Structured Electronic Design

EE3C11
Design of low-noise feedback amplifier configurations

Anton J.M. Montagne

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Negative feedback: a powerful error reduction technique

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Negative feedback: a powerful error reduction technique

With a high-gain controller the static and dynamic transfer
are predominantly determined by the feedback network

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Study the noise behavior of nonenergic and passive feedback amplifiers

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- Find rules for low-noise design

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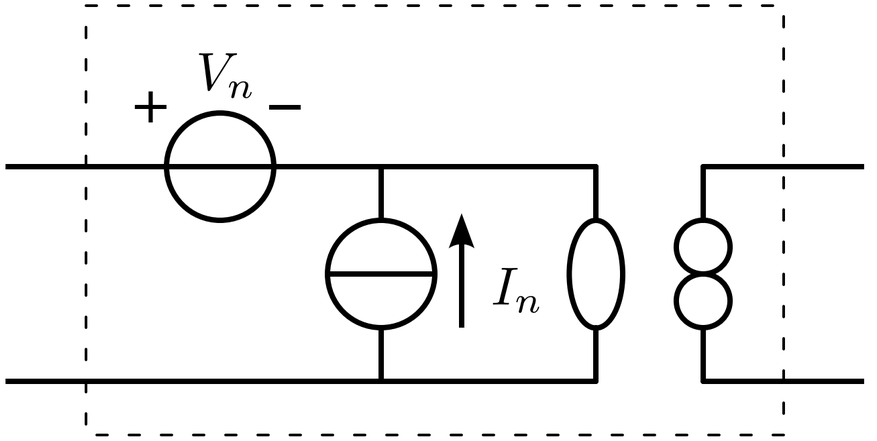

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Noise performance of nonenergic feedback amplifiers

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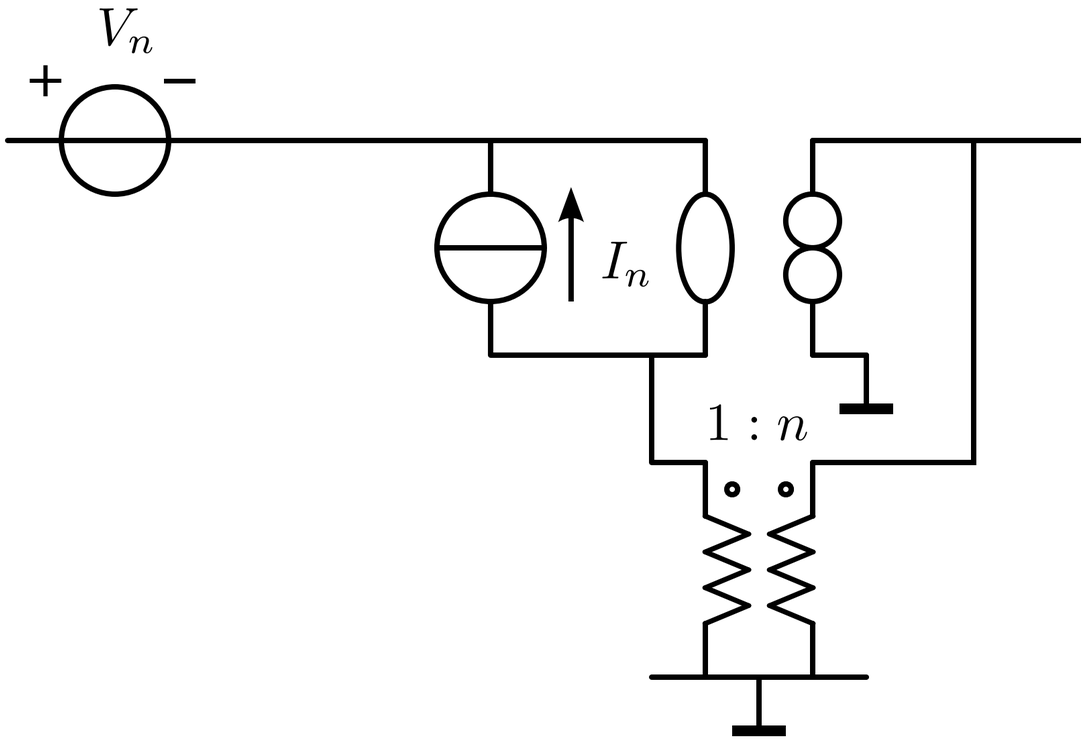

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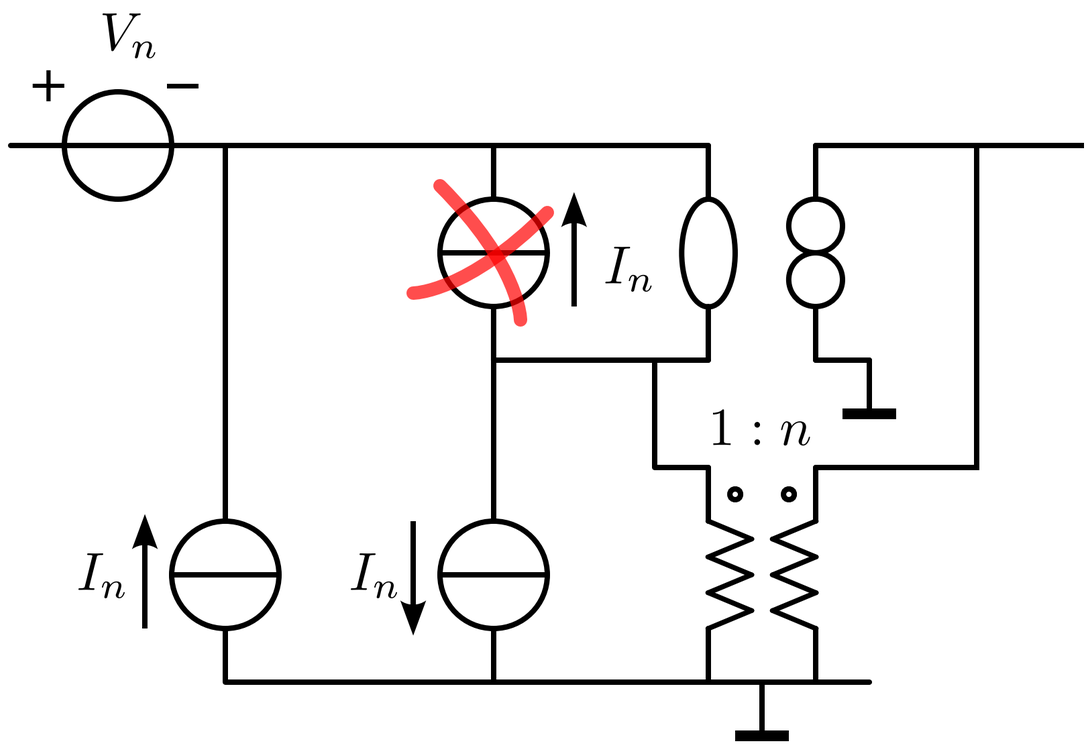
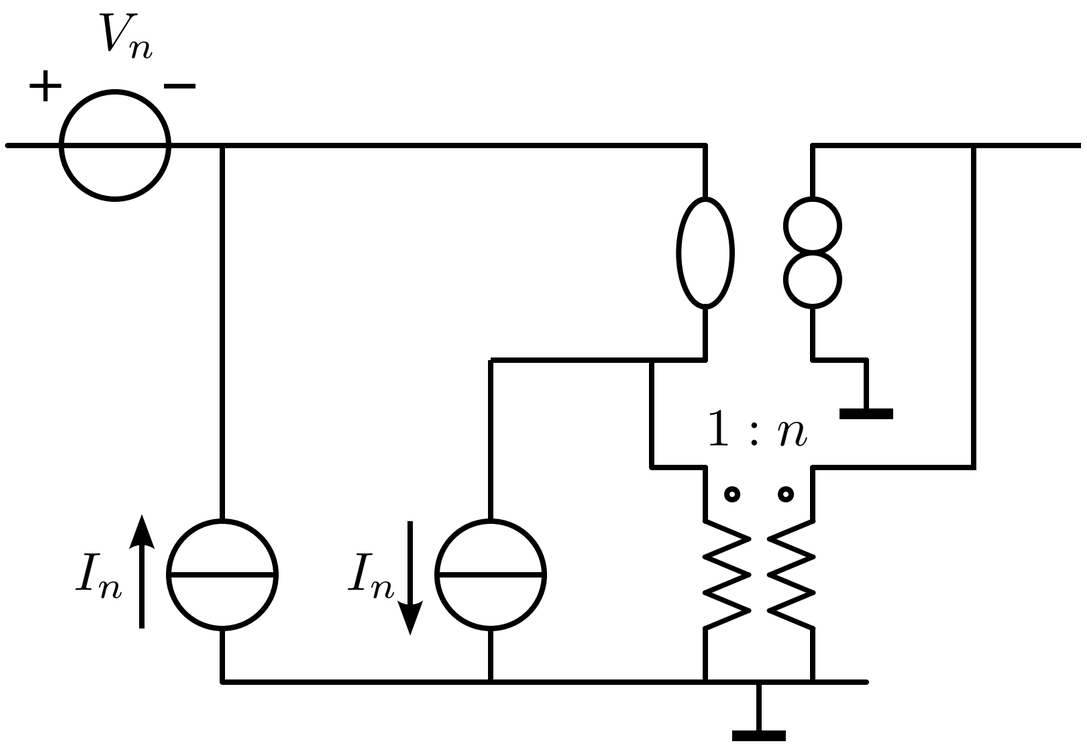


Redirect the current noise source via ground

Noise performance of nonenergic feedback amplifiers



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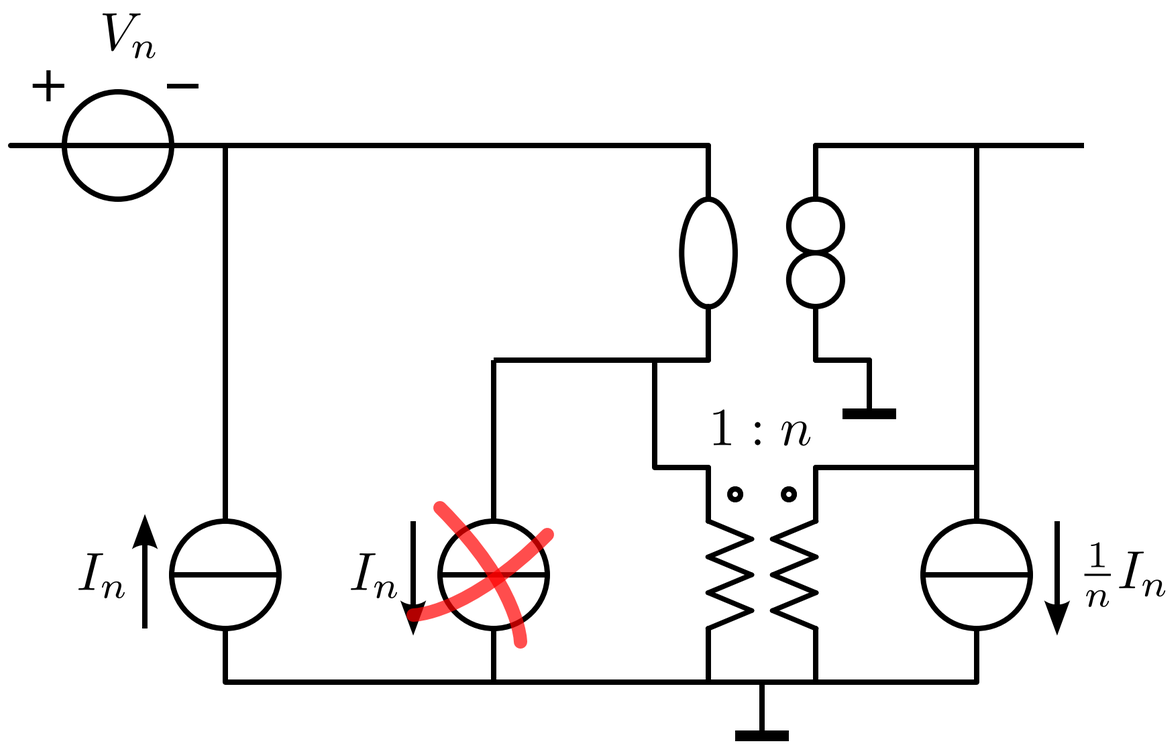

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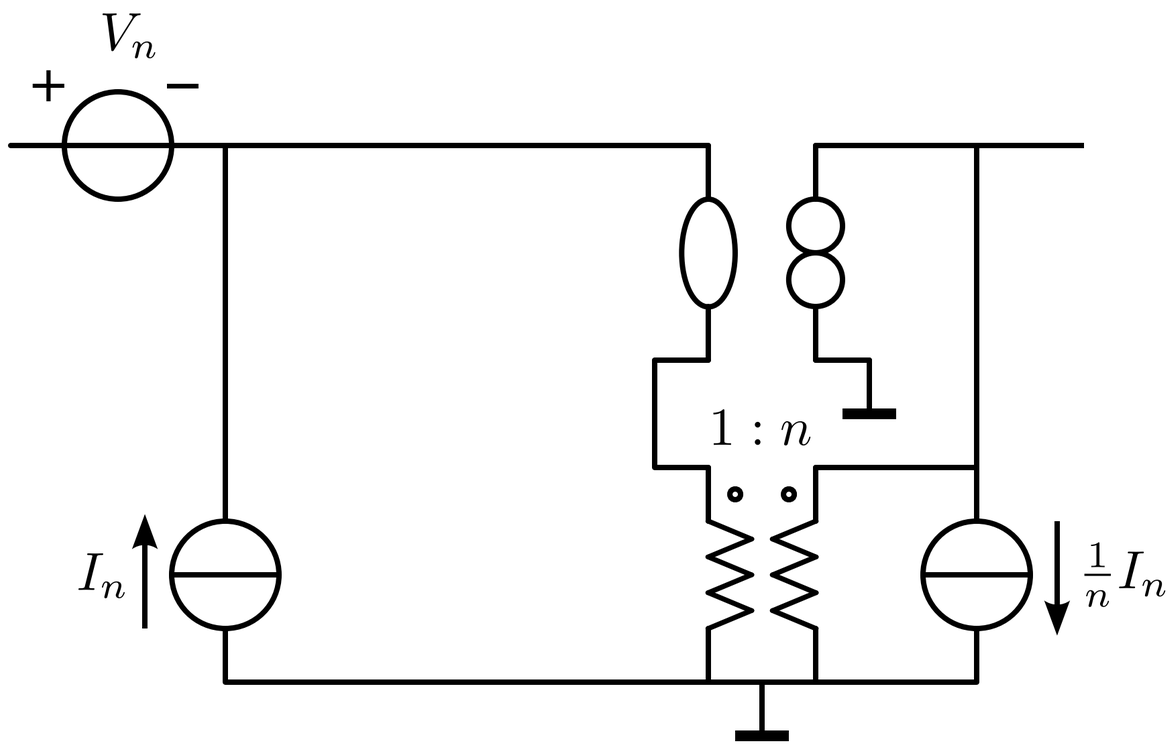
Replace the equivalent input current noise source of the transformer with an equivalent output current noise source; use:

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

Noise performance of nonenergic feedback amplifiers



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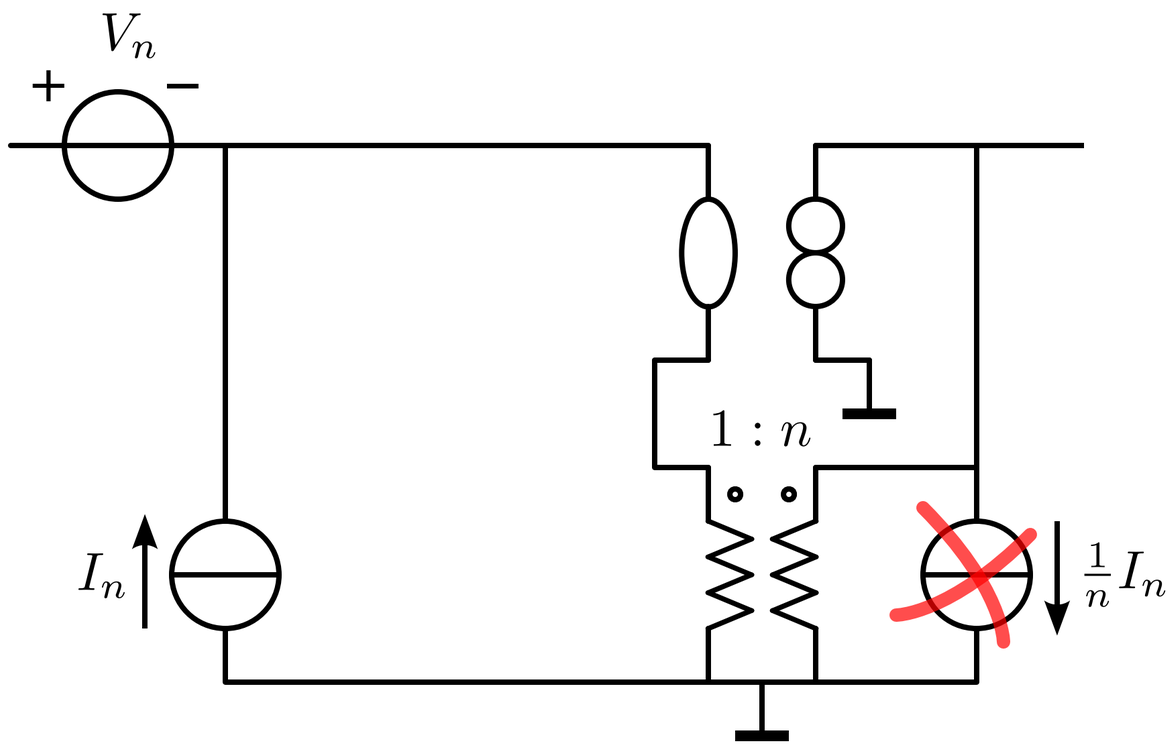

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The current source in parallel with the output of the nullor can be ignored. Replacing it with equivalent input sources yields zero because:

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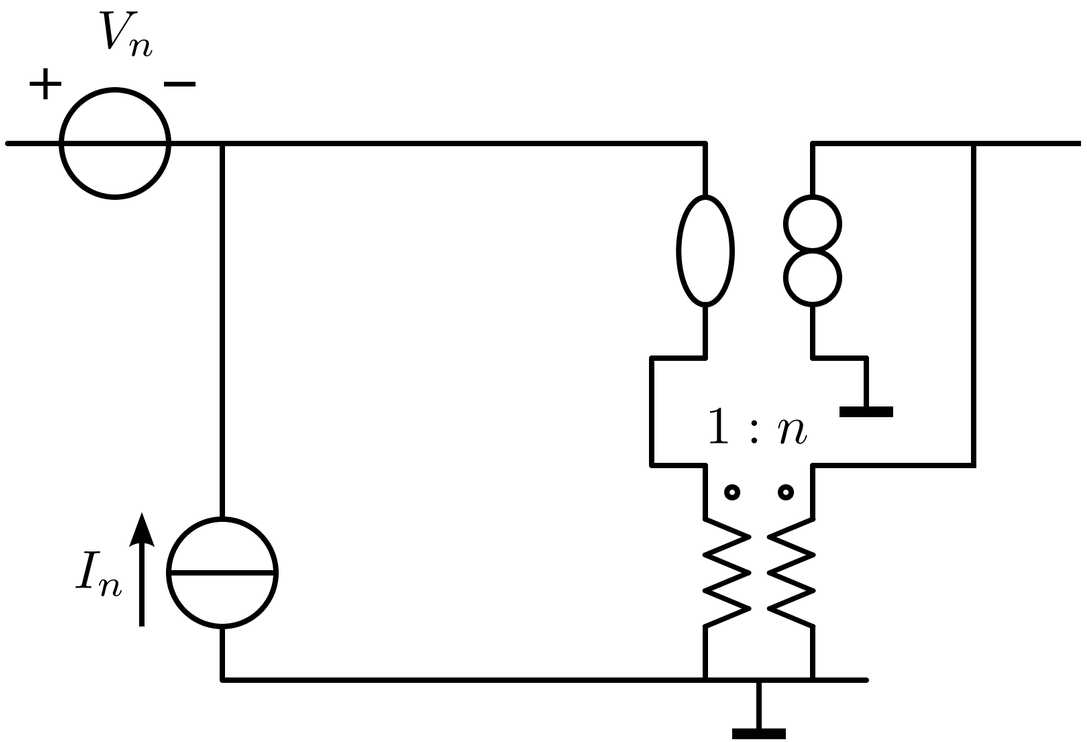

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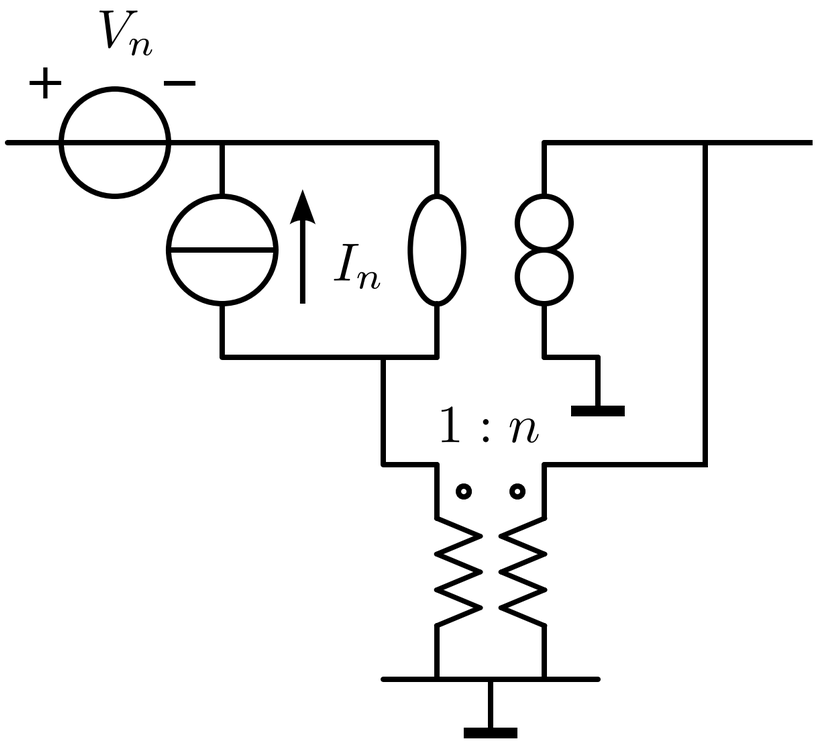

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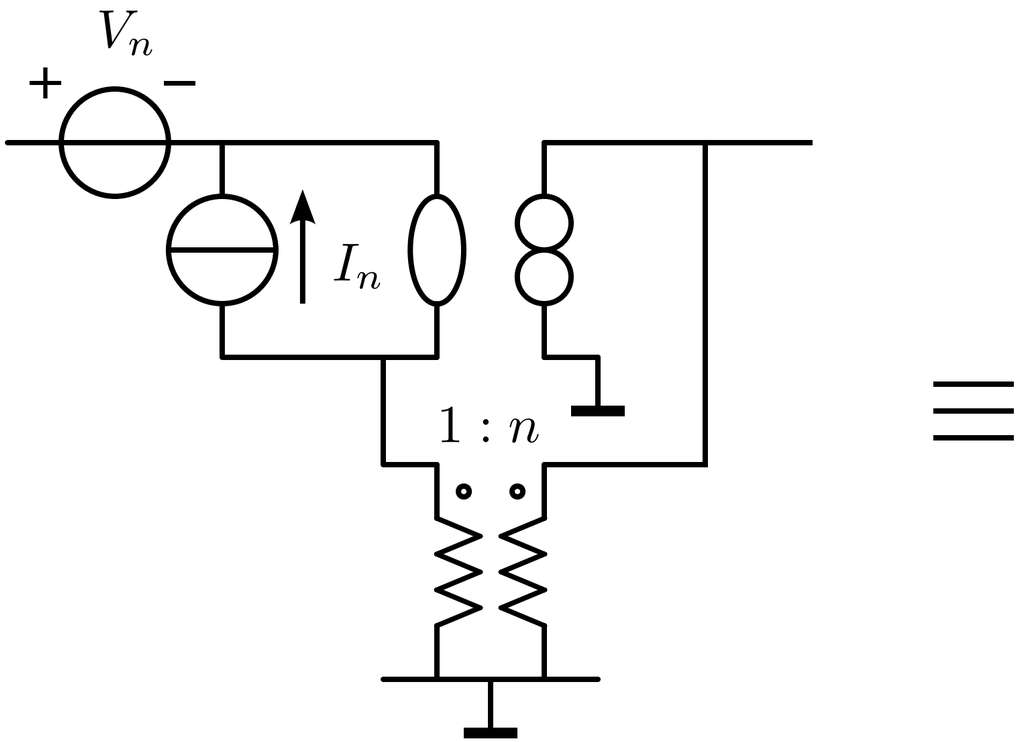

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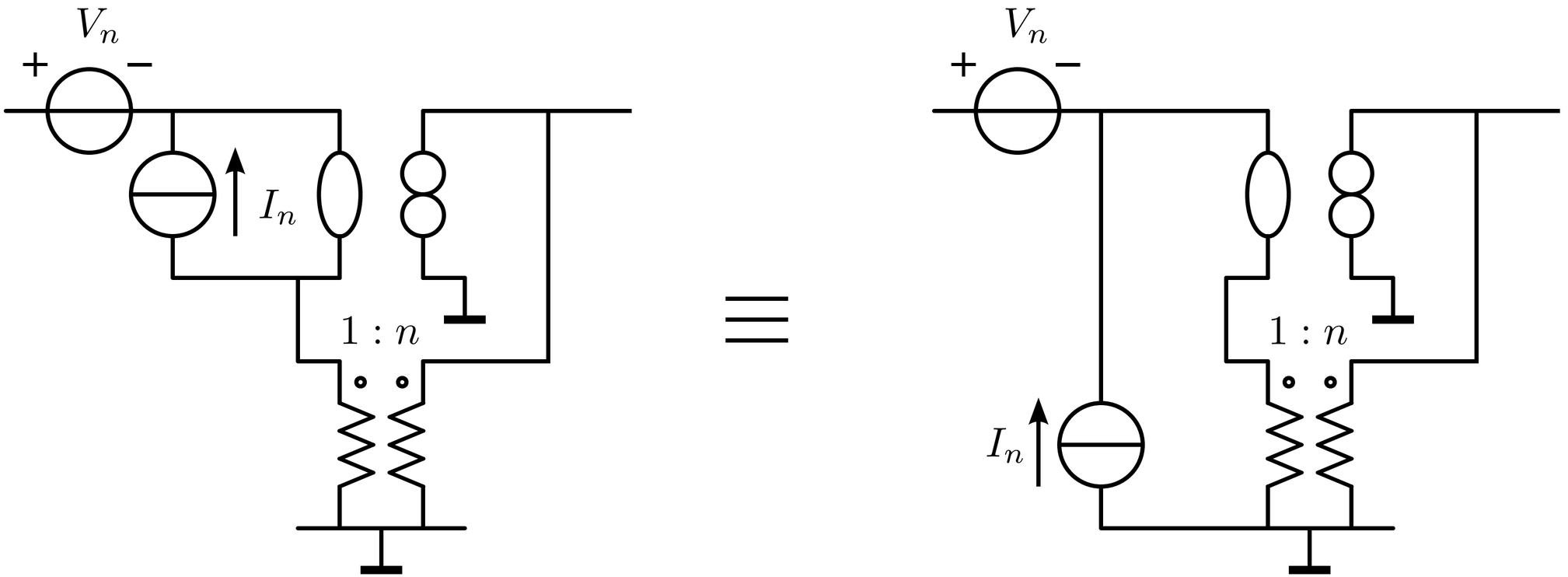

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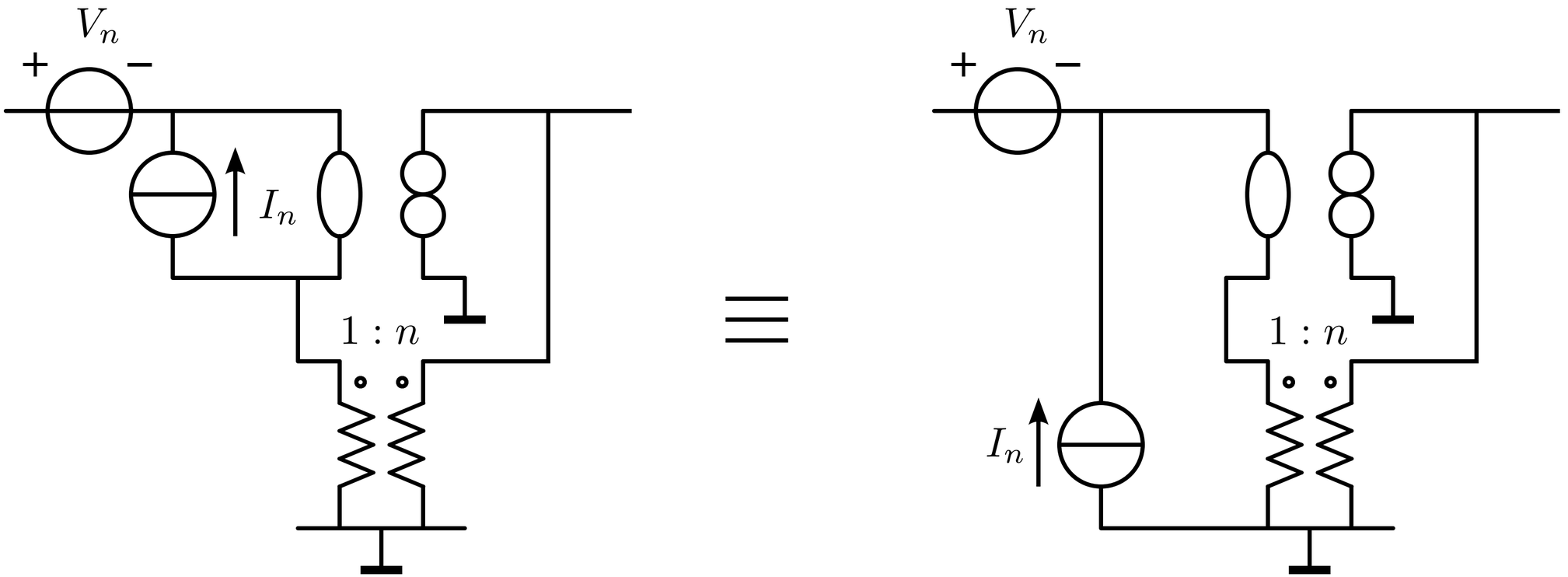

The equivalent input noise sources of a nonenergic feedback amplifier are equal to those of its controller

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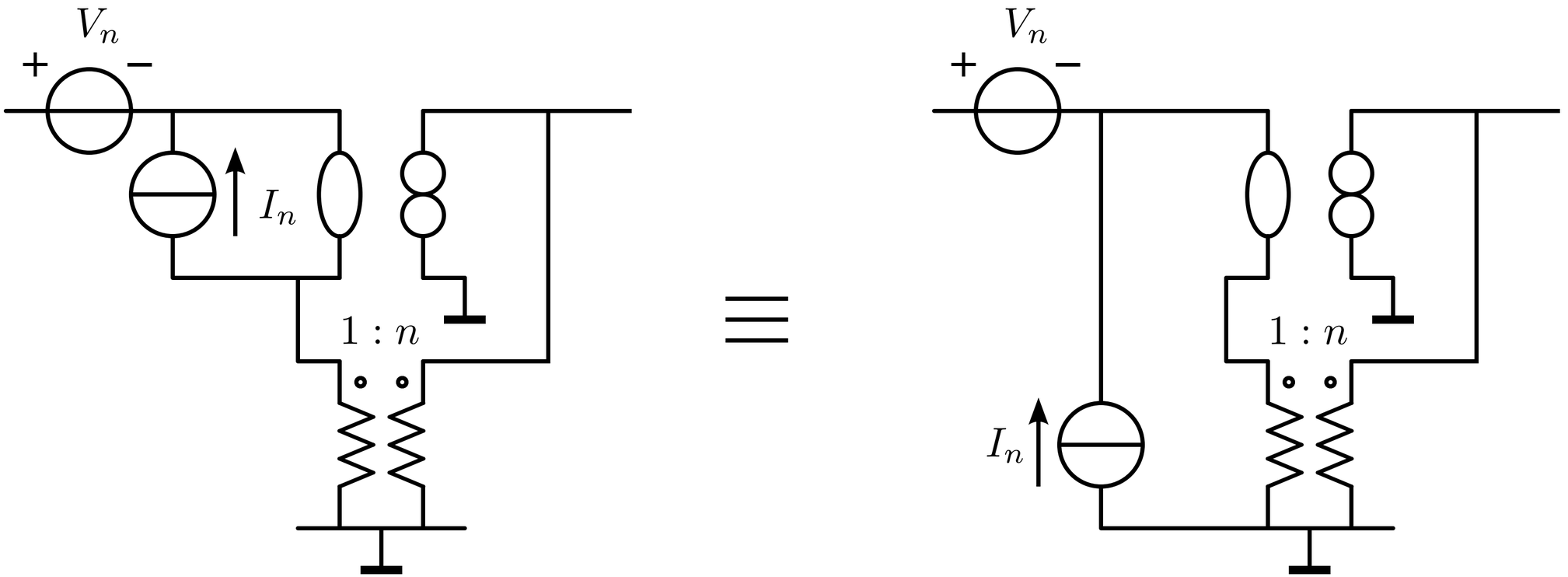

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Noise performance of passive feedback amplifiers

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Noise performance of passive feedback amplifiers

Study the noise performance of
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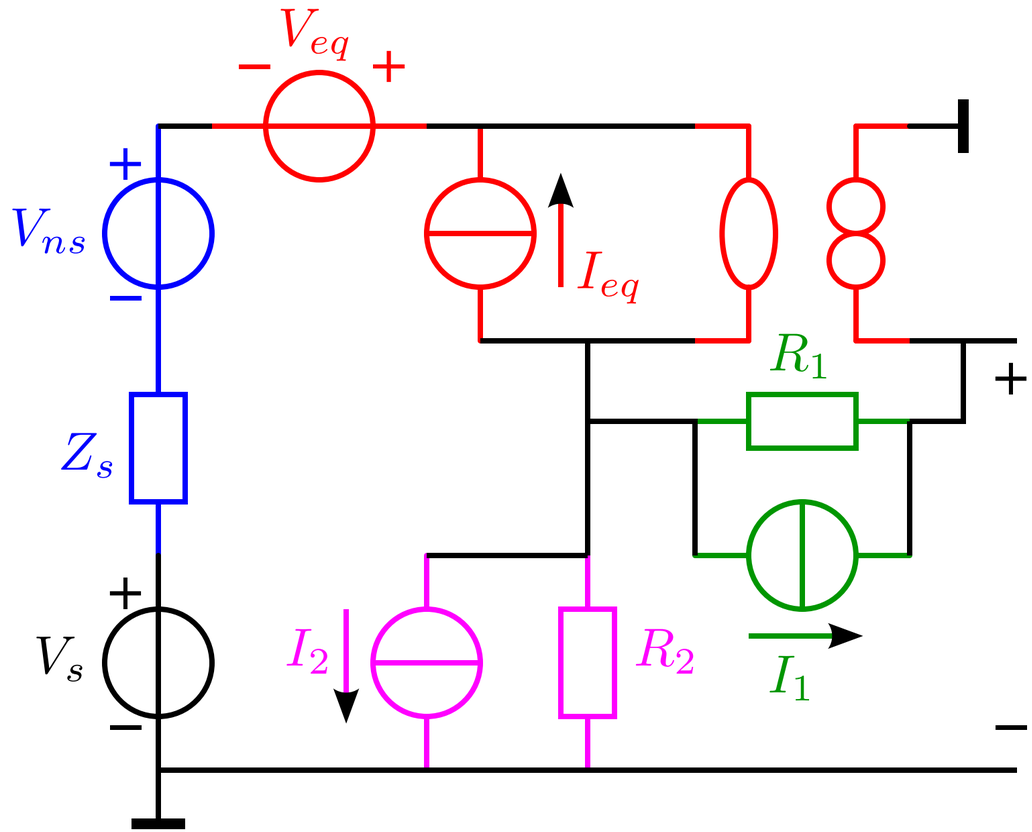
Noise performance of passive feedback amplifiers

Study the noise performance of passive feedback voltage amplifier

Use an alternative method:

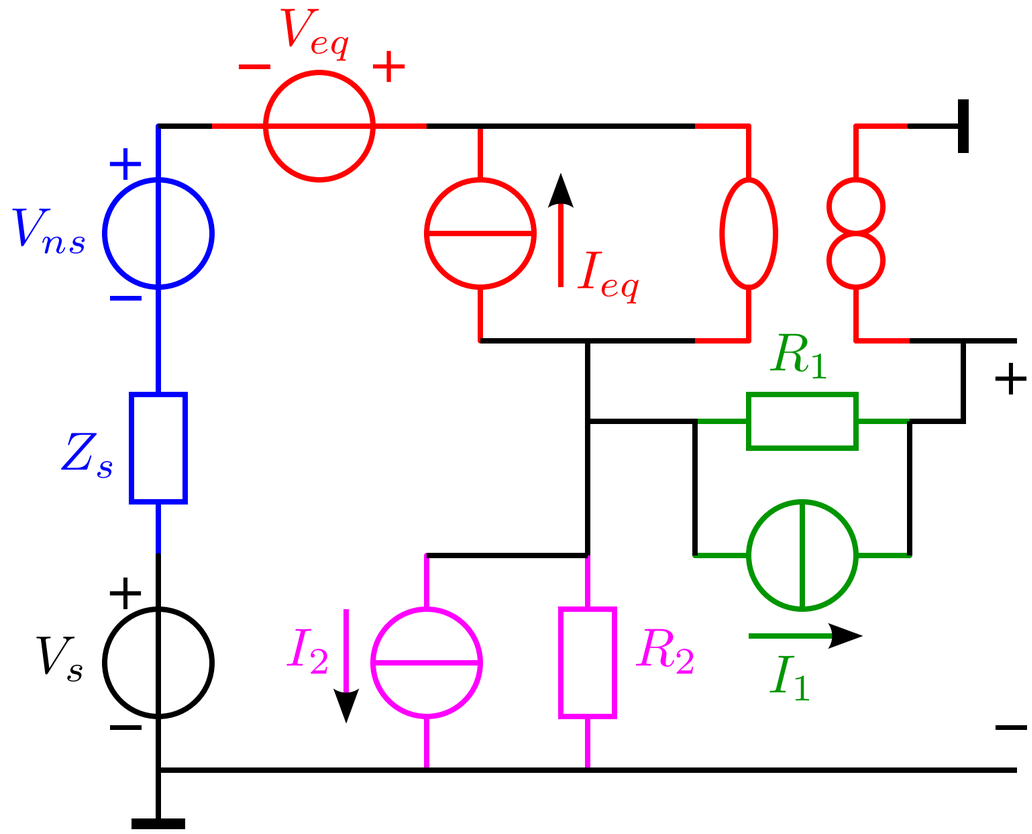


Noise performance of passive feedback amplifiers

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



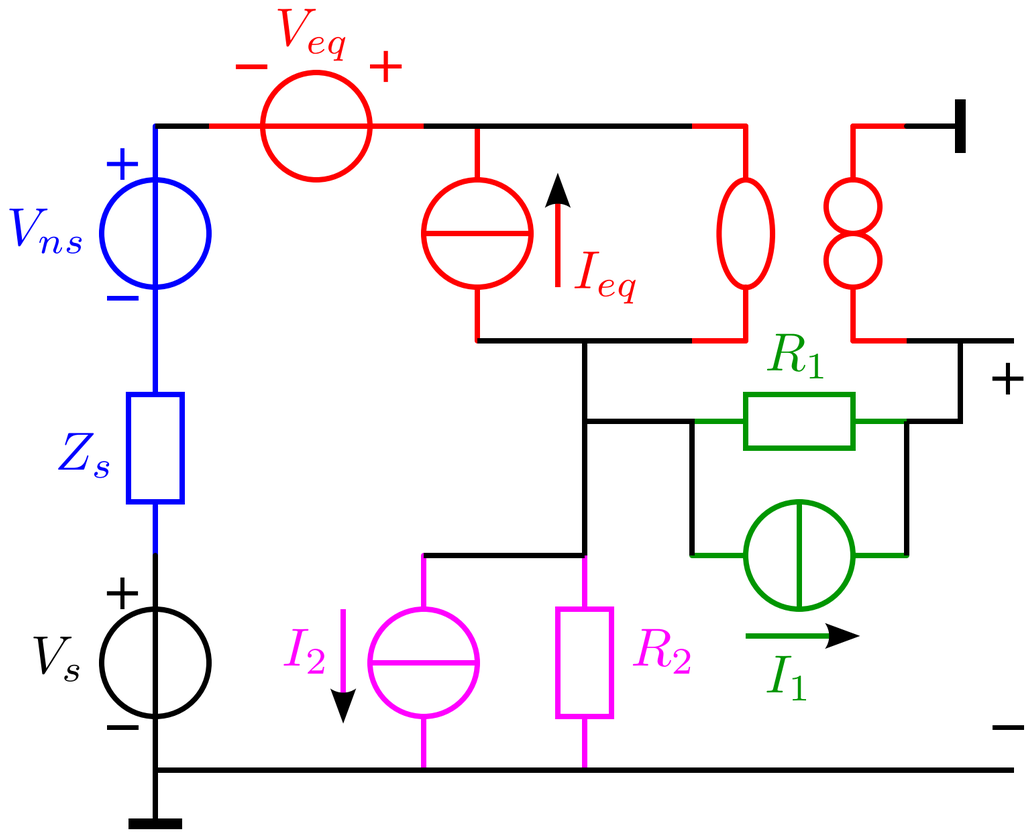
Noise performance of passive feedback amplifiers

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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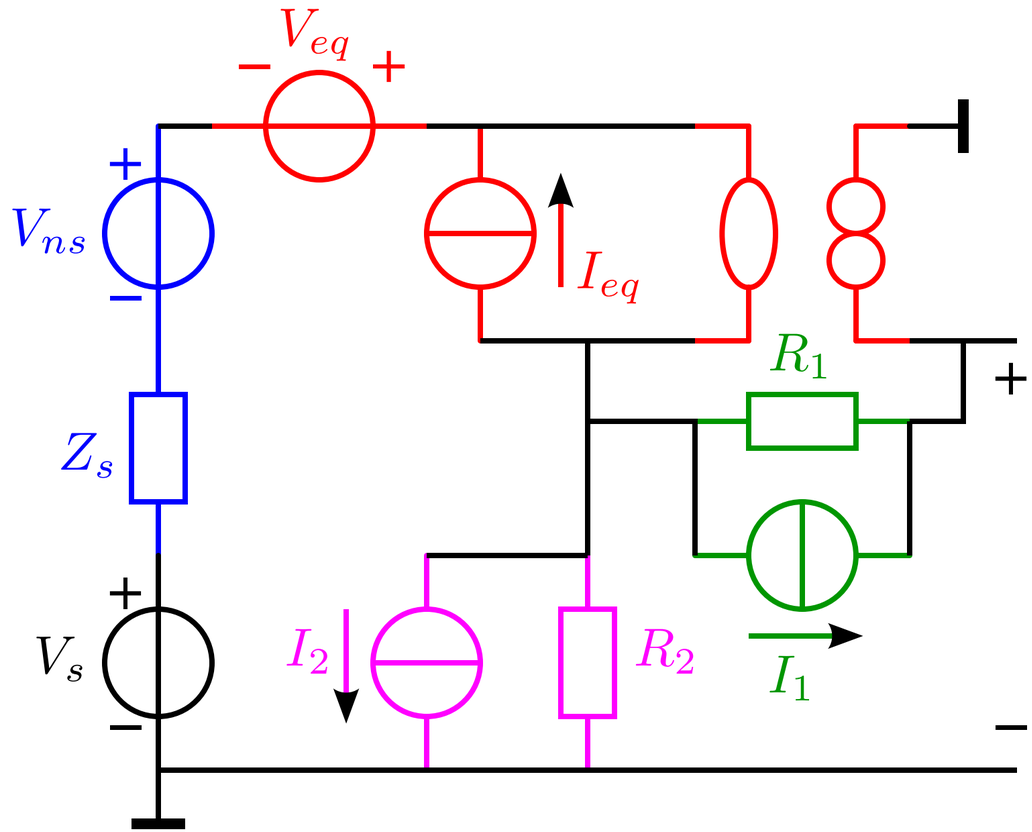
1. Determine contribution of each noise source to output noise spectral density
2. Multiply this with the reciprocal value of the source-to-load transfer to obtain the contribution to the source-referred noise spectral density
3. Sum all contributions to these spectral densities to obtain the total source-referred and the total detector-referred noise spectra



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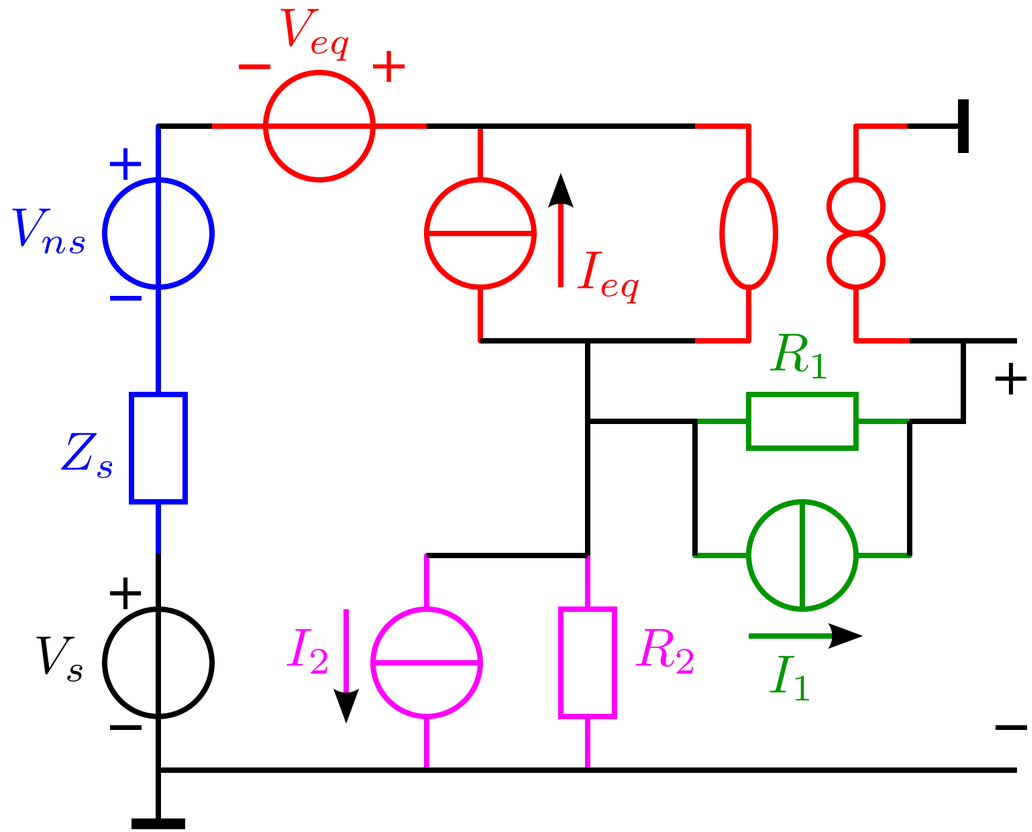

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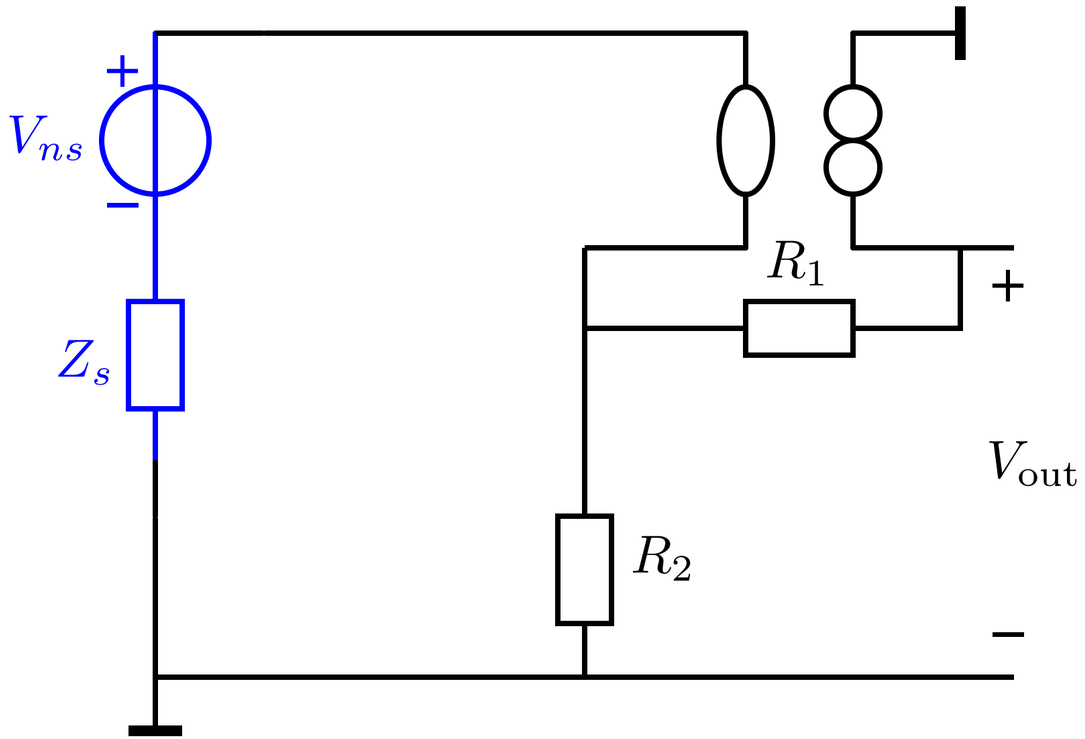
Noise performance of passive feedback amplifiers

Contribution of V_{ns}

Source spectral density: $4kT\mathrm{Re}(Z_s)$

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



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

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

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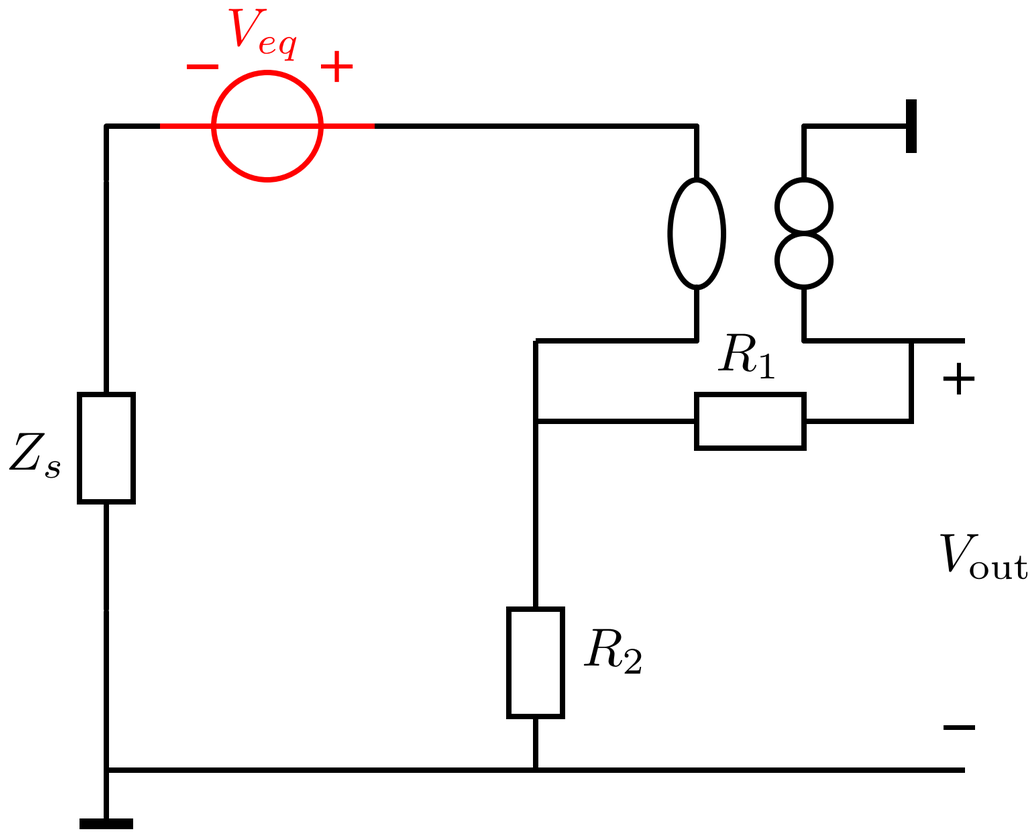
Noise performance of passive feedback amplifiers

Contribution of: V_{eq}

Source spectral density: $S_{V_{eq}}$

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



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

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

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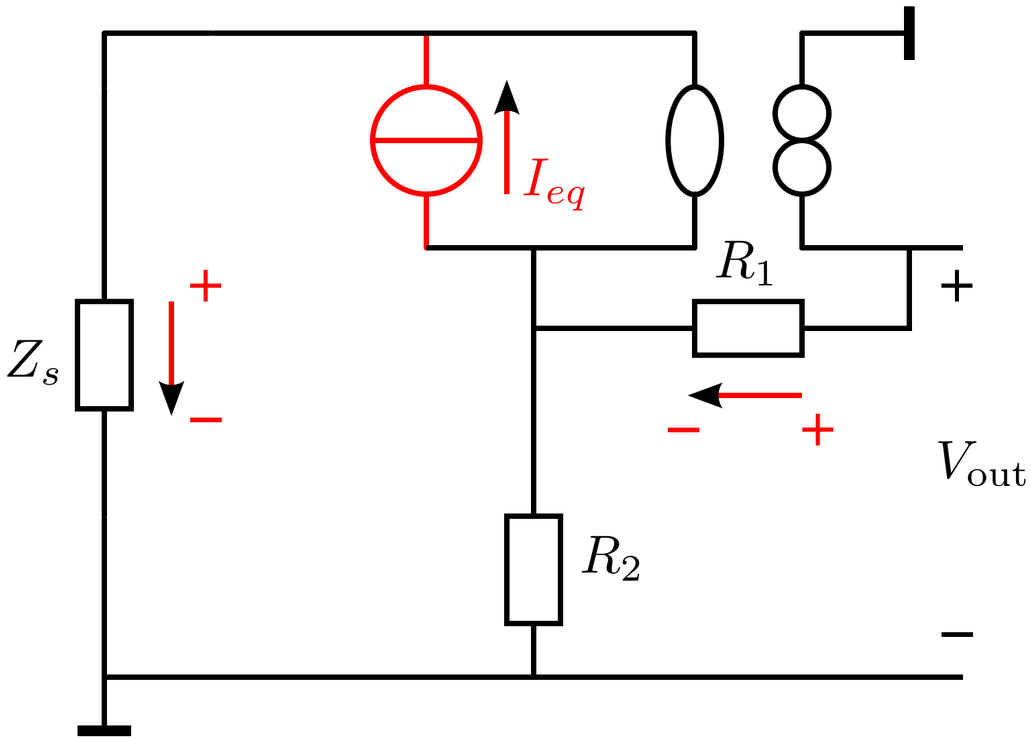
Noise performance of passive feedback amplifiers

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



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

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

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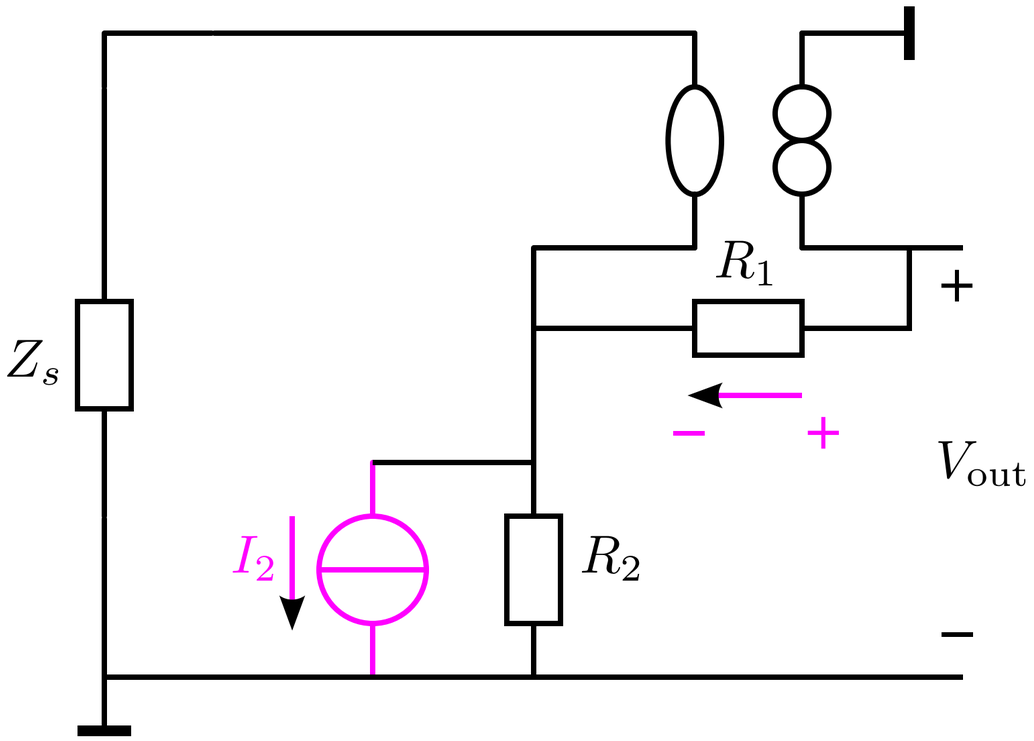
Noise performance of passive feedback amplifiers

Contribution of: I_2

Source spectral density: $\frac{4kT}{R_2}$

Transfer to output: R_1



$$S_{V_{\text{out}}} = 4kT\text{Re}(Z_s)\left(\frac{R_1+R_2}{R_2}\right)^2 + S_{V_{eq}}\left(\frac{R_1+R_2}{R_2}\right)^2 + S_{I_{eq}}\left(\frac{R_1+R_2}{R_2}\right)^2\left(Z_s + \frac{R_1R_2}{R_1+R_2}\right)^2 + 4kT\frac{R_1^2}{R_2}$$

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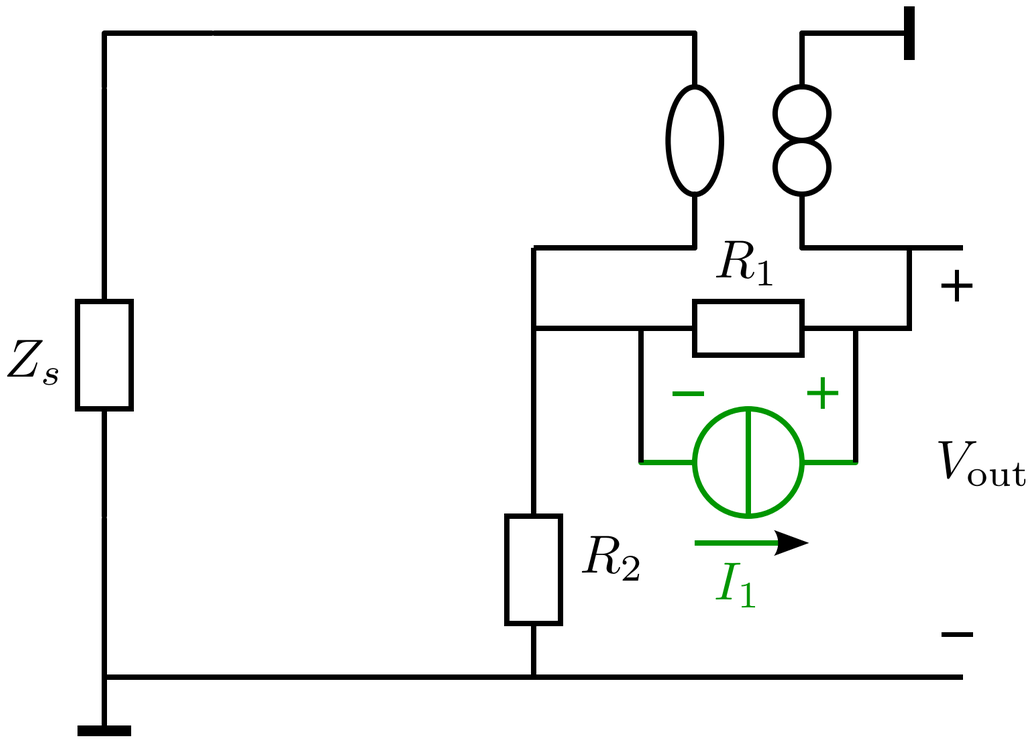
Noise performance of passive feedback amplifiers

Contribution of: I_1

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

Transfer to output: R_1



$$S_{V_{\text{out}}} = 4kT\text{Re}(Z_s)\left(\frac{R_1+R_2}{R_2}\right)^2 + S_{V_{eq}}\left(\frac{R_1+R_2}{R_2}\right)^2 + S_{I_{eq}}\left(\frac{R_1+R_2}{R_2}\right)^2\left(Z_s + \frac{R_1R_2}{R_1+R_2}\right)^2 + 4kT\frac{R_1^2}{R_2} + 4kTR_1$$

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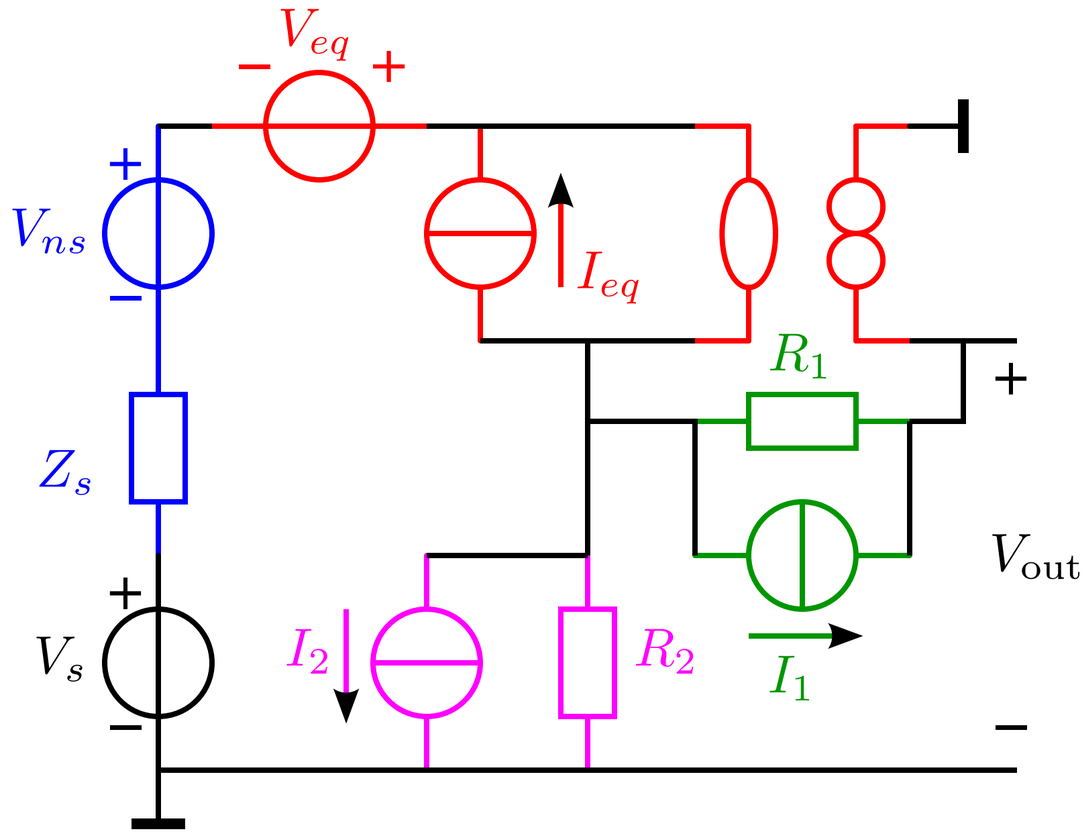
Noise performance of passive feedback amplifiers

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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Conclusions noise performance of passive feedback amplifiers

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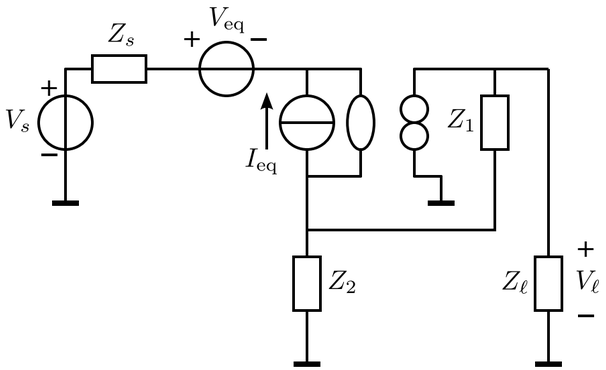
A

Voltage amplifier



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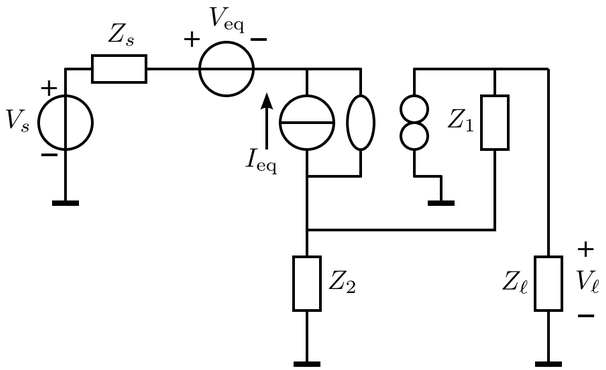
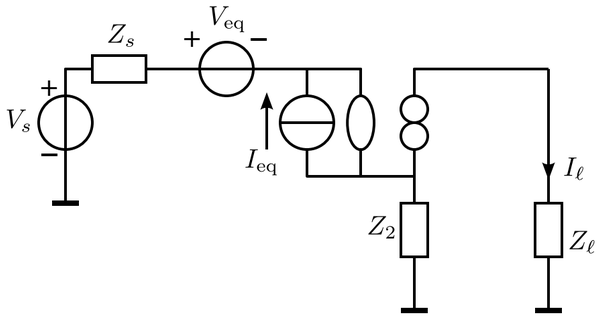


B

Transadmittance



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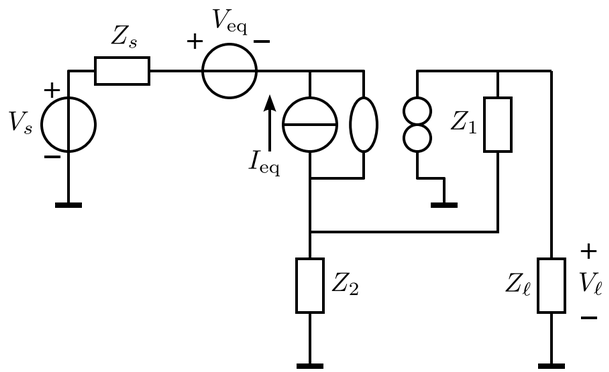

B

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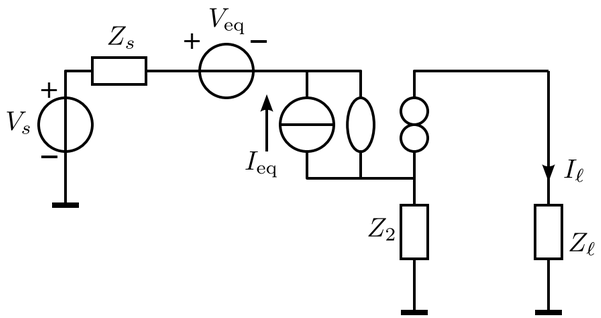
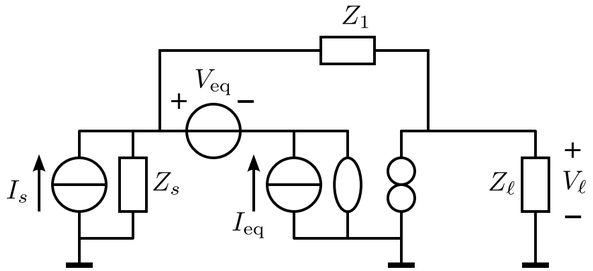


C

Transimpedance



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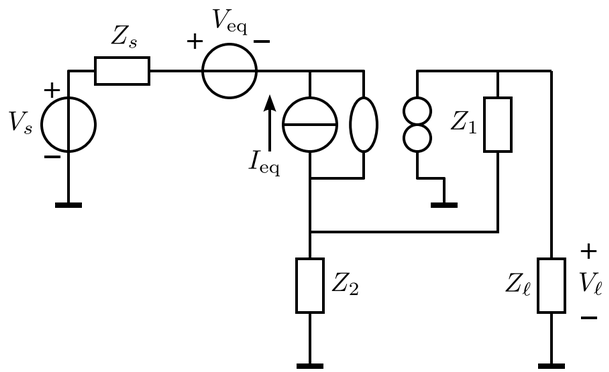

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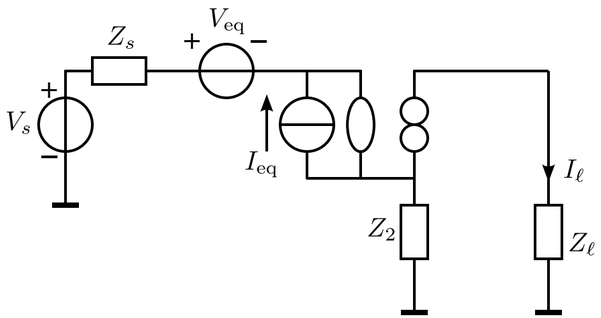

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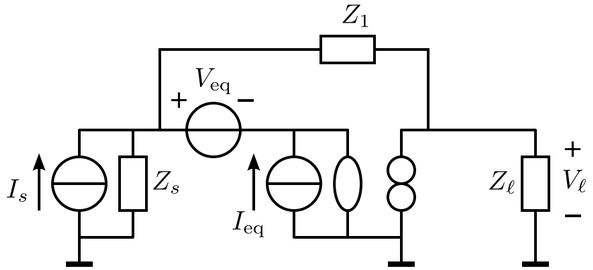
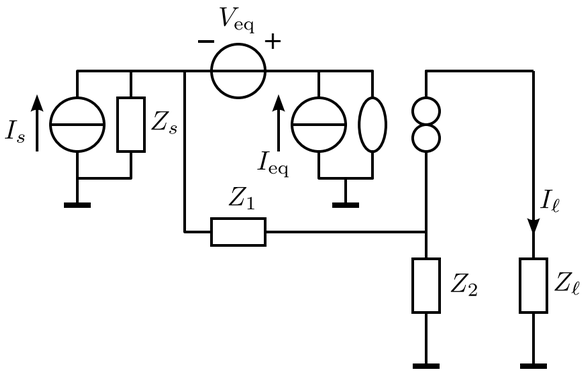


D

Current amplifier



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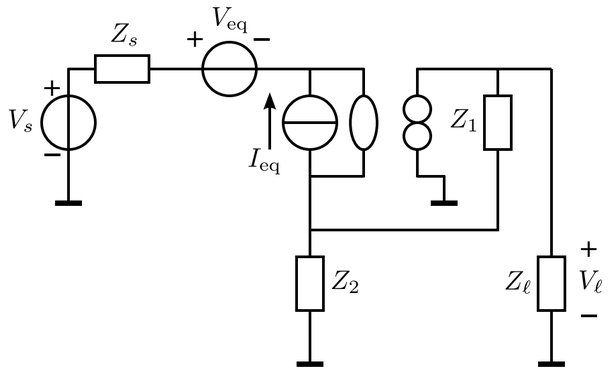
Conclusions noise performance of passive feedback amplifiers

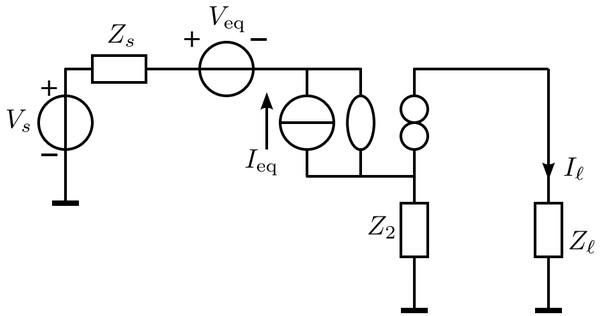
A

Voltage amplifier



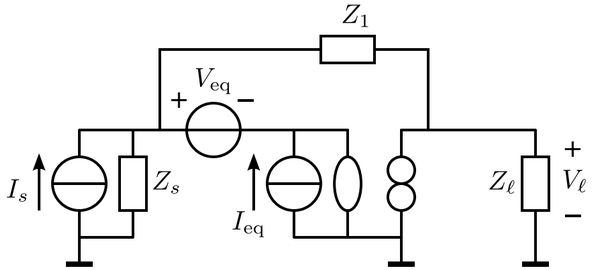
B

Transadmittance



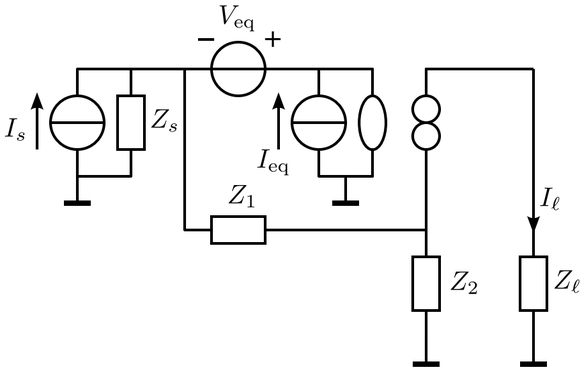
C

Transimpedance



D

Current amplifier



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Conclusions noise performance of passive feedback amplifiers

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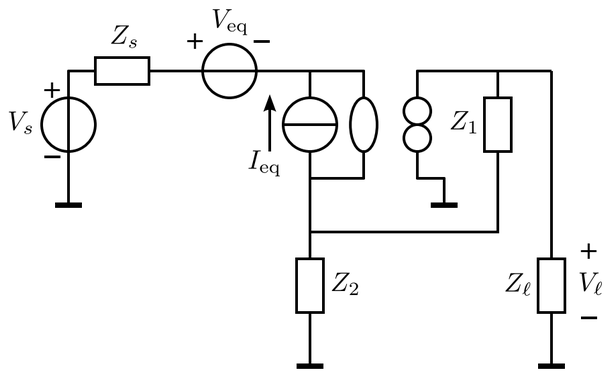
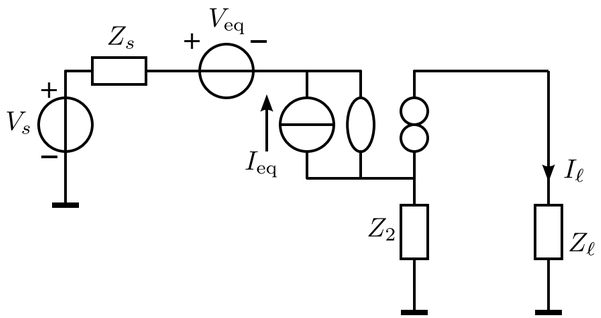


B

Transadmittance



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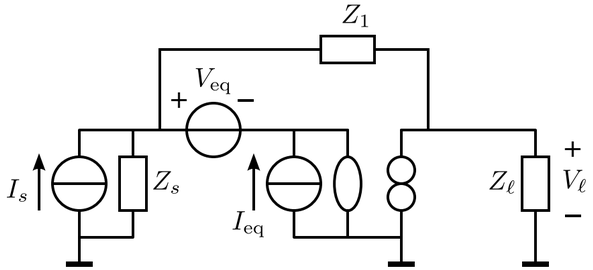
Transimpedance



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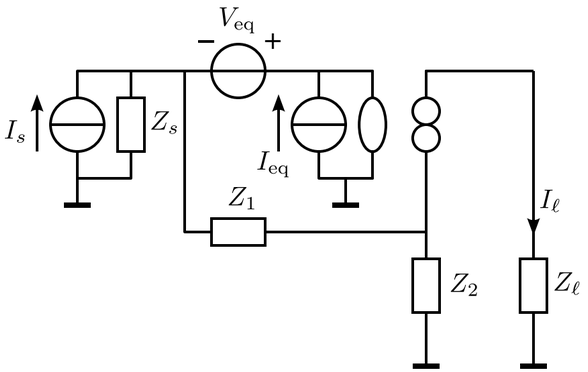
Current amplifier



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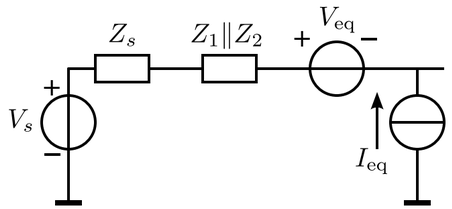
is in series with the source



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Conclusions noise performance of passive feedback amplifiers

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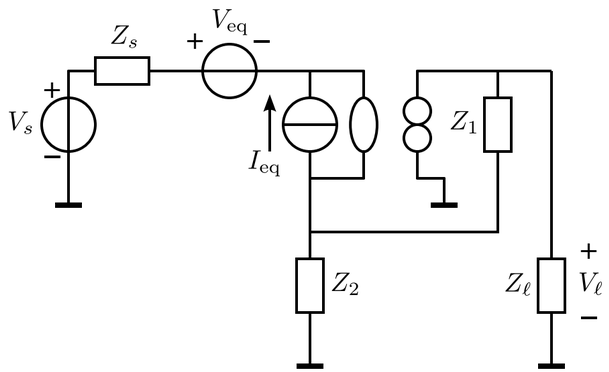
Voltage amplifier



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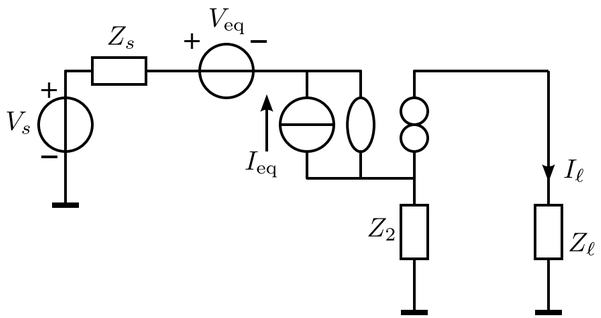
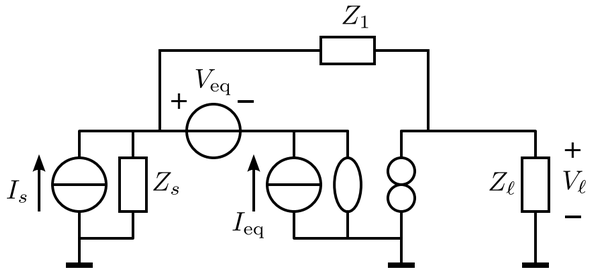
Transadmittance



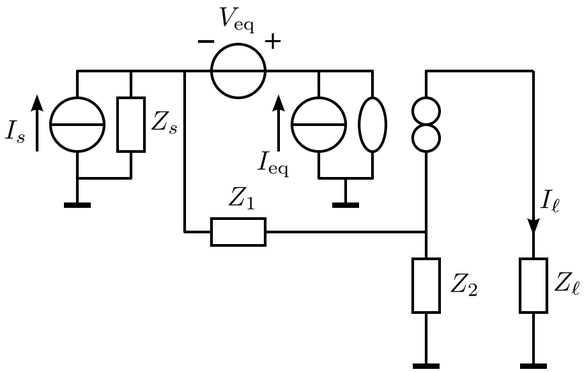
C

Transimpedance



D

Current amplifier



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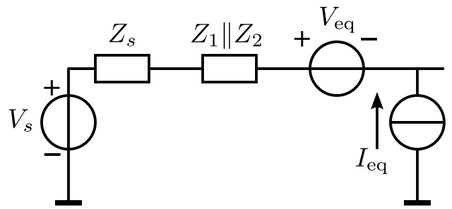

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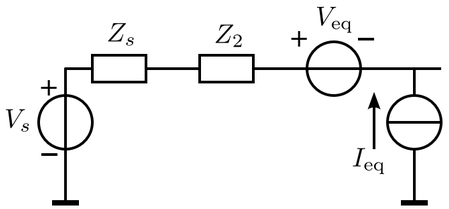

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Conclusions noise performance of passive feedback amplifiers

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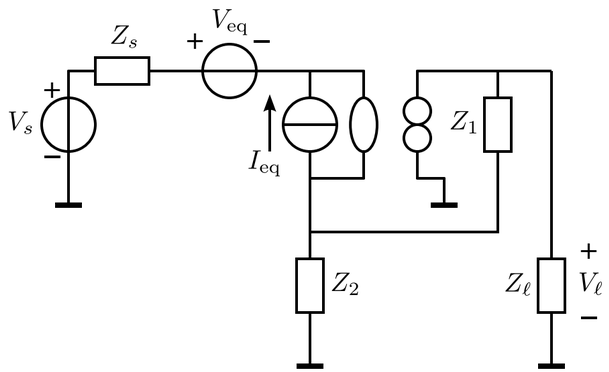
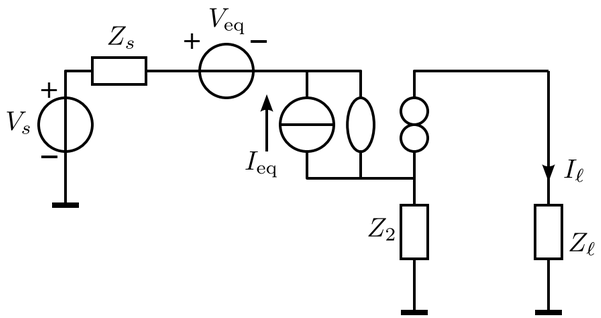
Voltage amplifier



B

Transadmittance



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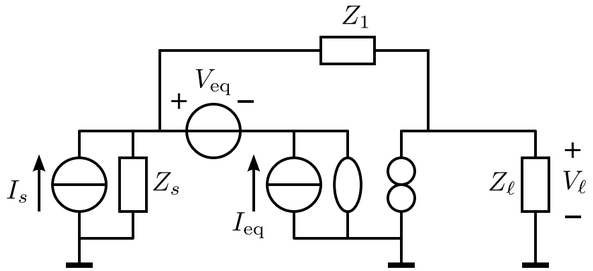
Transimpedance



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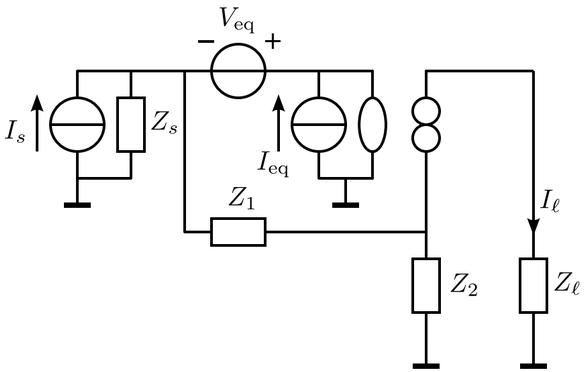

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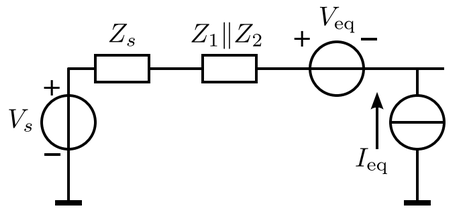

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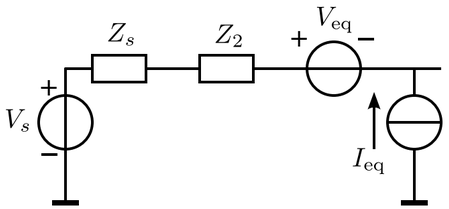
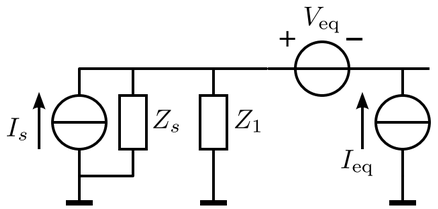


As if the feedback impedance is in parallel with the source



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Conclusions noise performance of passive feedback amplifiers

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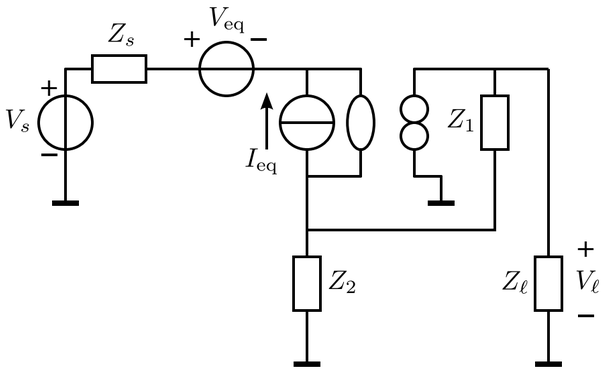
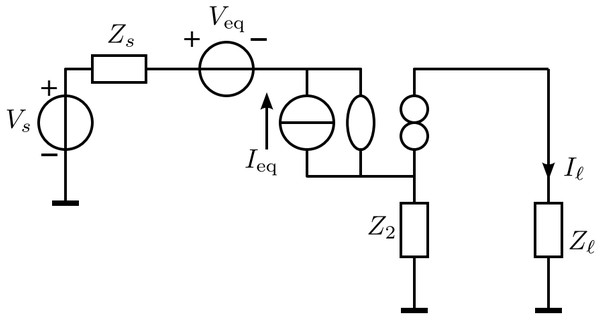
Voltage amplifier



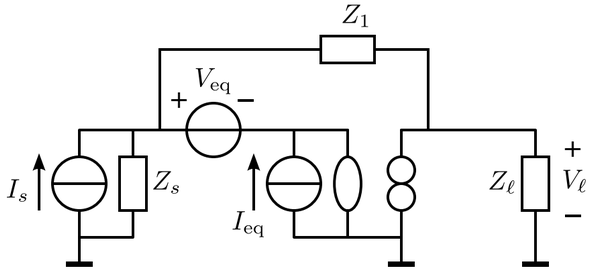
B

Transadmittance



C

Transimpedance



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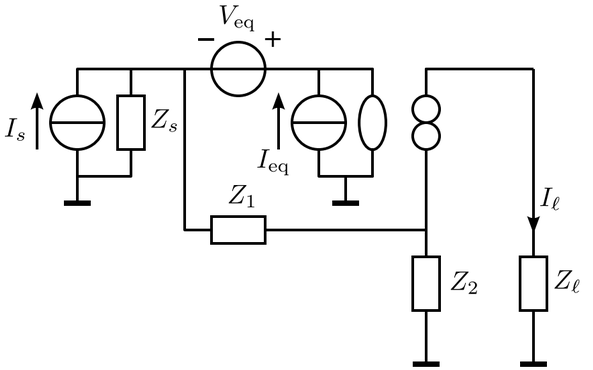

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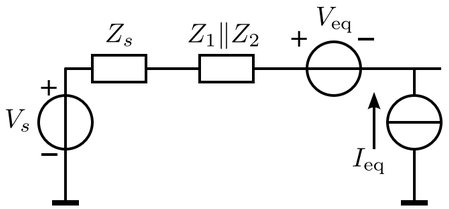

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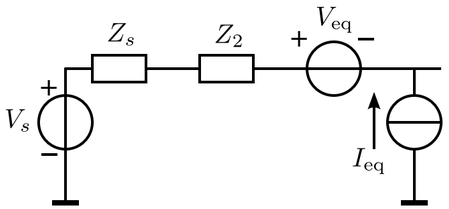

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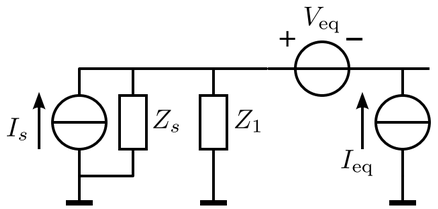

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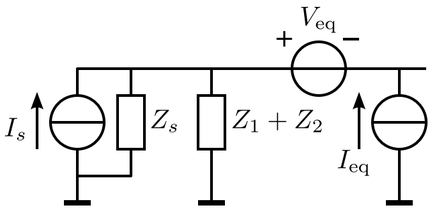

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Conclusions noise performance of passive feedback amplifiers

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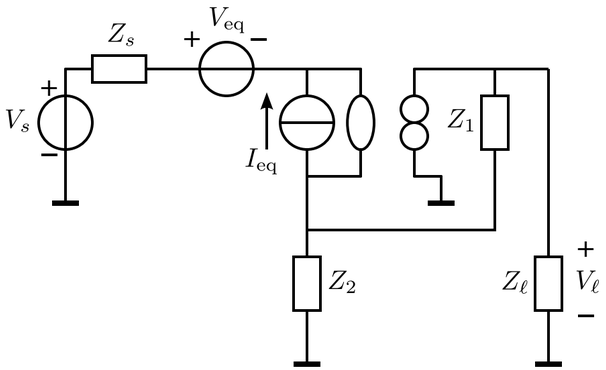

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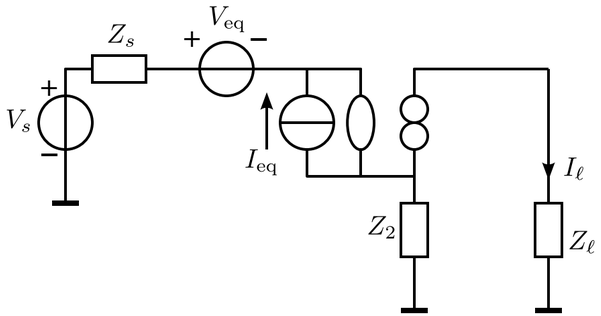

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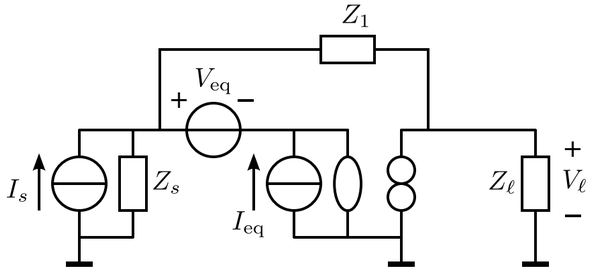

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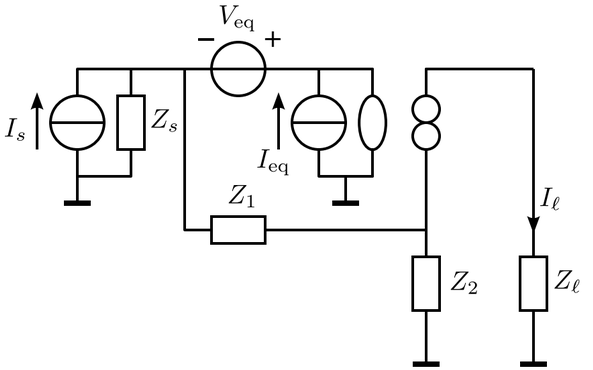

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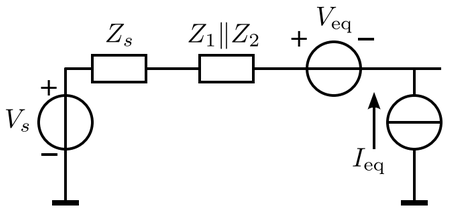

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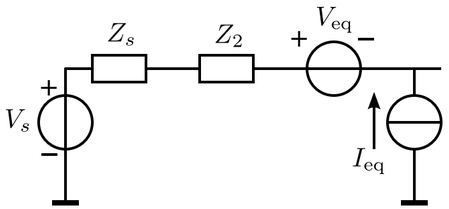

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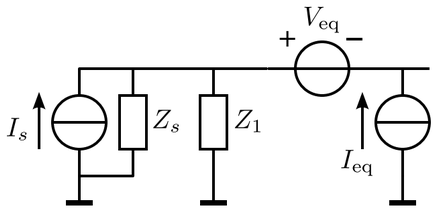

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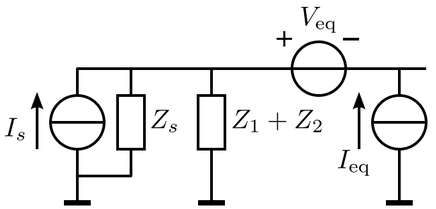

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