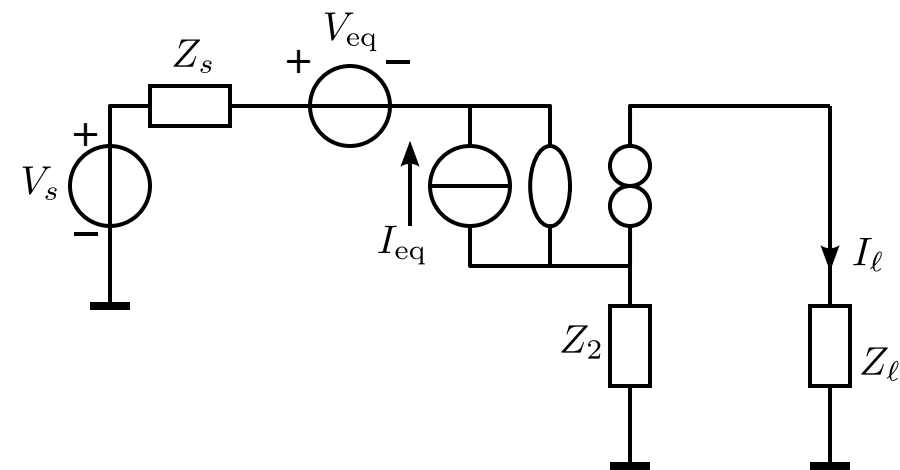
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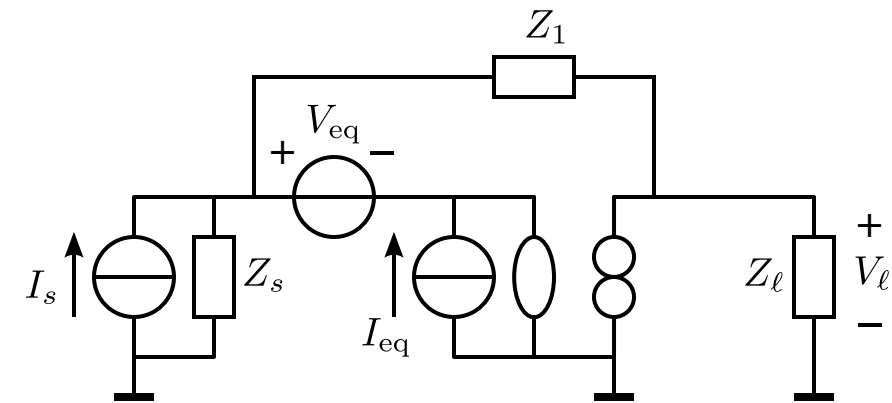
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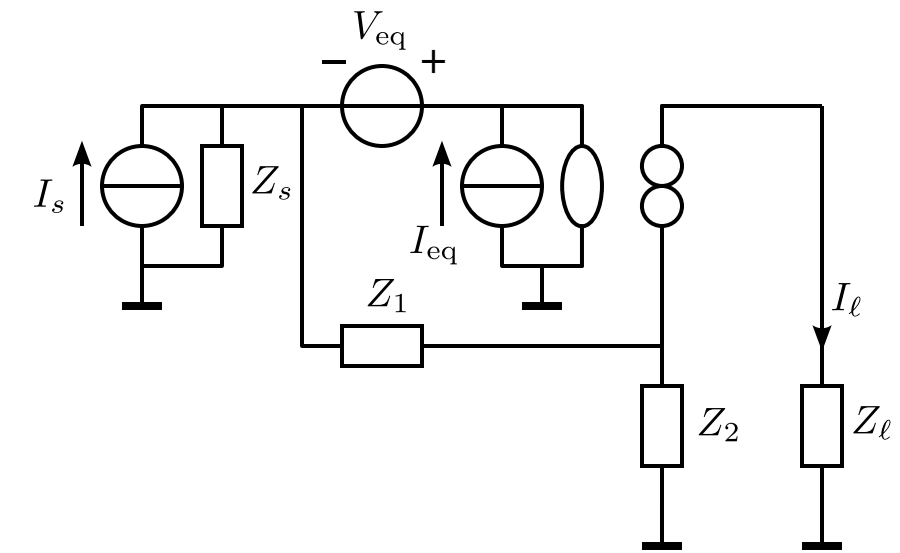
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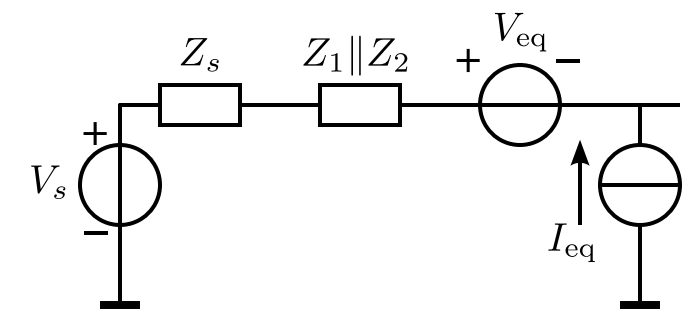
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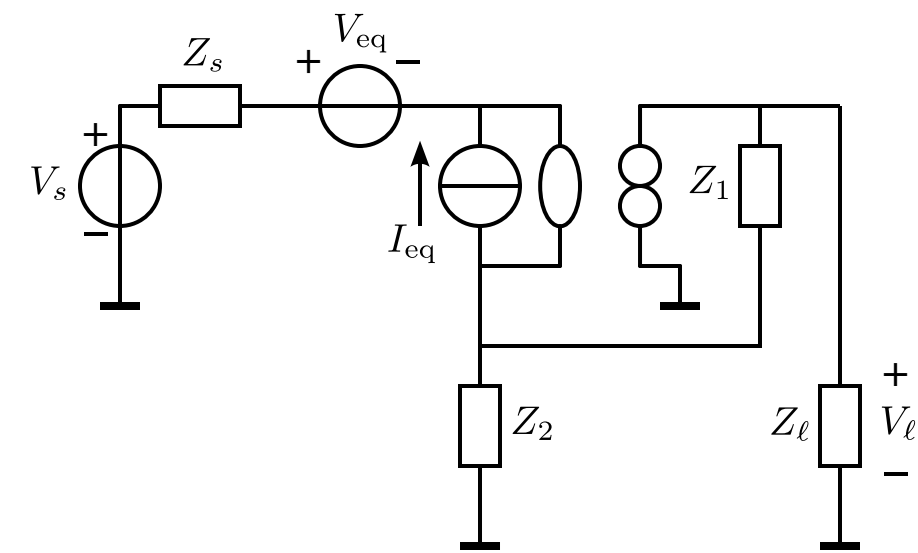
As if the parallel connection of the feedback impedances is in series with the source



Conclusions noise performance of passive feedback amplifiers

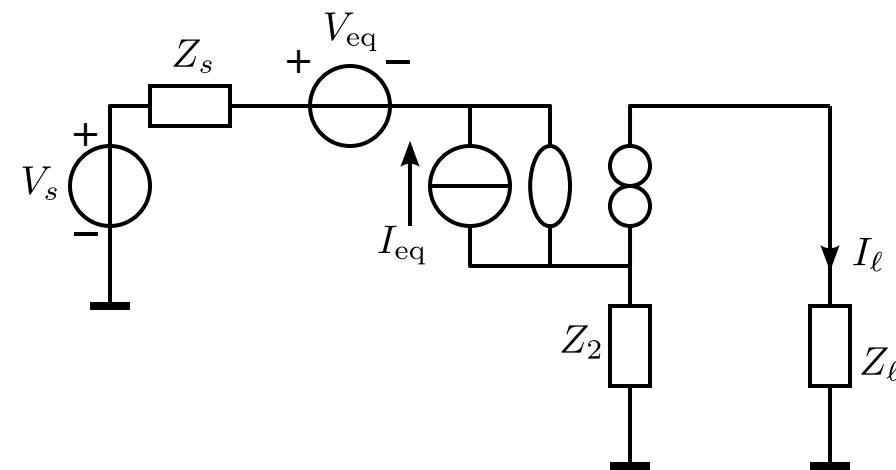
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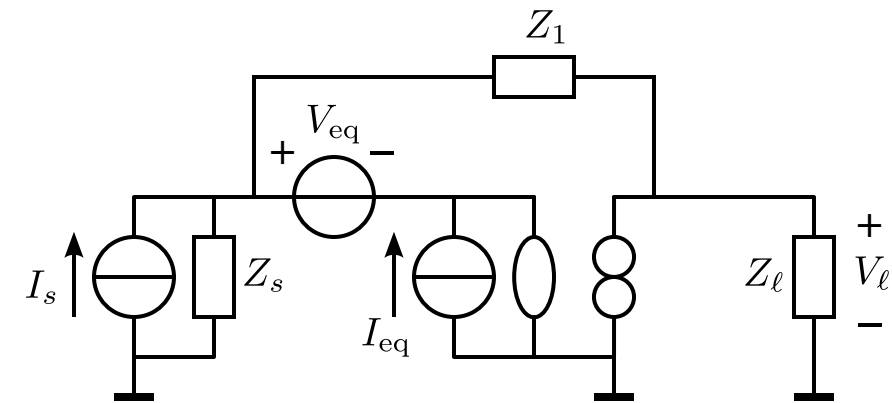
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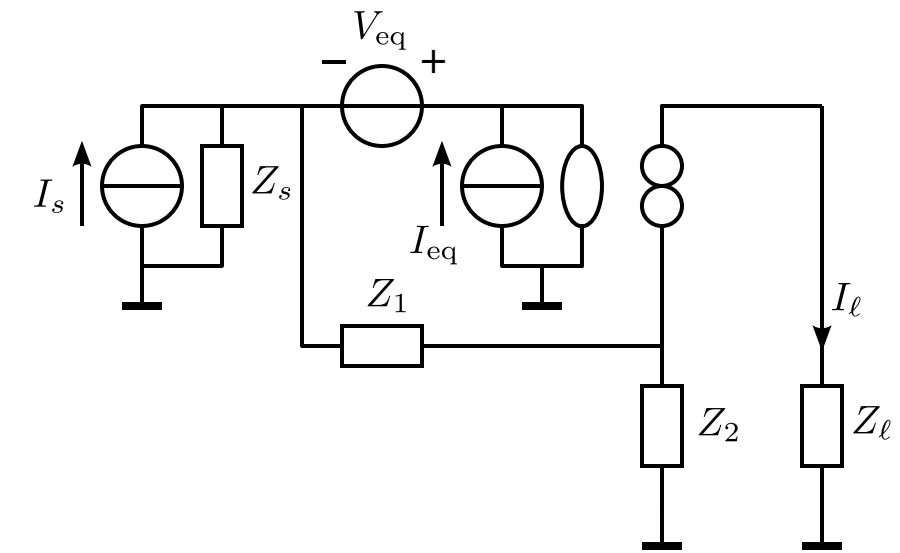
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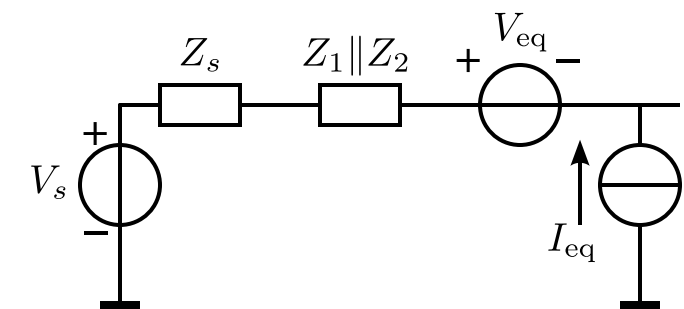
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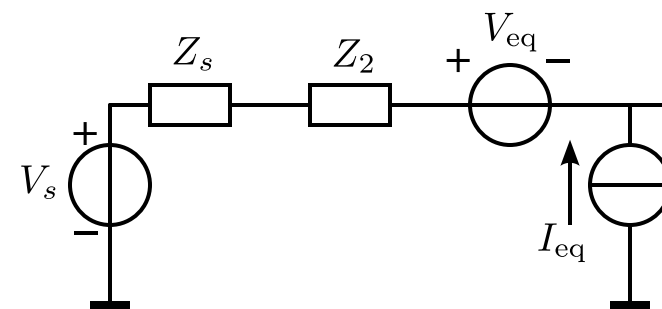


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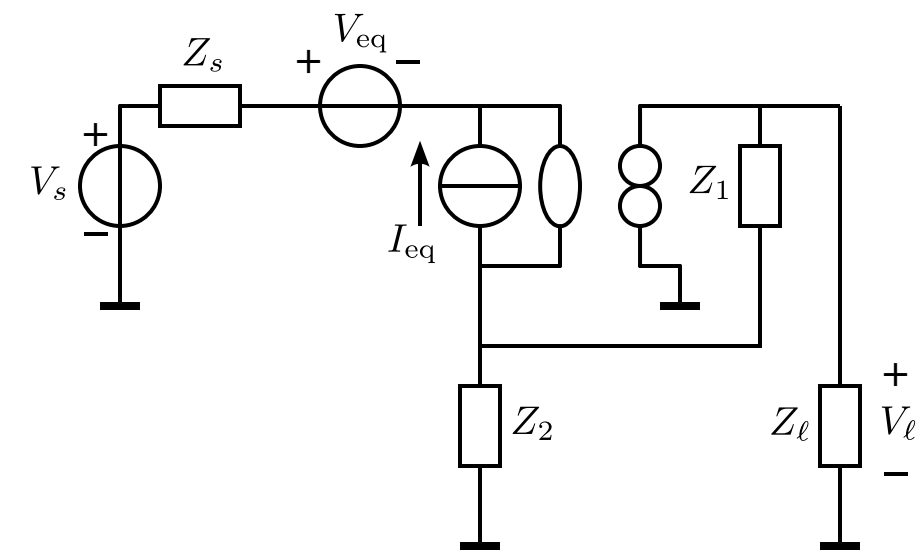
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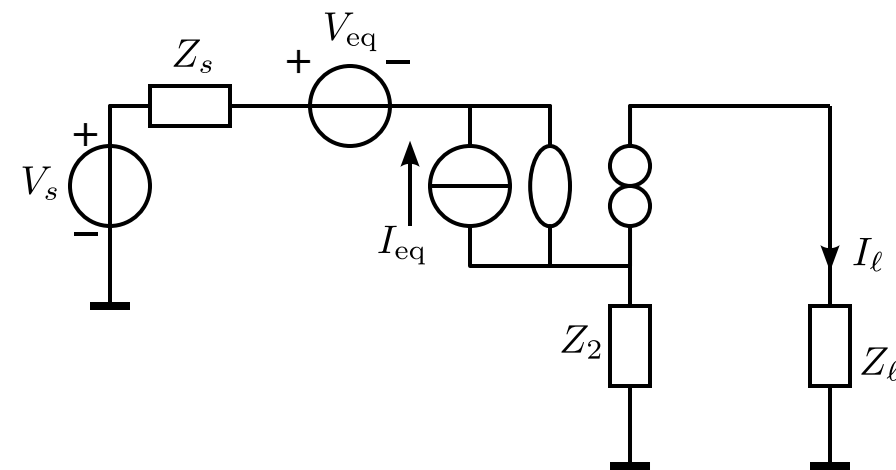
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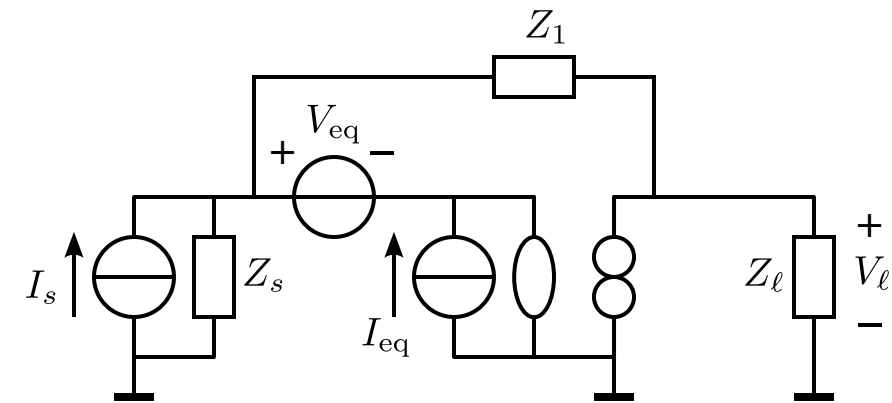
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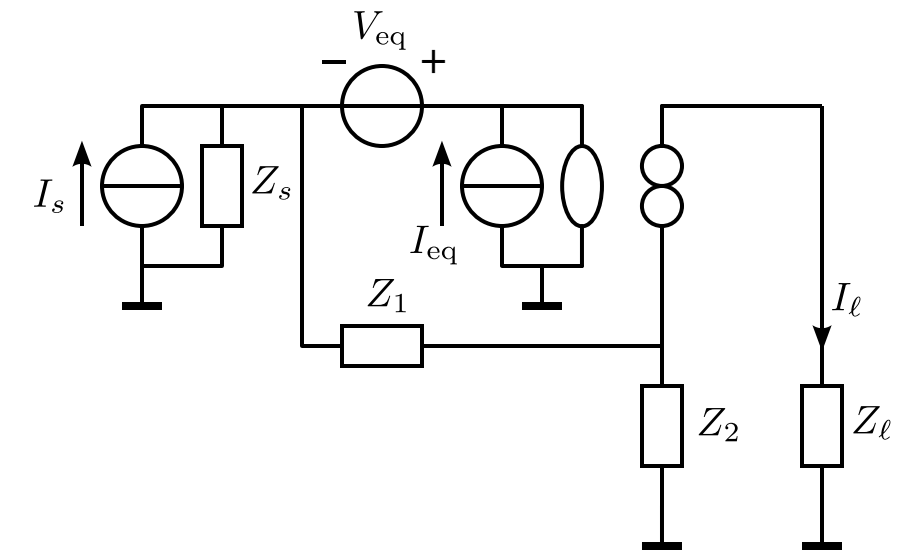
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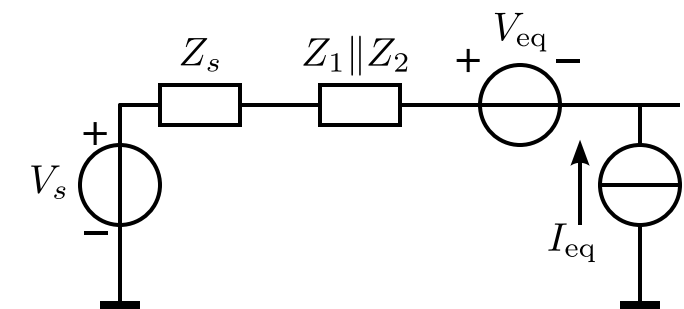
D

Current amplifier

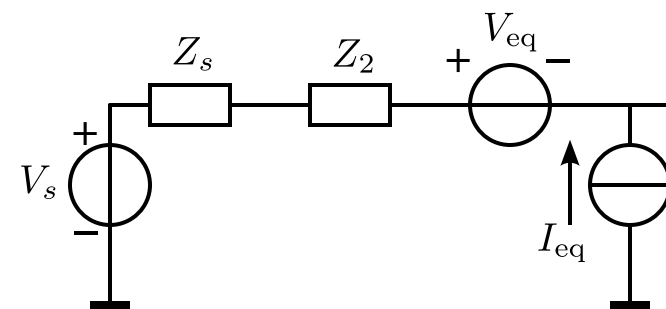


The noise contribution of the feedback impedances and their influence on the contribution of the equivalent input noise sources of the controller can be found:

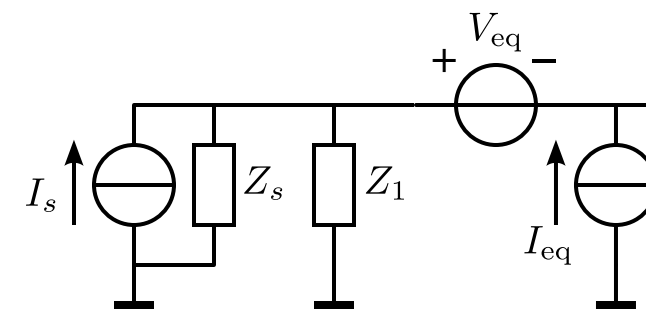
As if the parallel connection of the feedback impedances is in series with the source



As if the feedback impedance is in series with the source



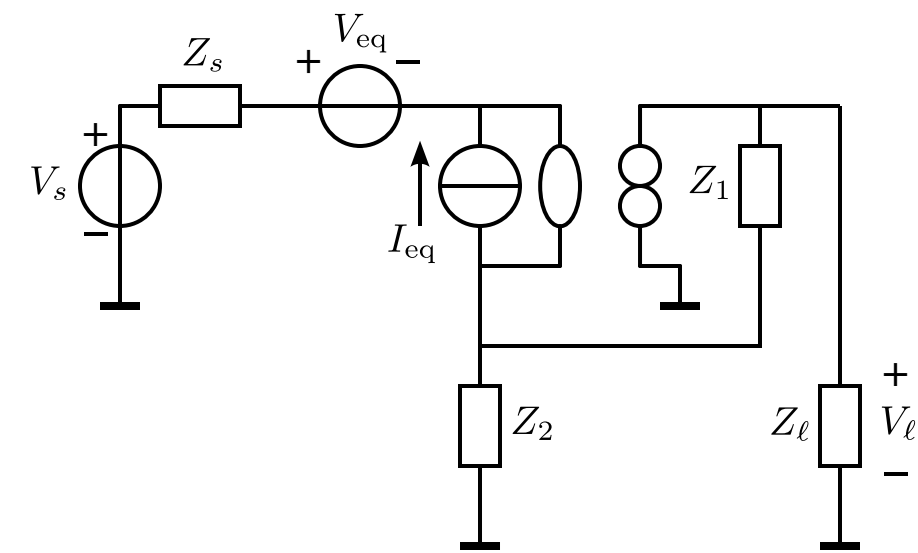
As if the feedback impedance is in parallel with the source



Conclusions noise performance of passive feedback amplifiers

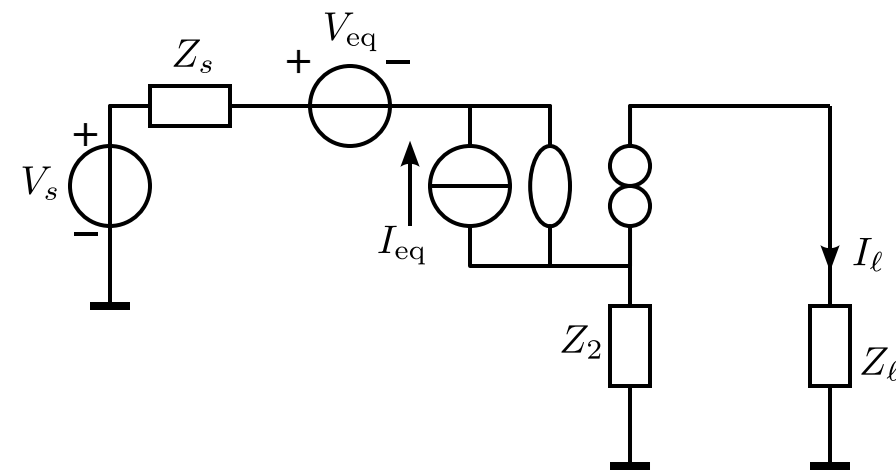
A

Voltage amplifier



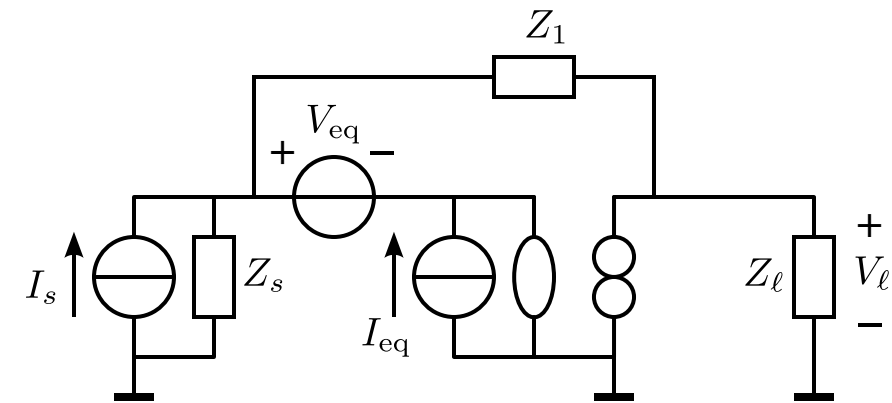
B

Transadmittance



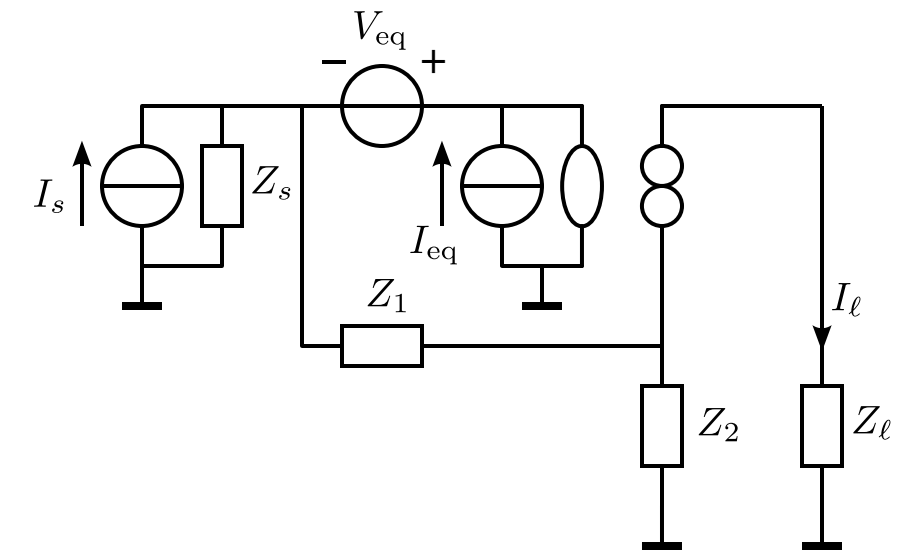
C

Transimpedance



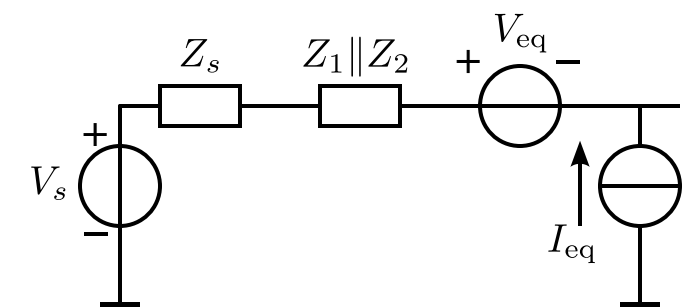
D

Current amplifier

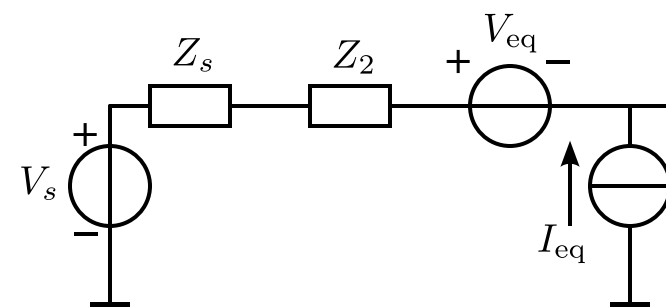


The noise contribution of the feedback impedances and their influence on the contribution of the equivalent input noise sources of the controller can be found:

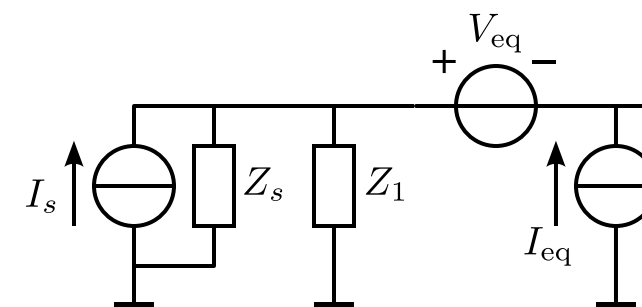
As if the parallel connection of the feedback impedances is in series with the source



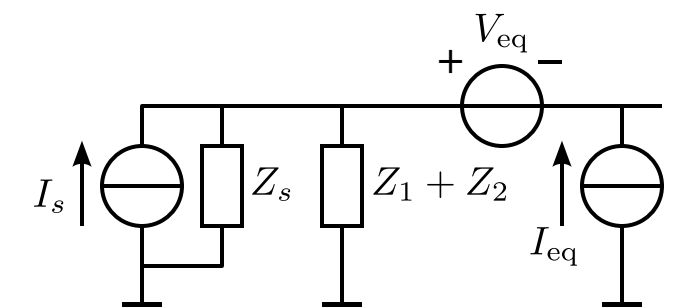
As if the feedback impedance is in series with the source



As if the feedback impedance is in parallel with the source



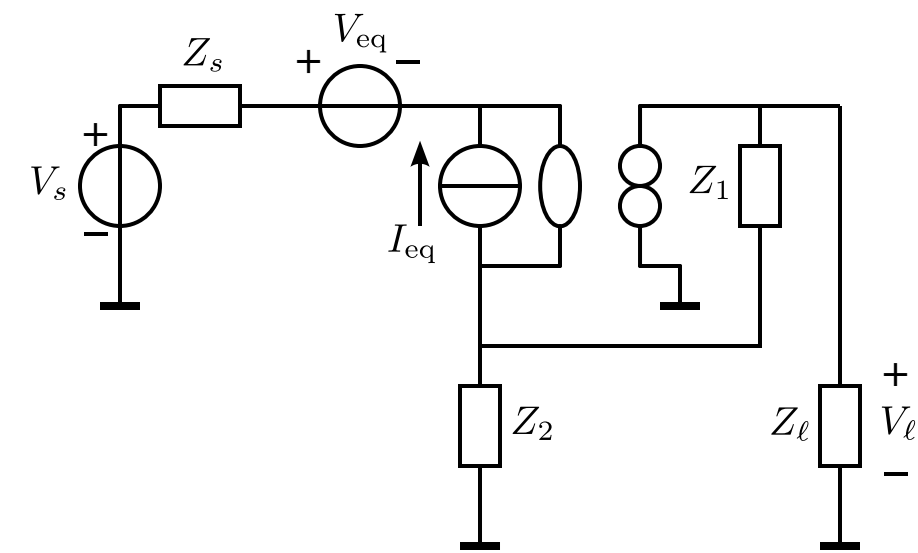
As if the series connection of the feedback impedances is in series with the source



Conclusions noise performance of passive feedback amplifiers

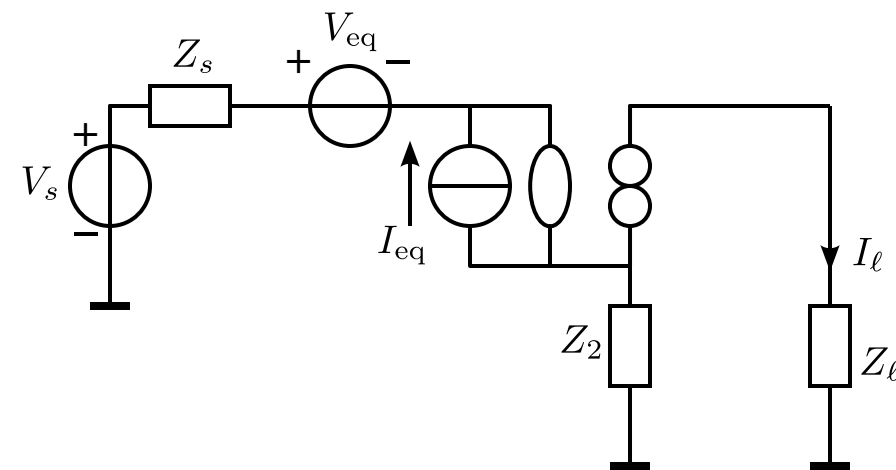
A

Voltage amplifier



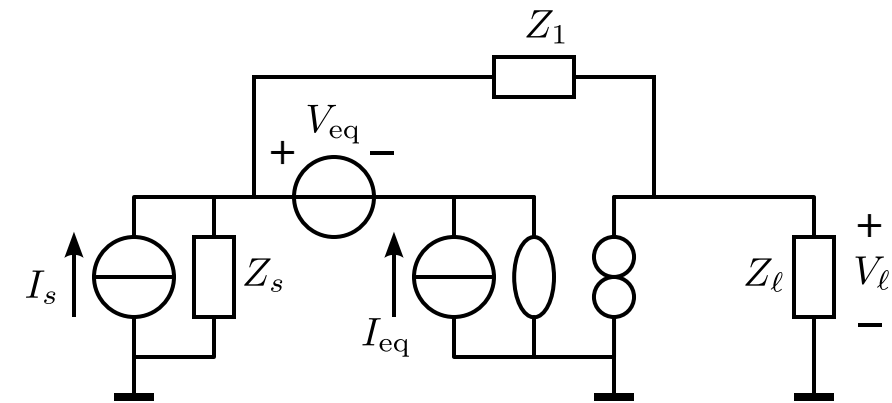
B

Transadmittance



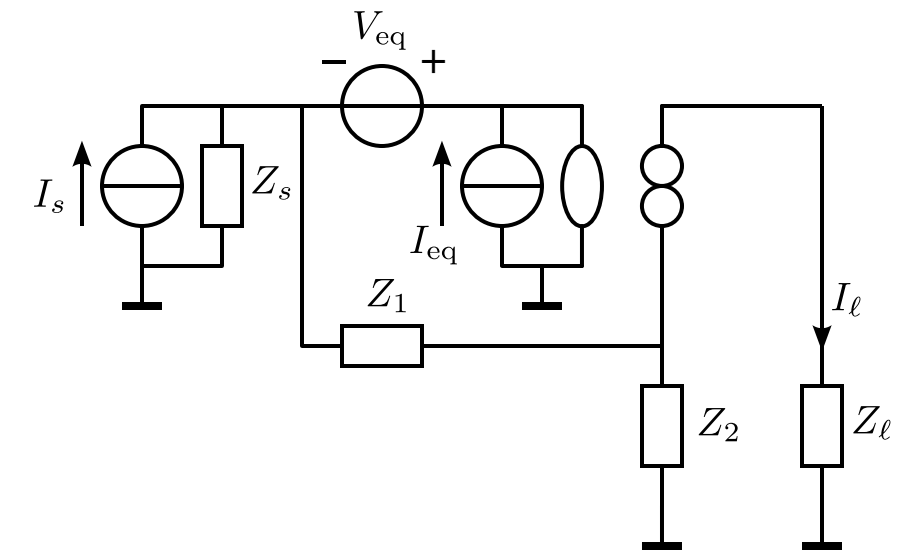
C

Transimpedance



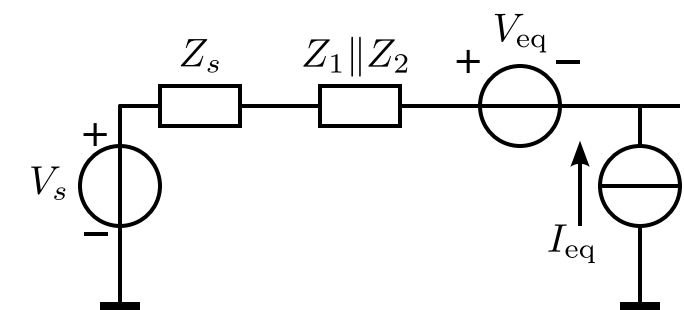
D

Current amplifier

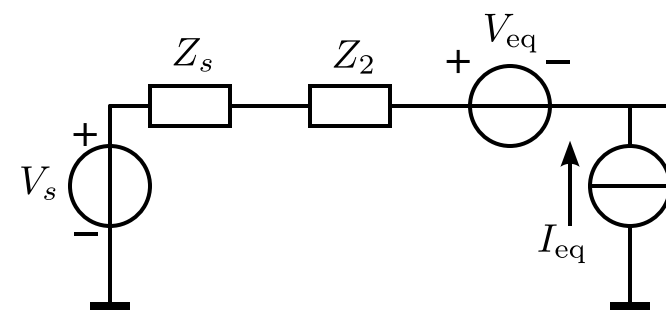


The noise contribution of the feedback impedances and their influence on the contribution of the equivalent input noise sources of the controller can be found:

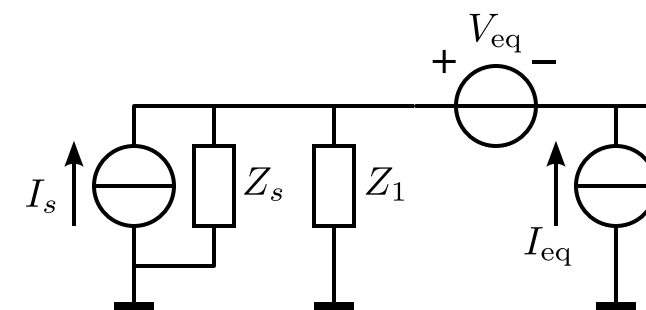
As if the parallel connection of the feedback impedances is in series with the source



As if the feedback impedance is in series with the source



As if the feedback impedance is in parallel with the source



As if the series connection of the feedback impedances is in series with the source

