Structured Electronic Design
Noise in Electronic Circuits

Noise mechanisms

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Thermal noise

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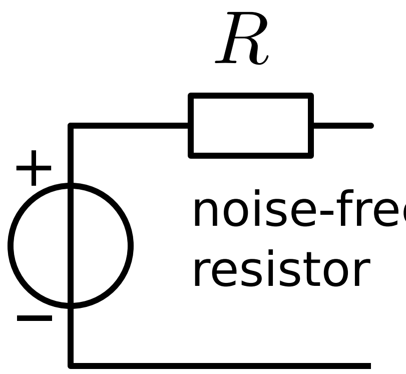

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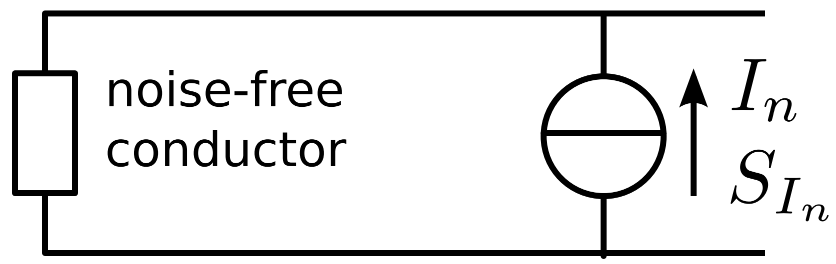

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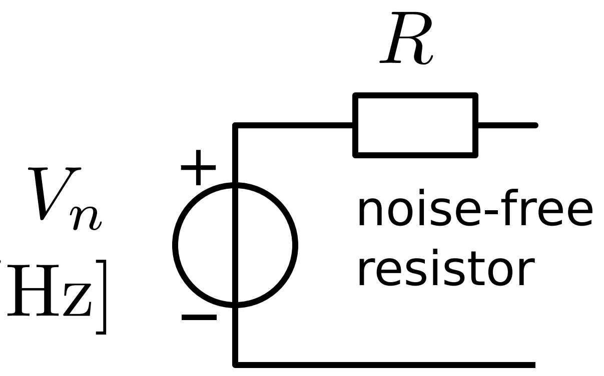
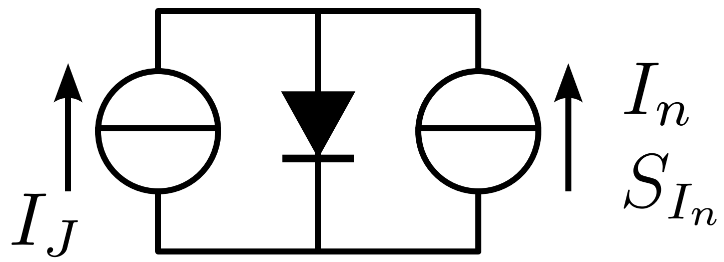


Shot noise

Noise current associated with a
DC current through a junction.



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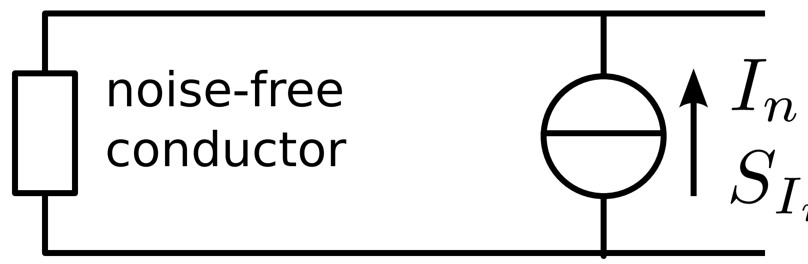

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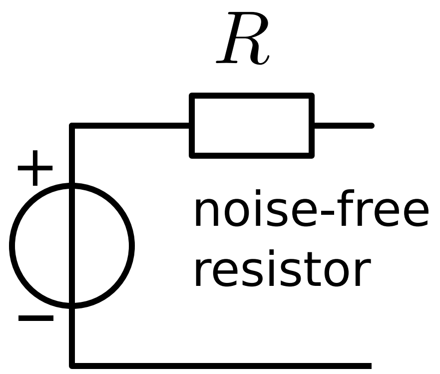

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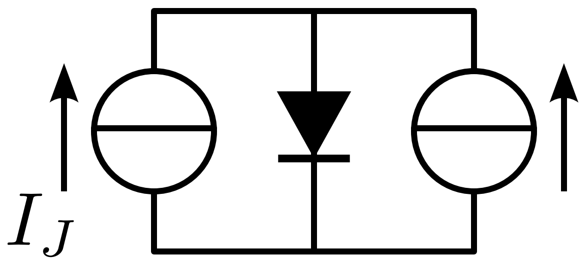

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Excess noise

Noise current resulting from fluctuations in conduction mechanism.

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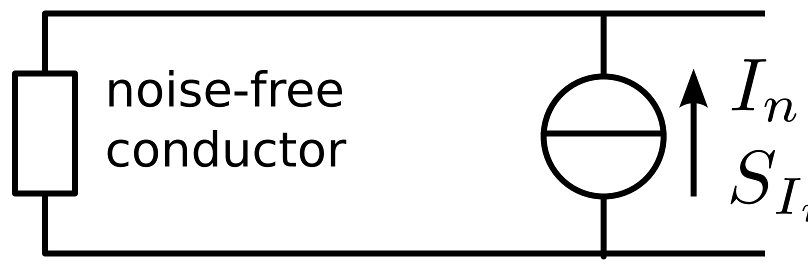

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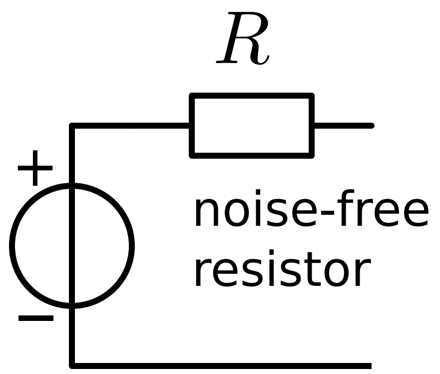

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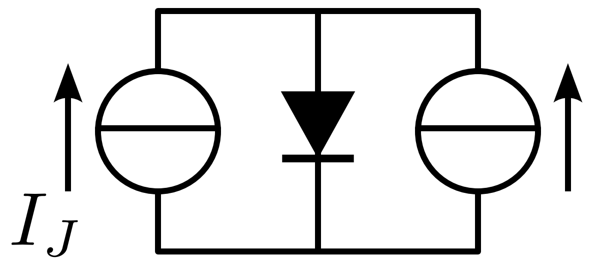

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In junctions $S_{I_n} = K\frac{I_J^{\alpha}}{f}$

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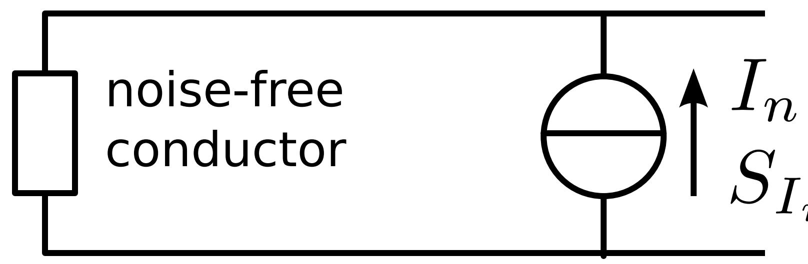

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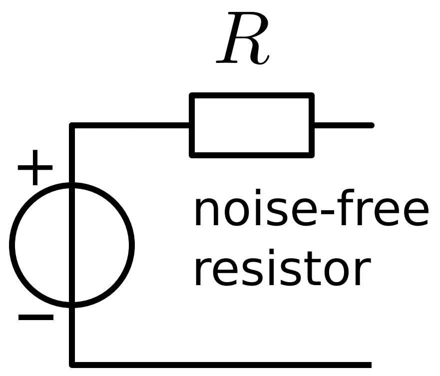

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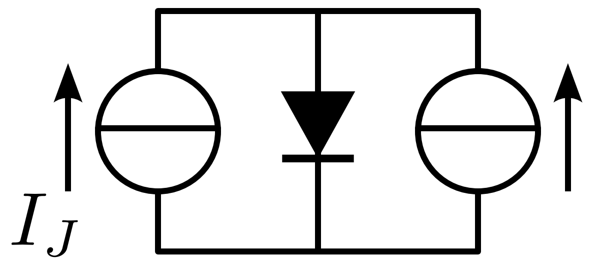

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Drawing conventions

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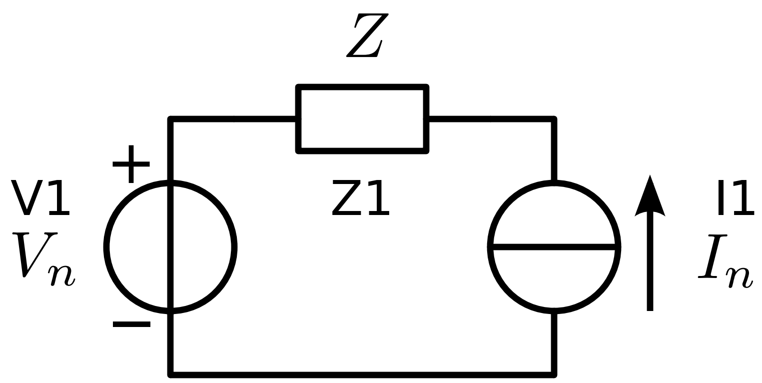
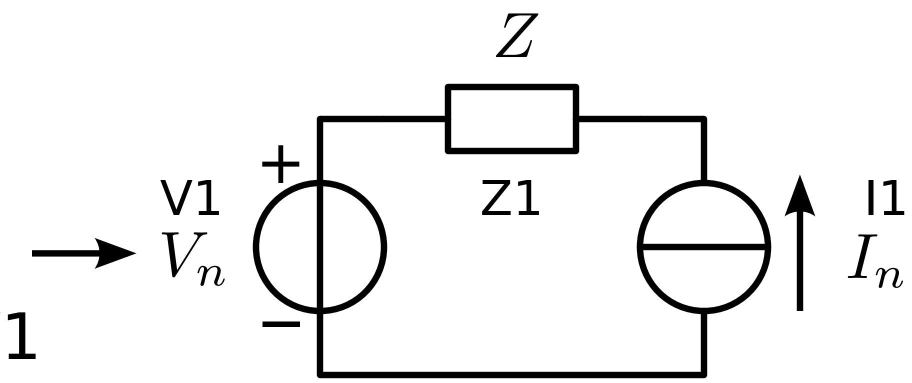


Drawing conventions

Fourier
Transform
of noise
voltage of V1



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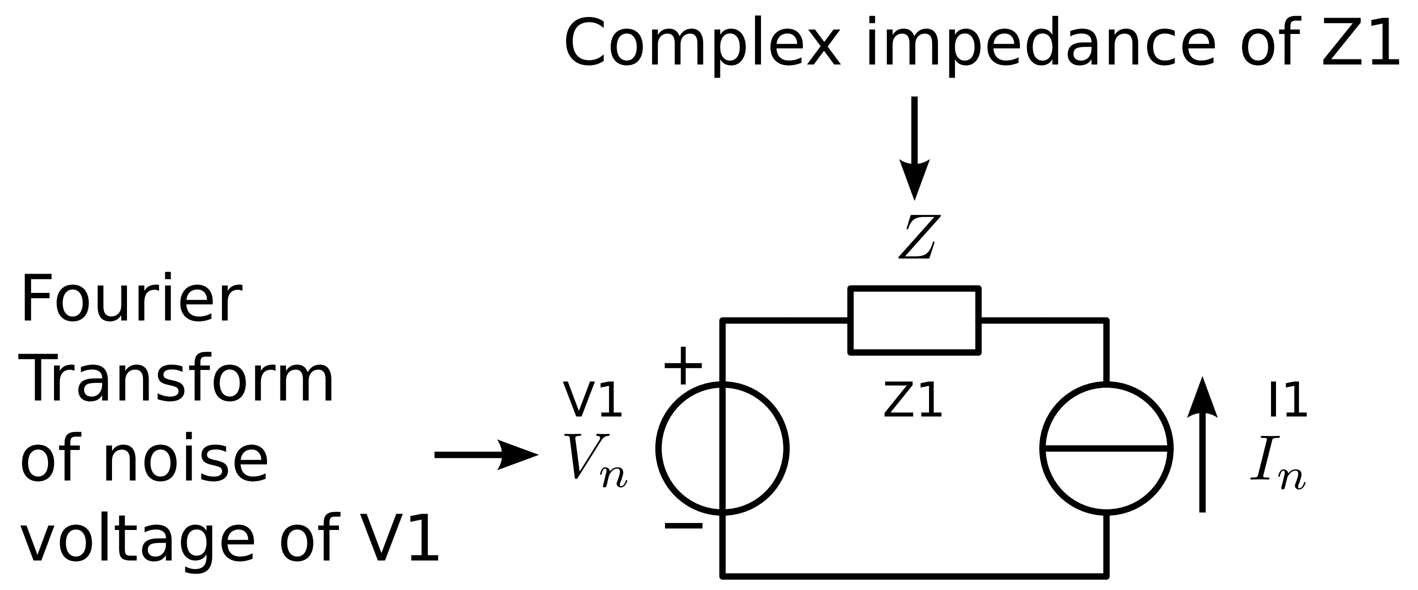

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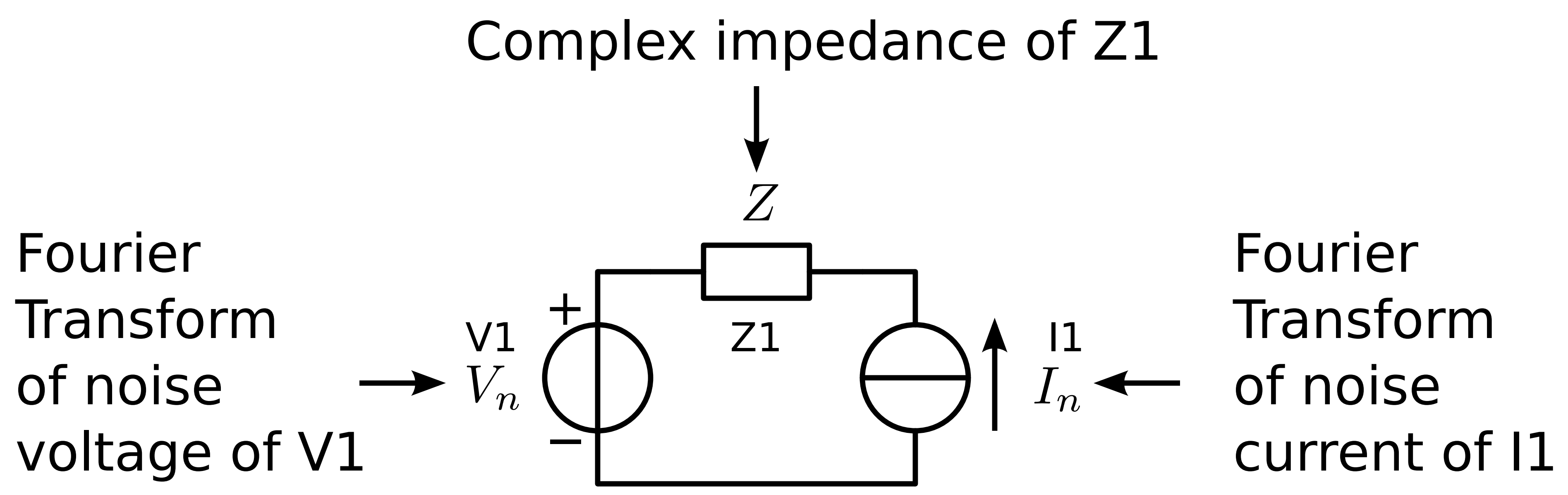

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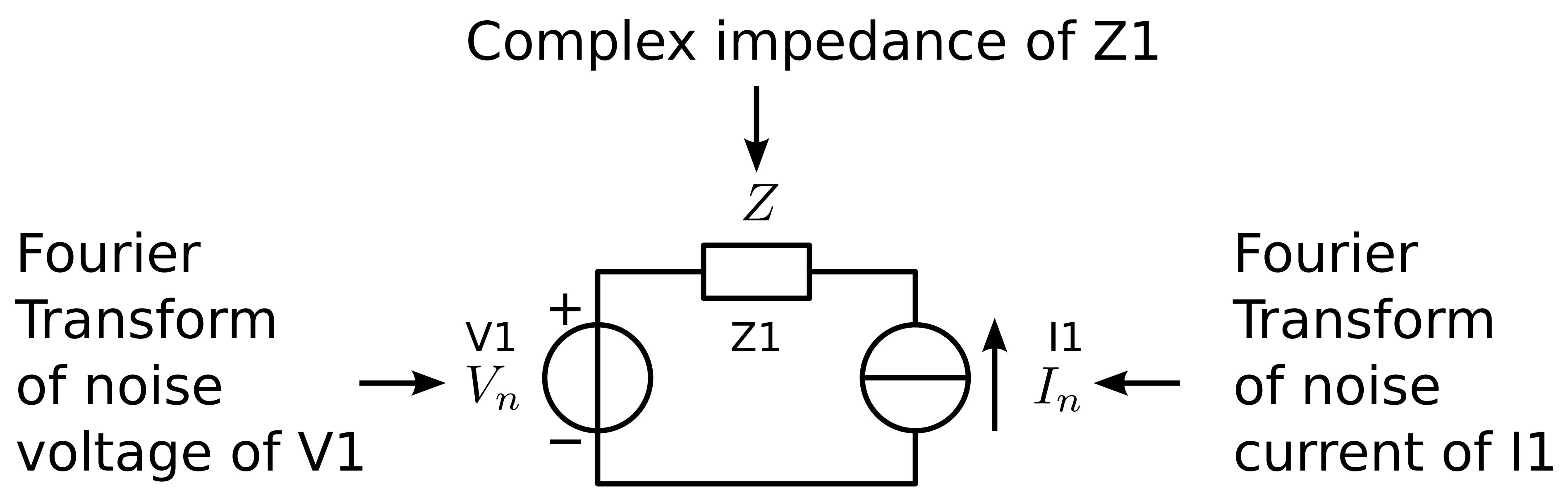
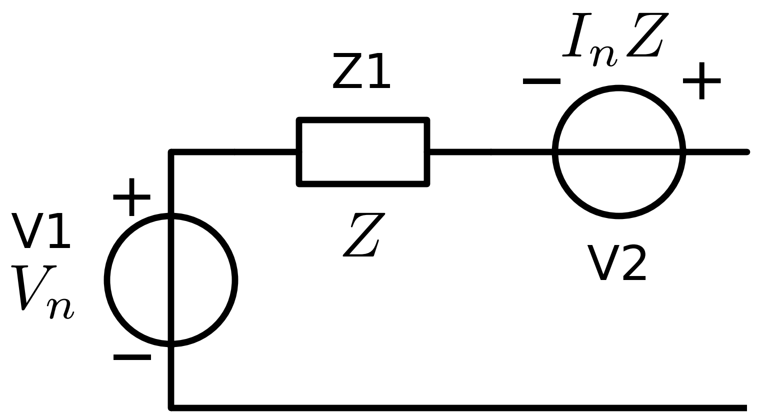


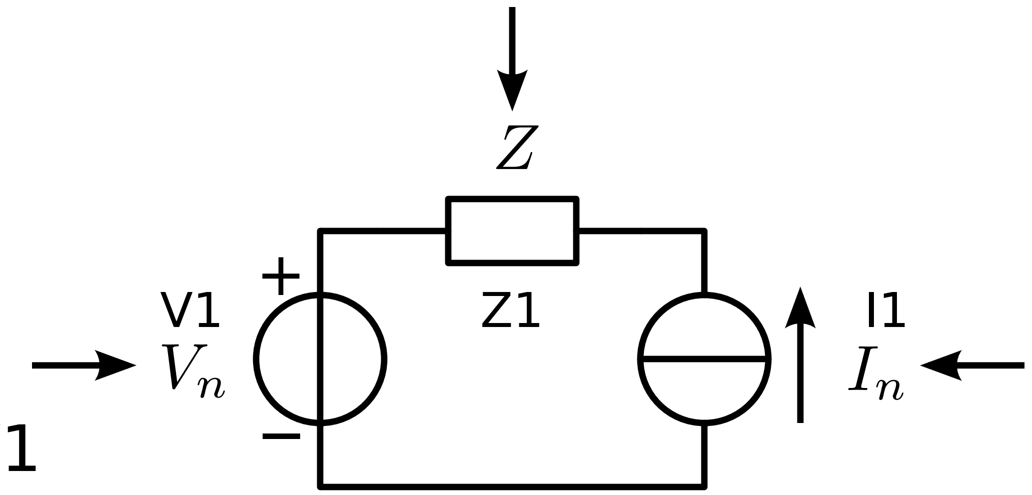
Equivalent circuit after Norton-Thevenin Transformation



Drawing conventions

Complex impedance of Z1

Fourier Transform of noise voltage of V1



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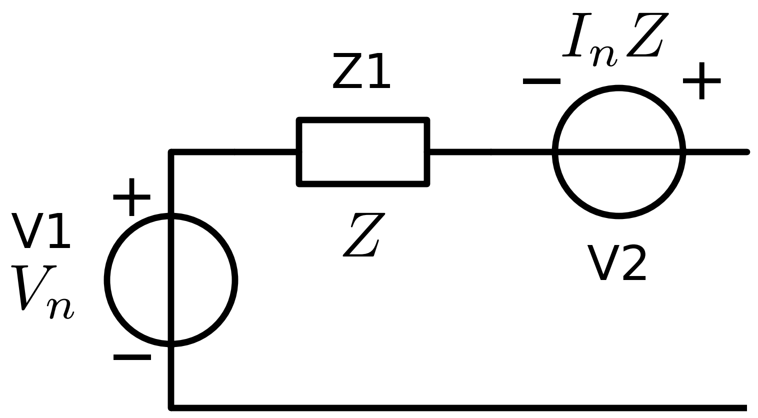
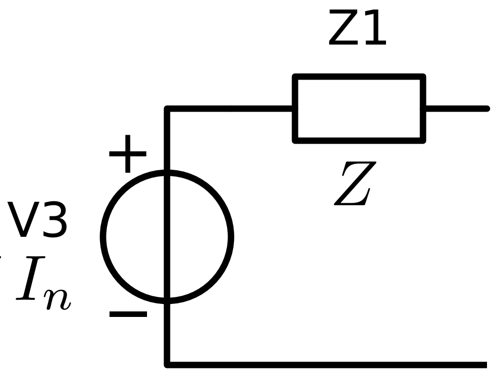


Equivalent circuit in which the voltage of V3 represents the total noise voltage

$$V_{n,tot} = V_n + Z\,I_n$$



Noise parameters

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Equivalent noise bandwidth of a system

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Noisy two-ports

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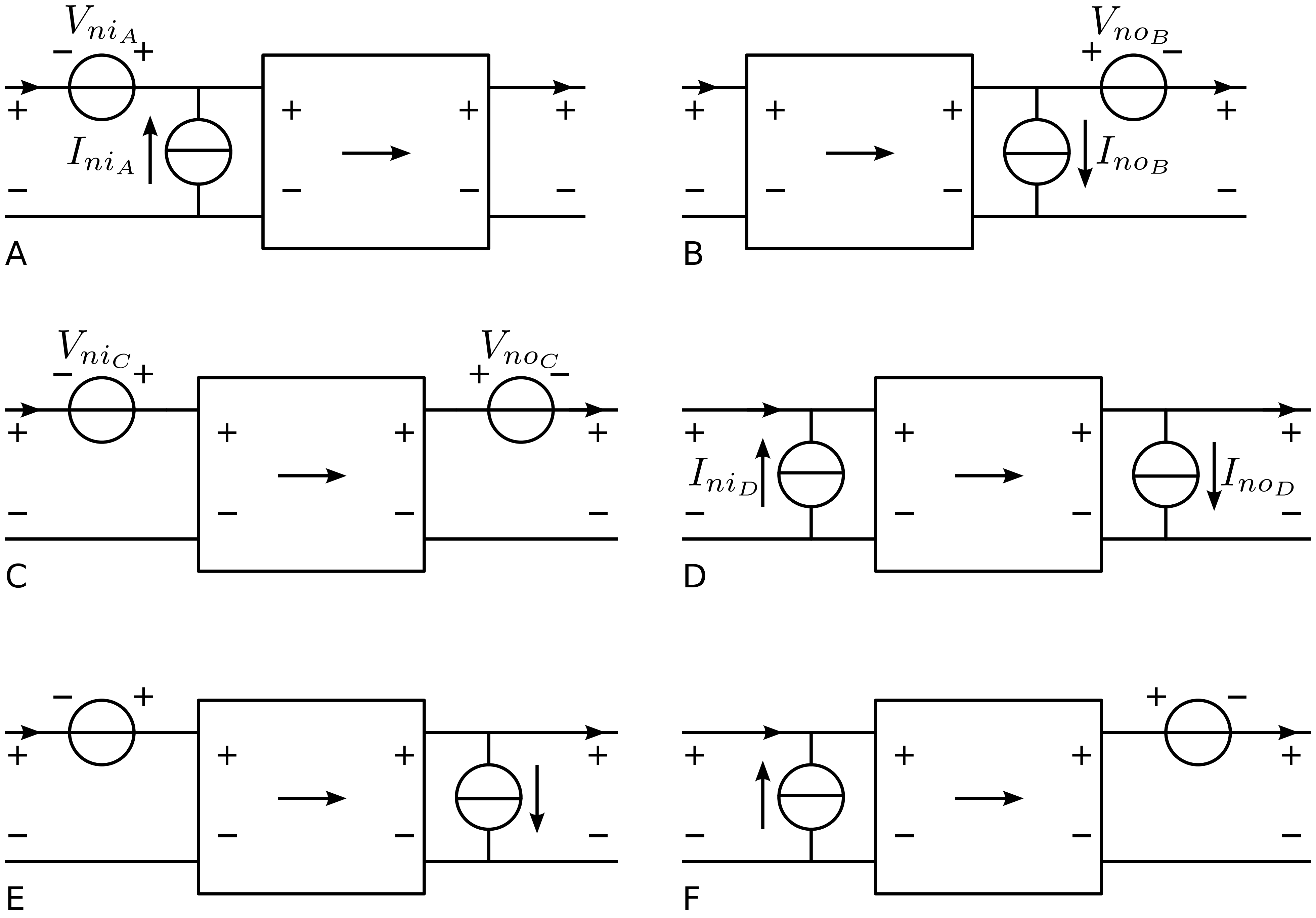

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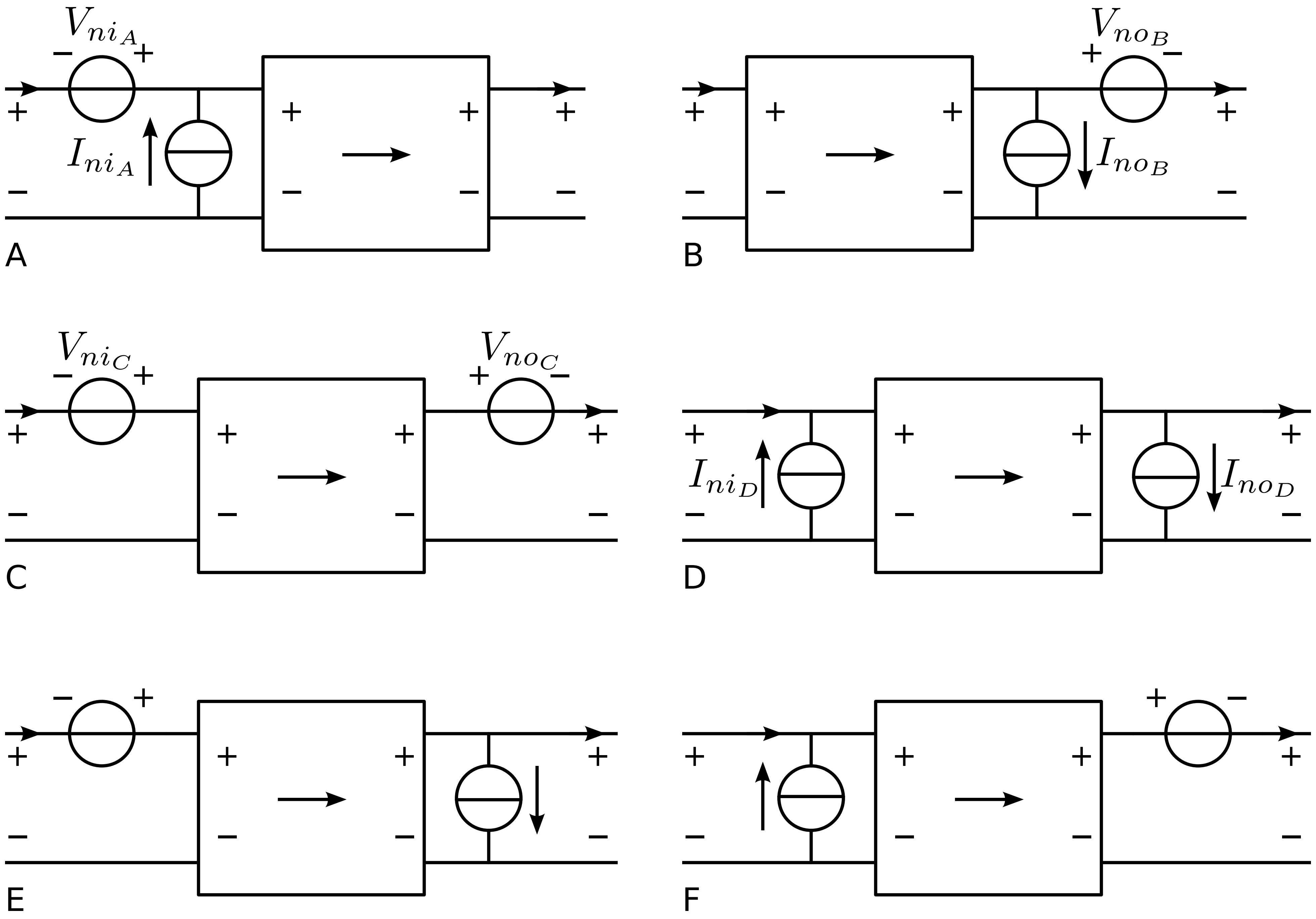

Noise representation

- A noise-free two-port with two noise sources
- Six representations: 4 port variables:
  * two independent variables
  * two dependent variables

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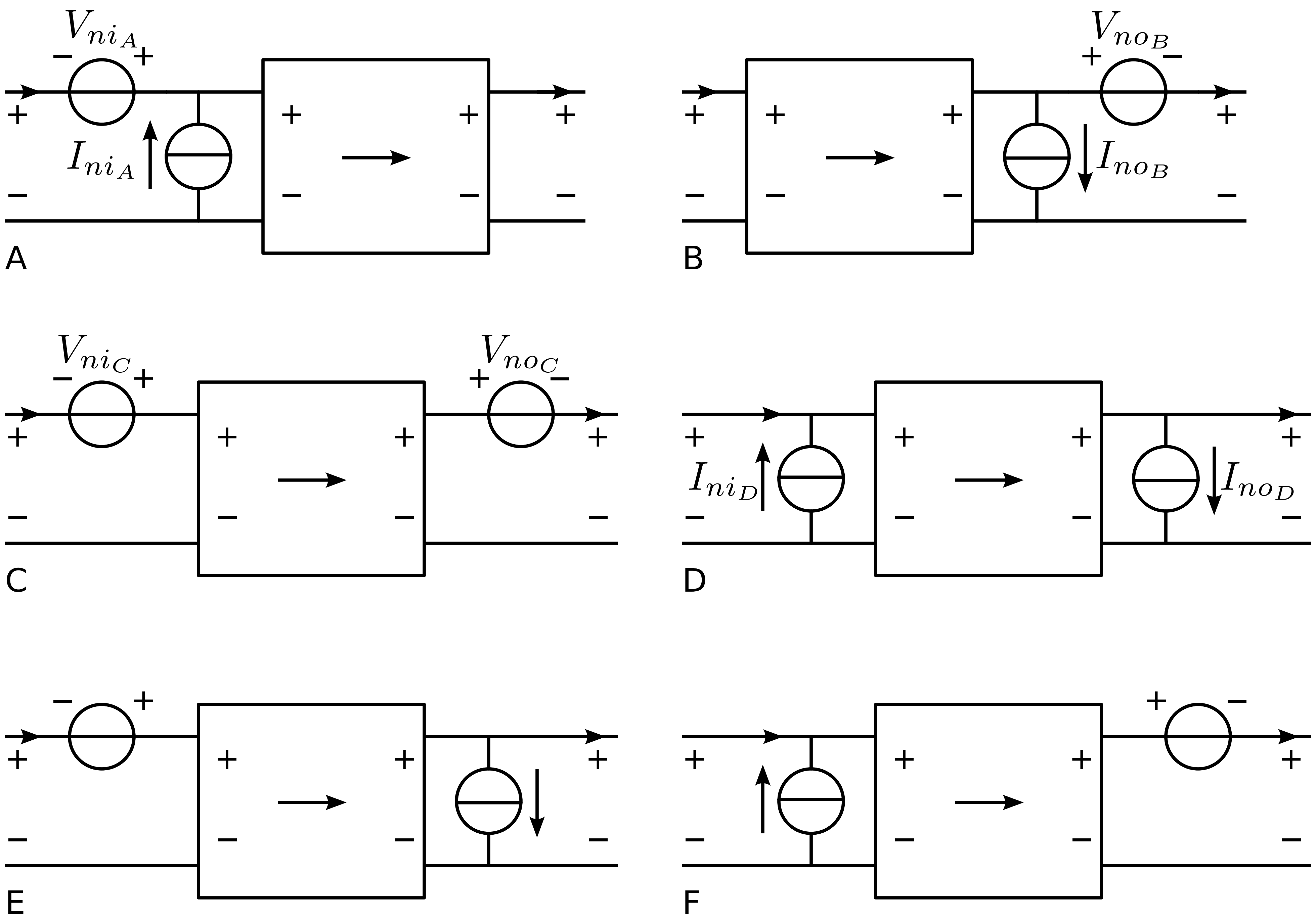

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Can be translated into each other

- Example 2.9
- Example 19.2

Amplifier noise measurement

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- Measure spectrum of the output noise for open and shorted input
- Calculate input noise sources from load impedance and A,B,C,D.

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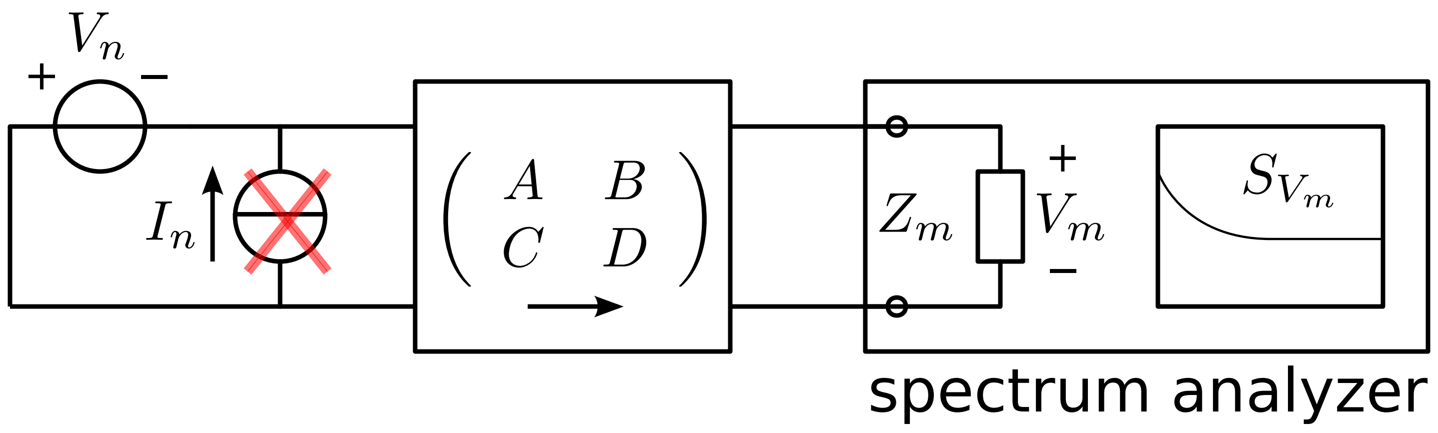
Input noise current does not contribute to amplifier output noise



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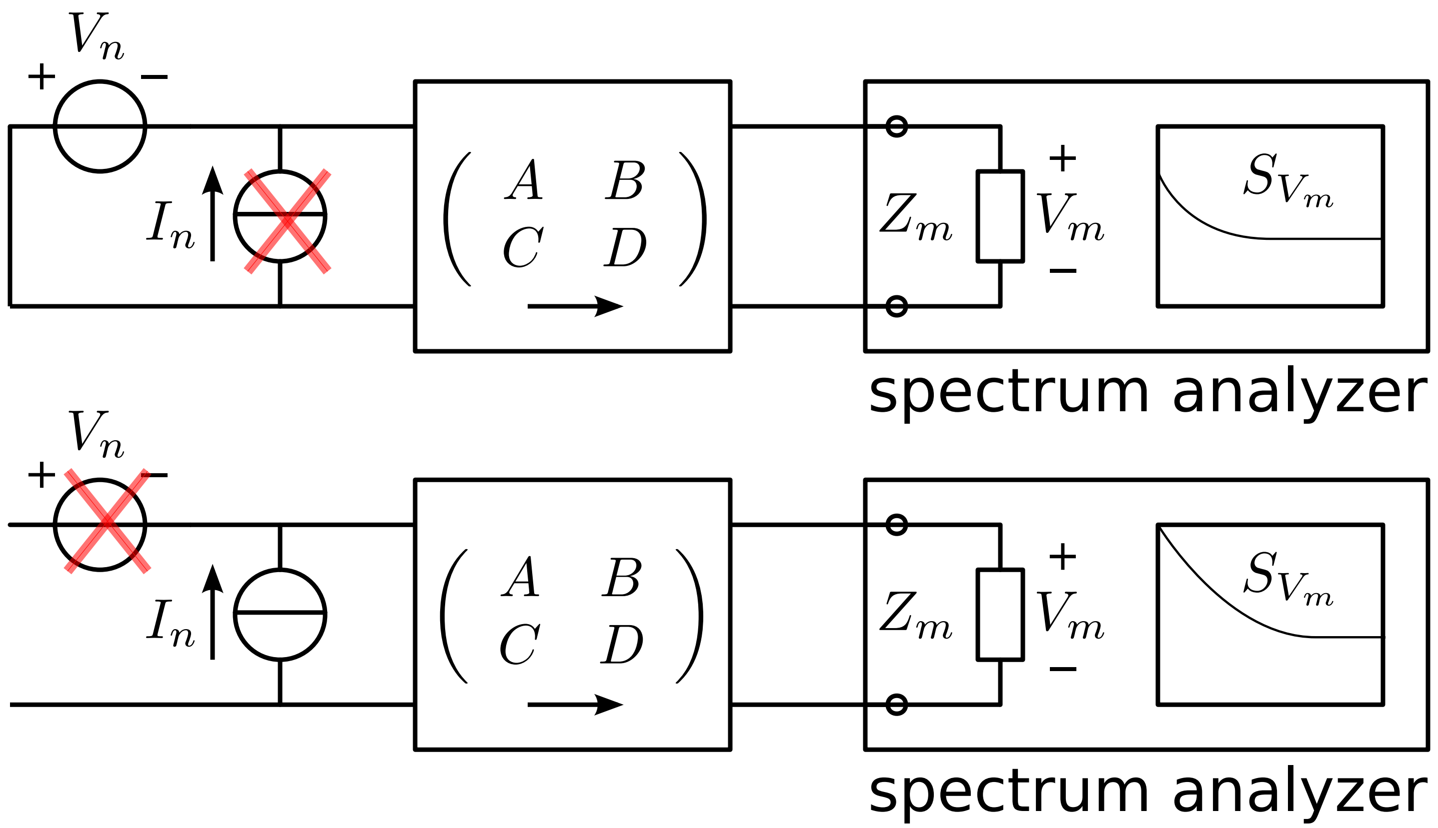

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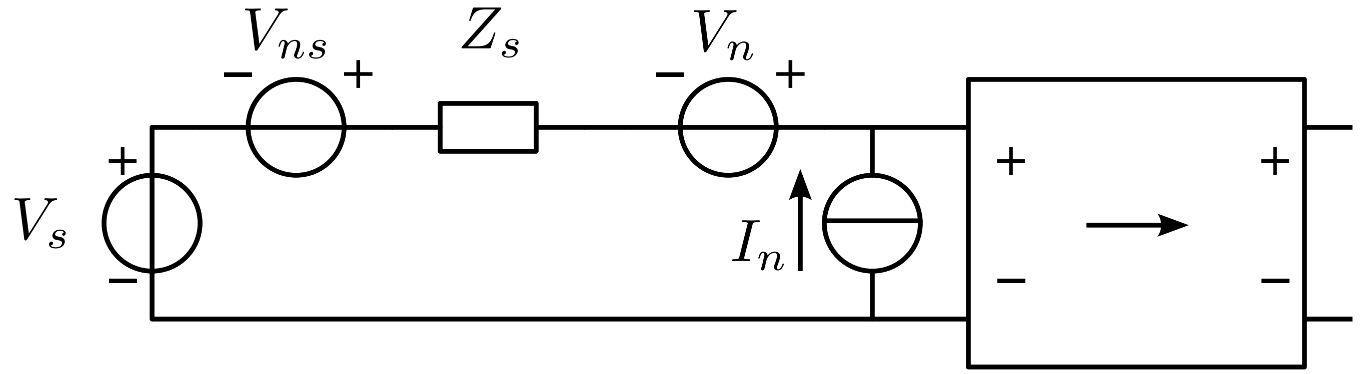

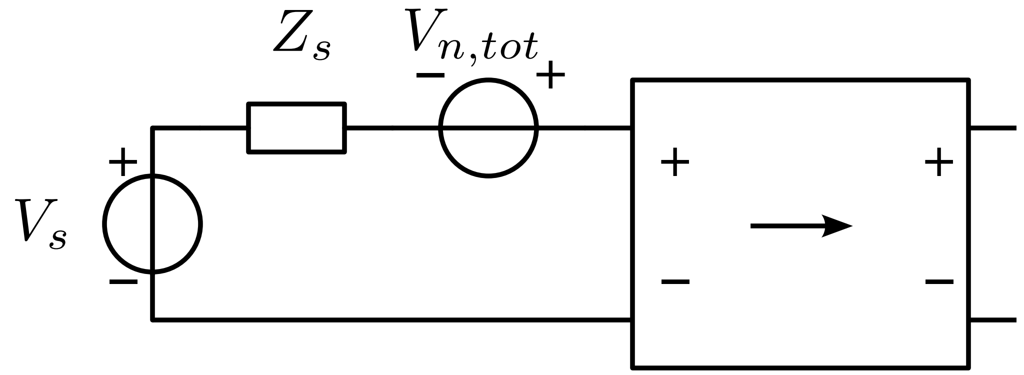

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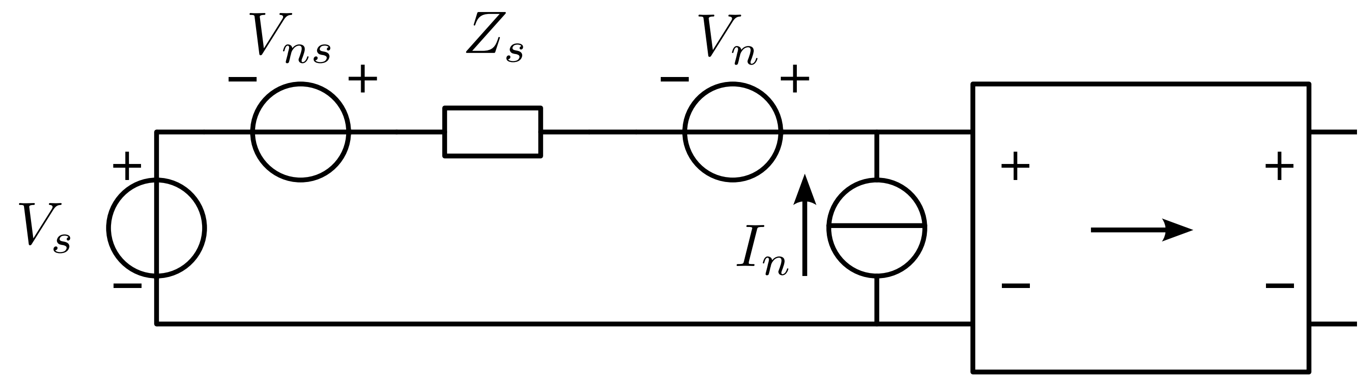

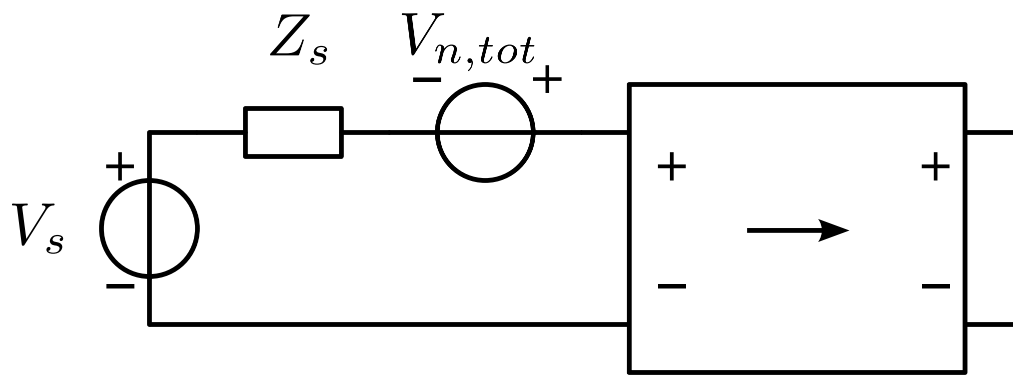

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equivalent-input notation:

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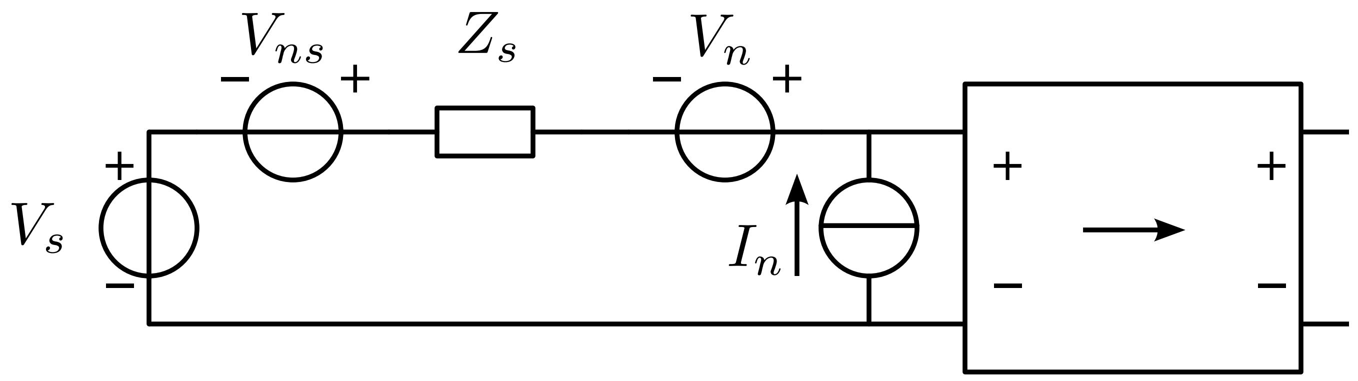

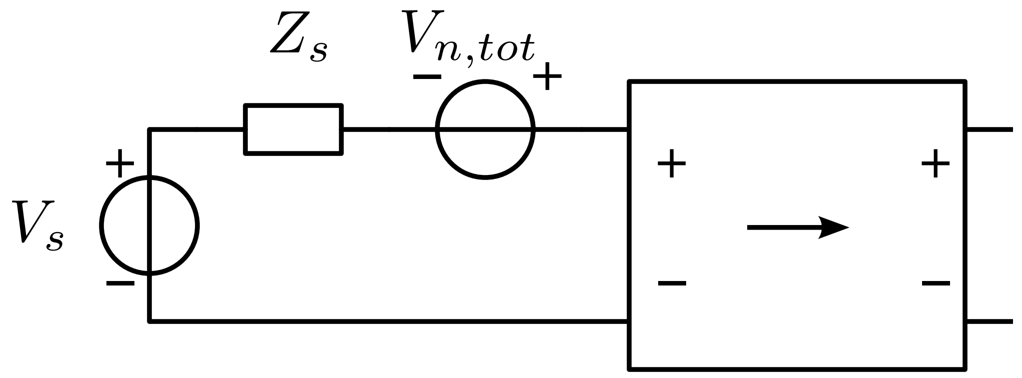

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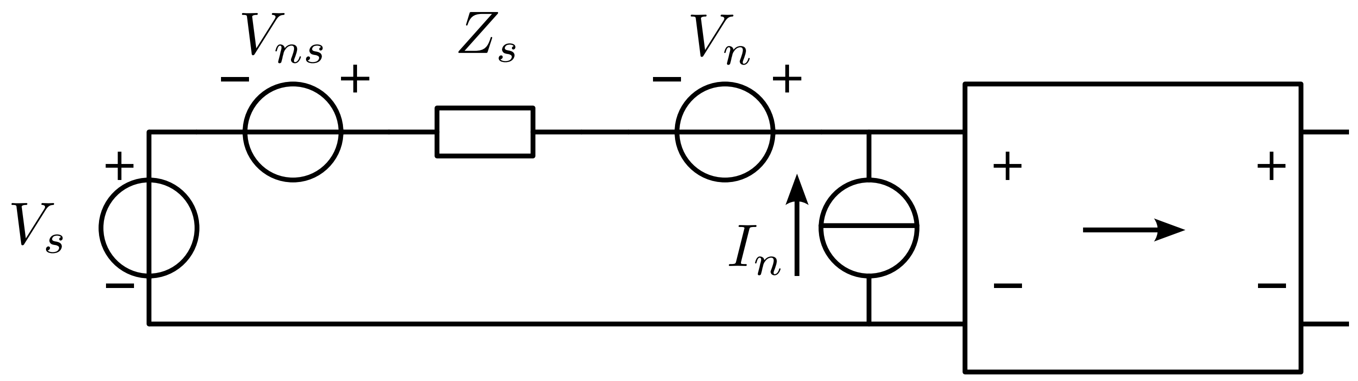

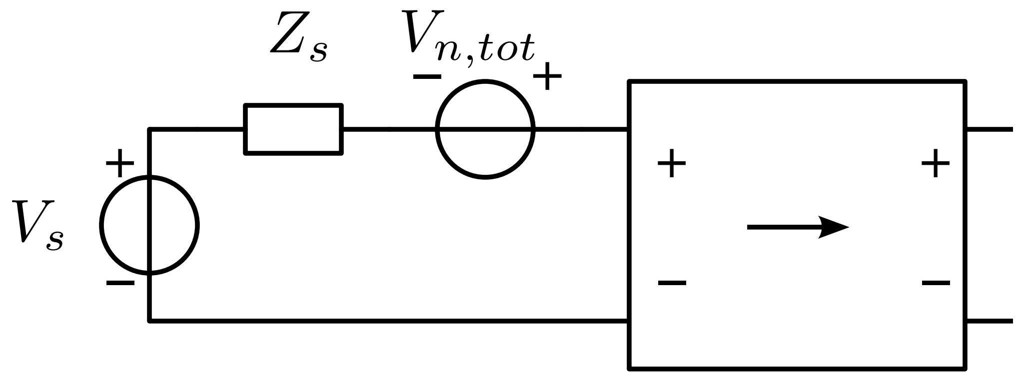

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$|W(f)|^2$

Squared magnitude of weighting function that models the sensitivity of the observer as a function of frequency

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Budgets for equivalent input noise sources can be determined
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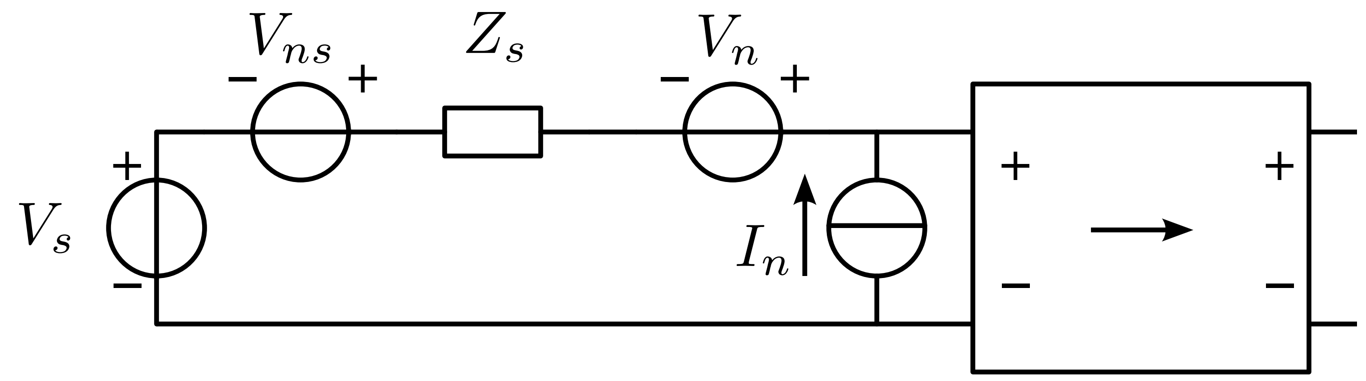
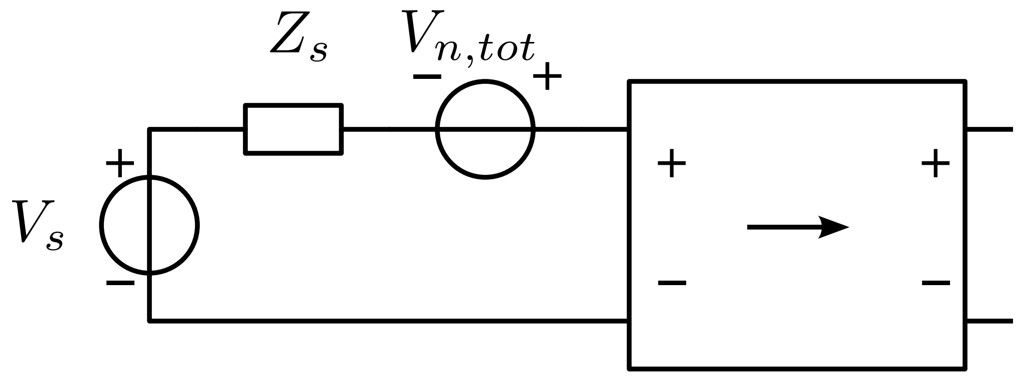




$$S_{V_{n,tot}} = S_{V_{ns}} + S_{V_n} + S_{I_n}|Z_s|^2$$

Noise figure
equivalent-input notation:

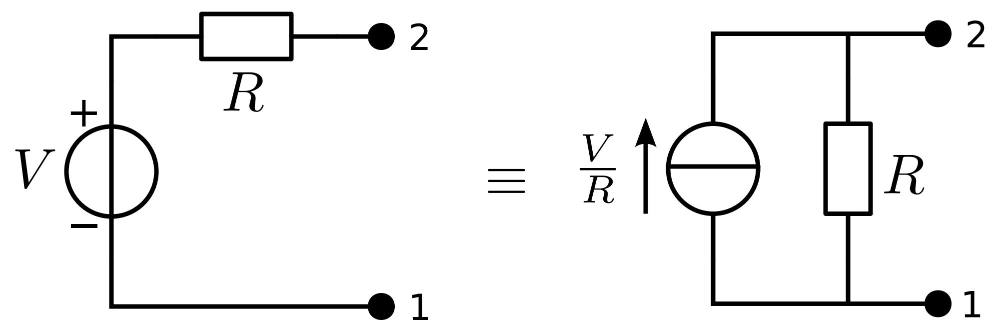
$$F = \frac{\int_0^\infty S_{V_{n,tot}} |W(f)|^2 df}{\int_0^\infty S_{V_{ns}} |W(f)|^2 df}$$

$|W(f)|^2$
Squared magnitude of weighting function that models the sensitivity of the observer as a function of frequency

Source transformation techniques

Source transformation techniques

Thévenin / Norton equivalent networks



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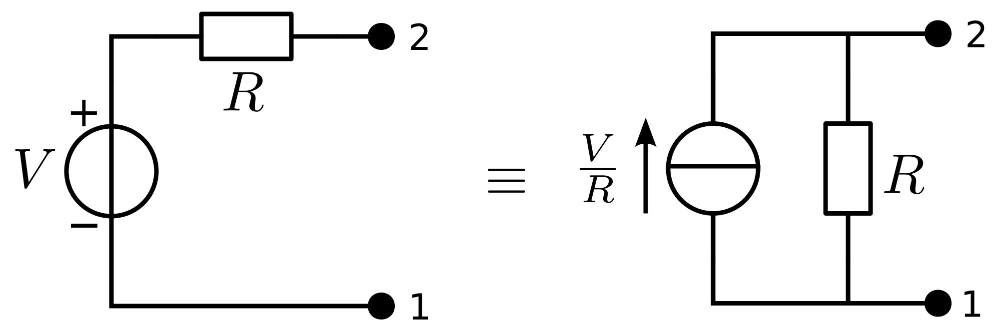
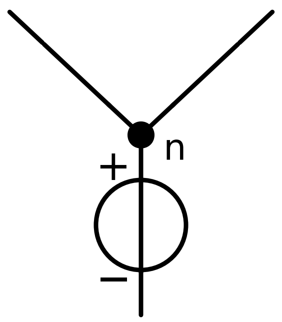


Blakesley voltage shift



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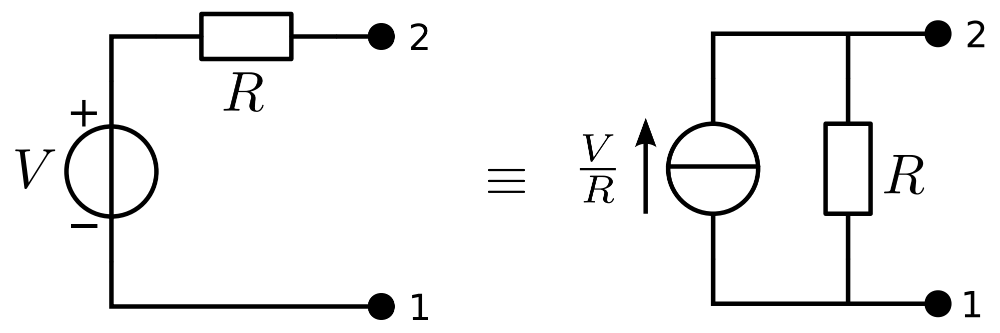

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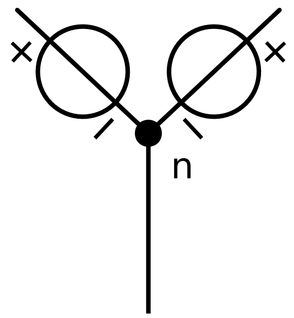

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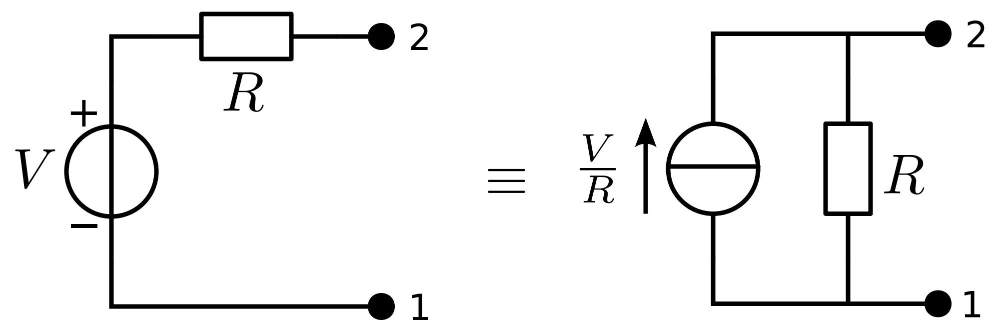

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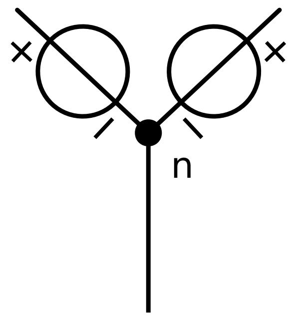
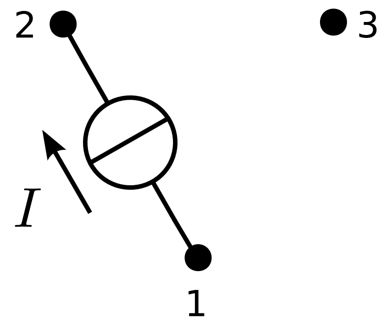


Current split / redirect



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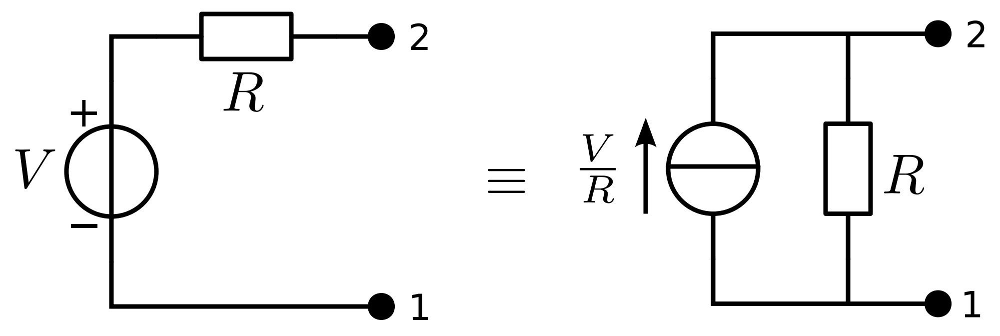

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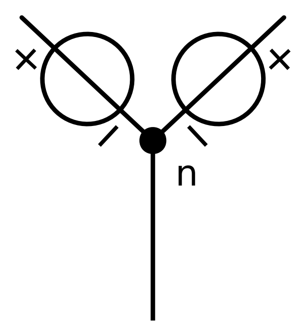

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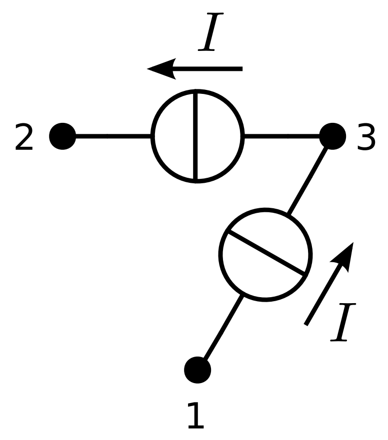

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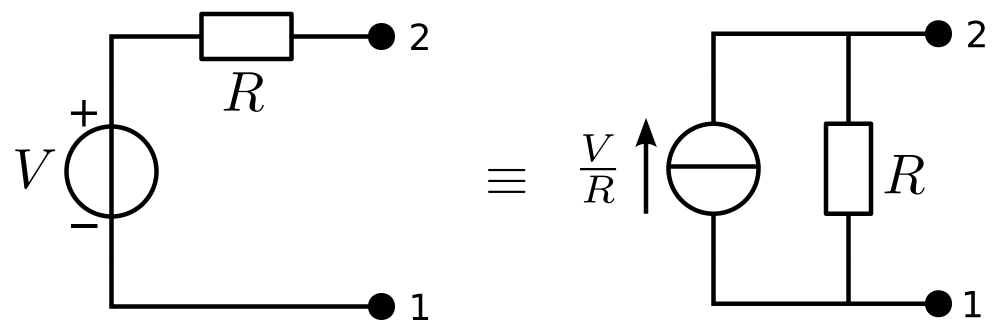

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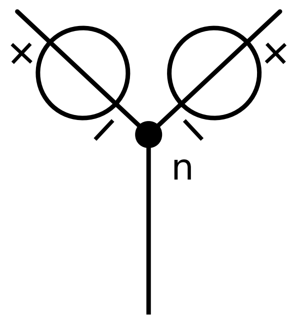

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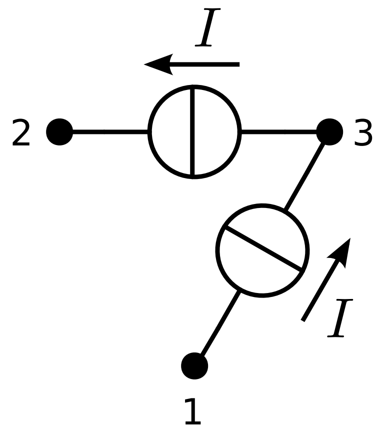
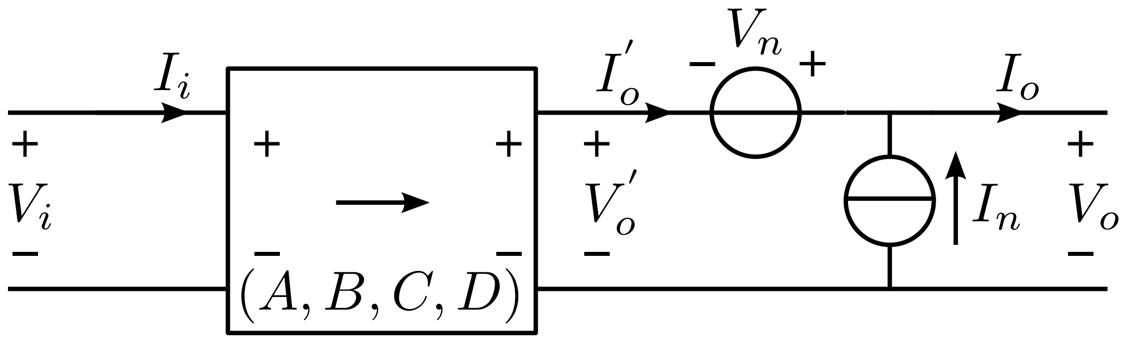
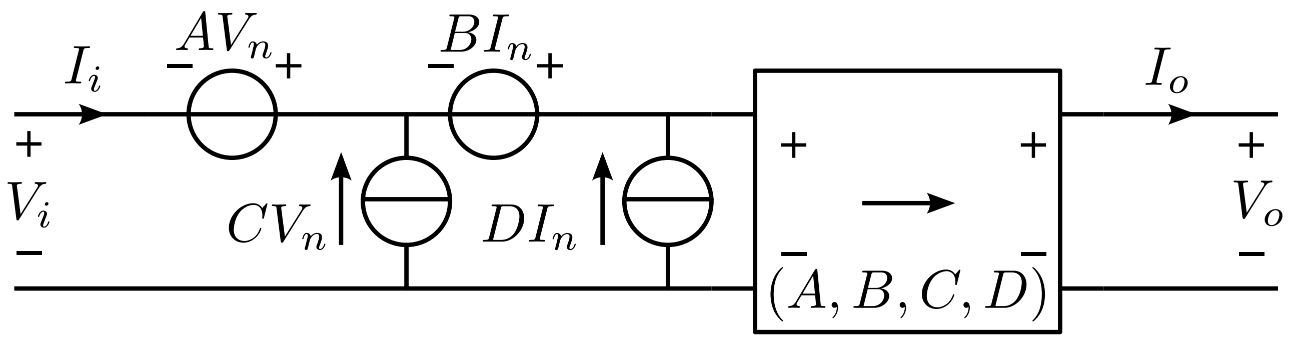
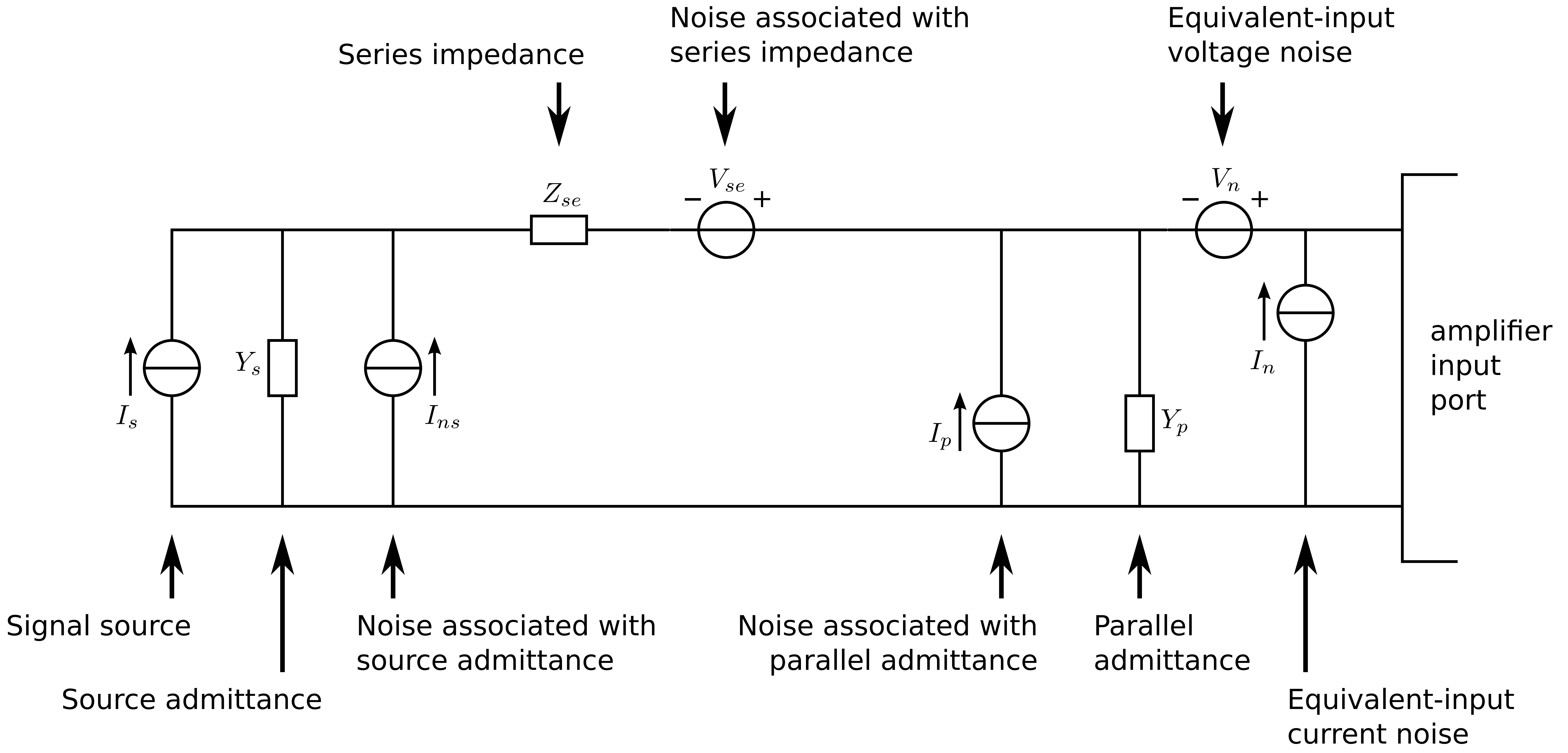


Equivalent two-port representations





Impedances in the signal path



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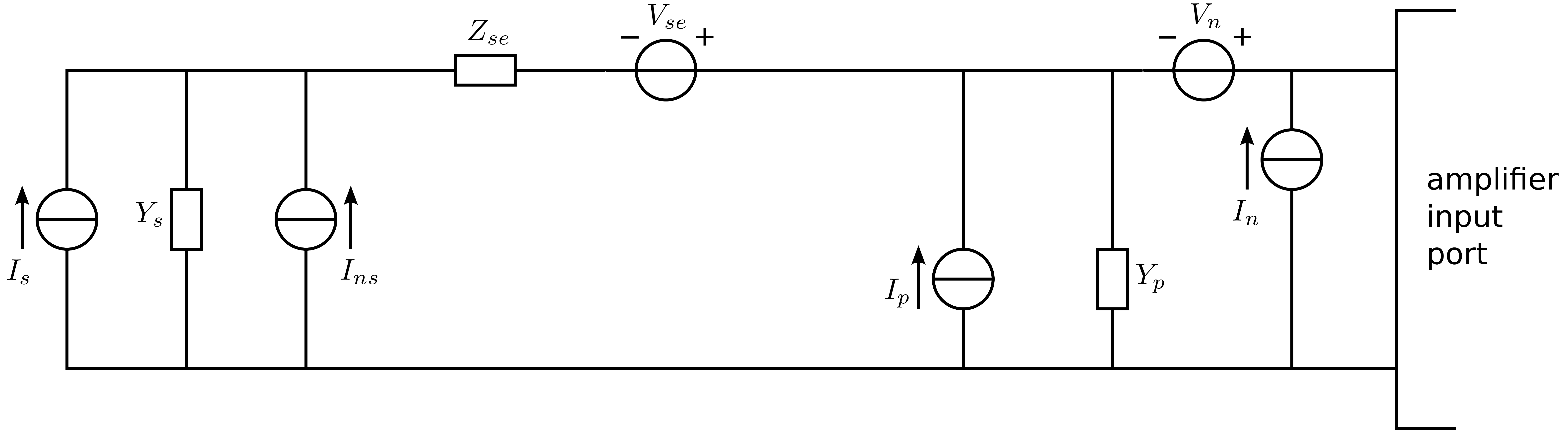

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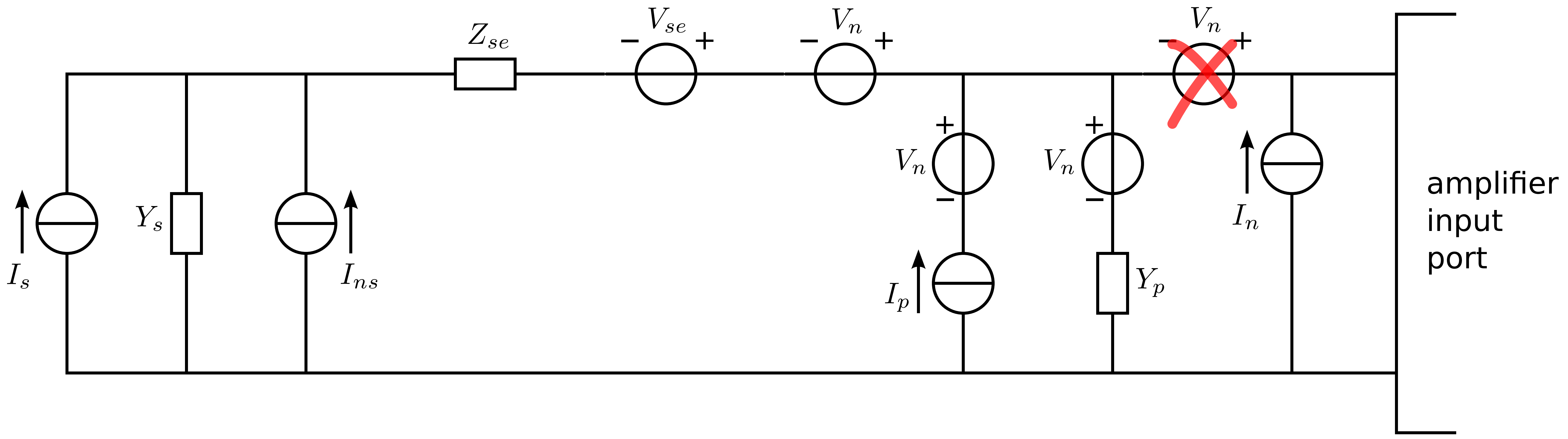

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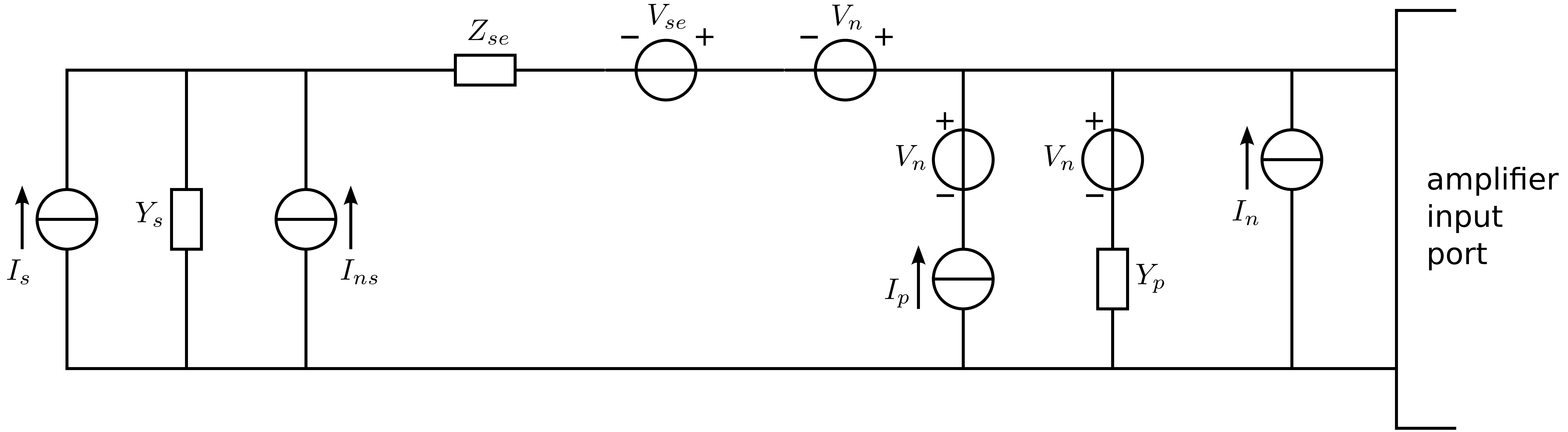

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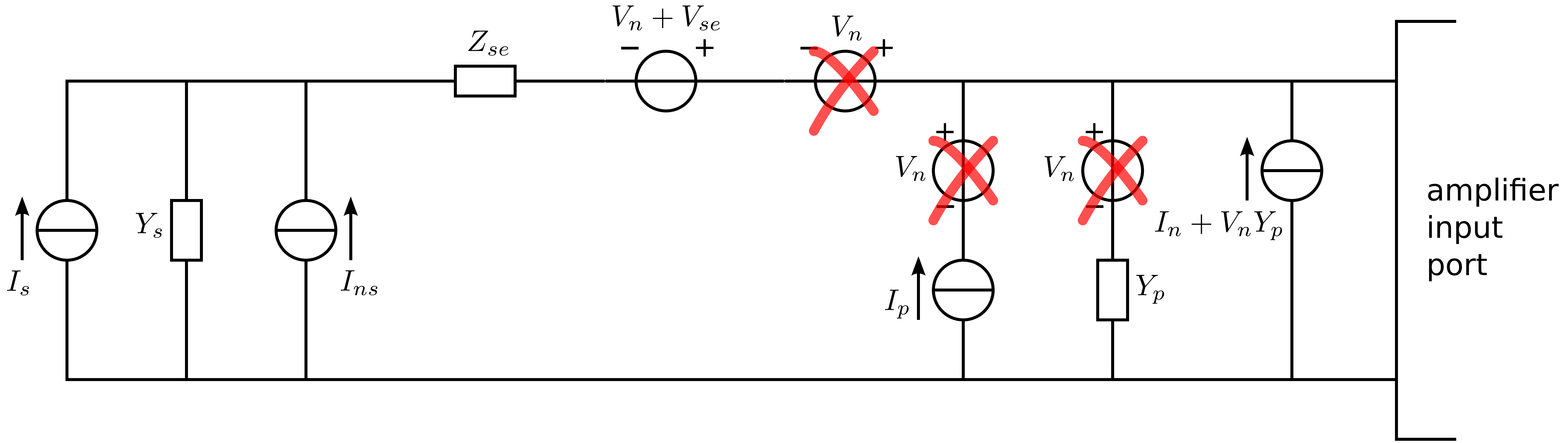

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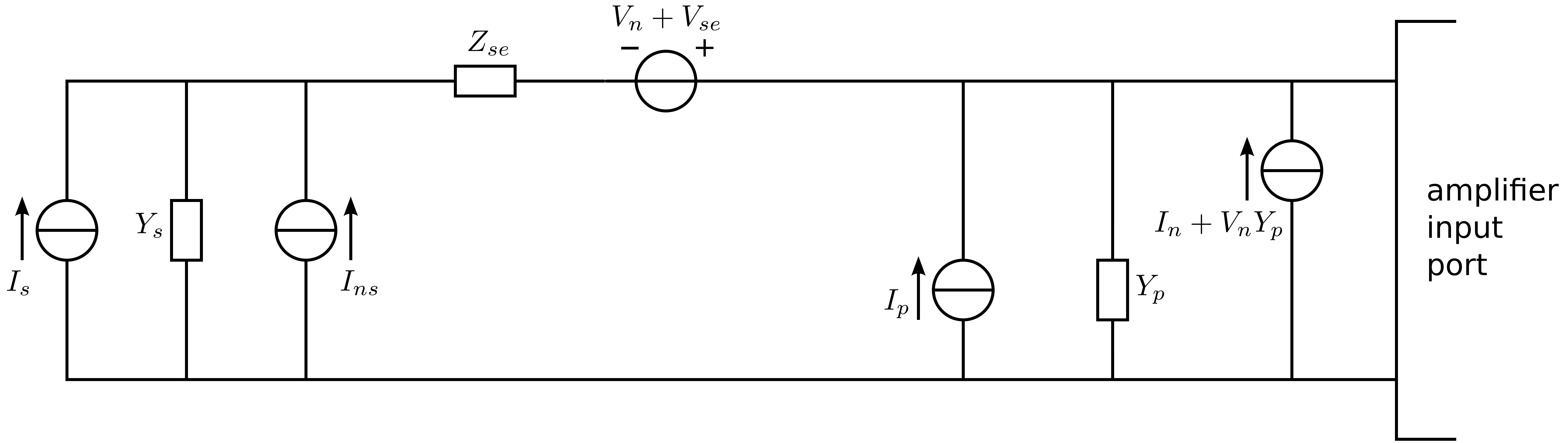

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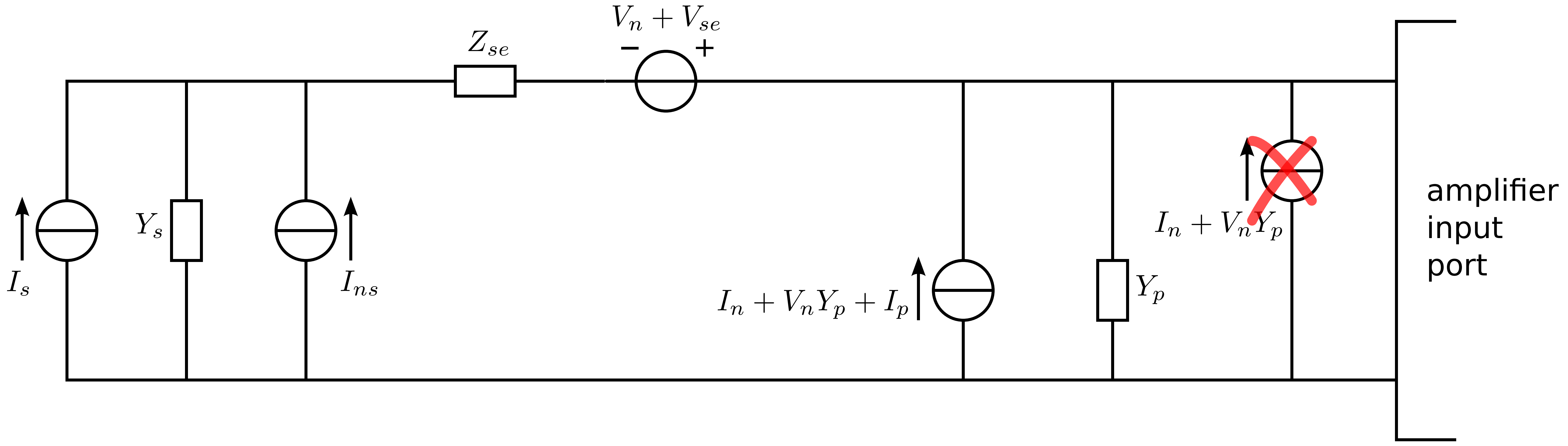

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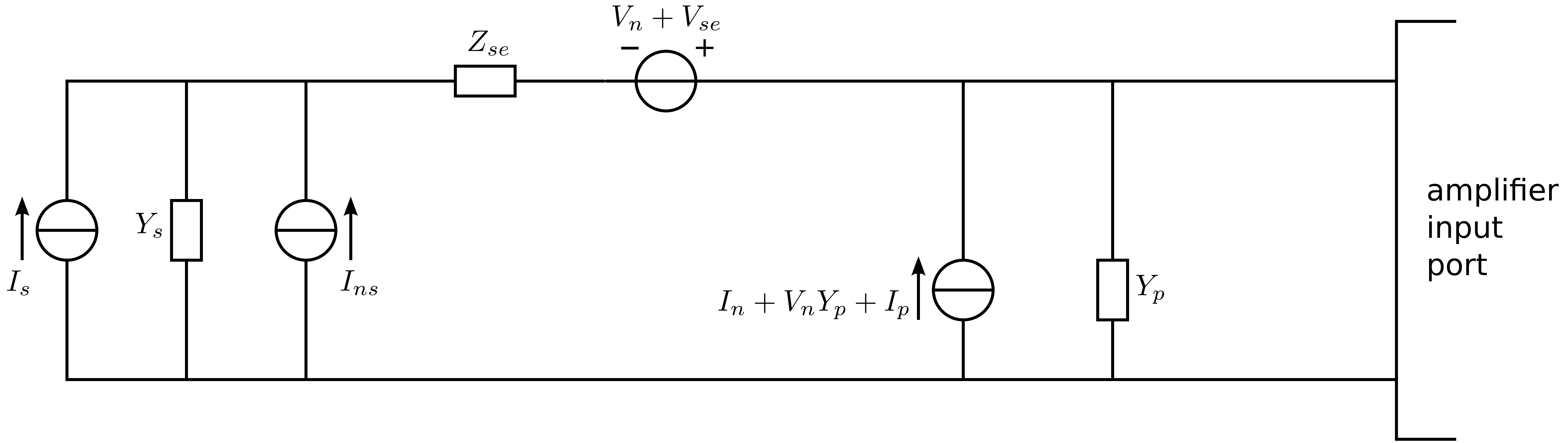

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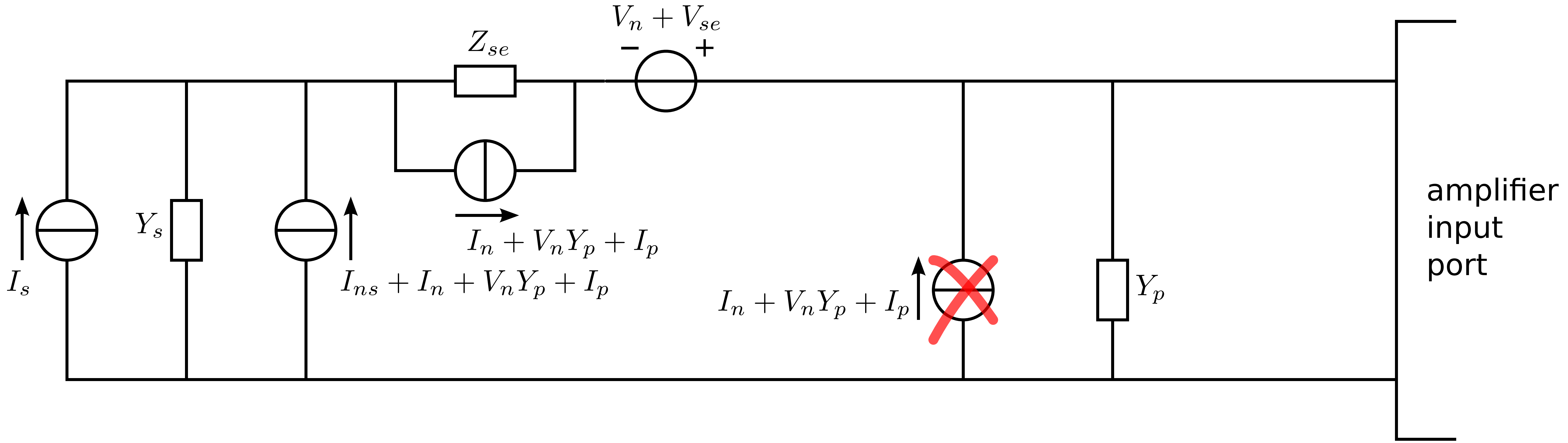

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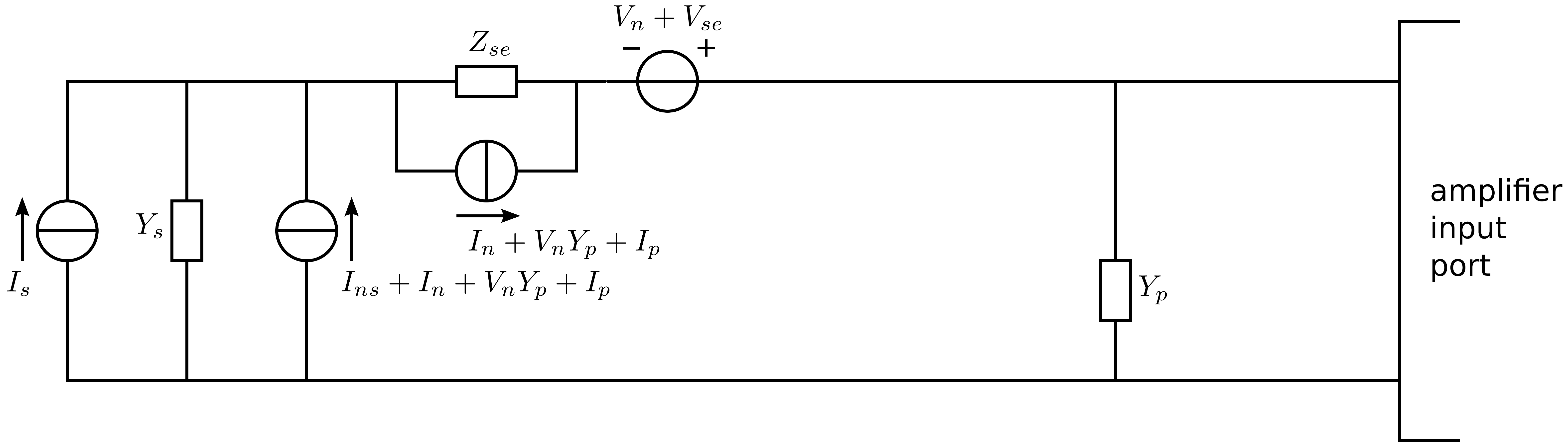

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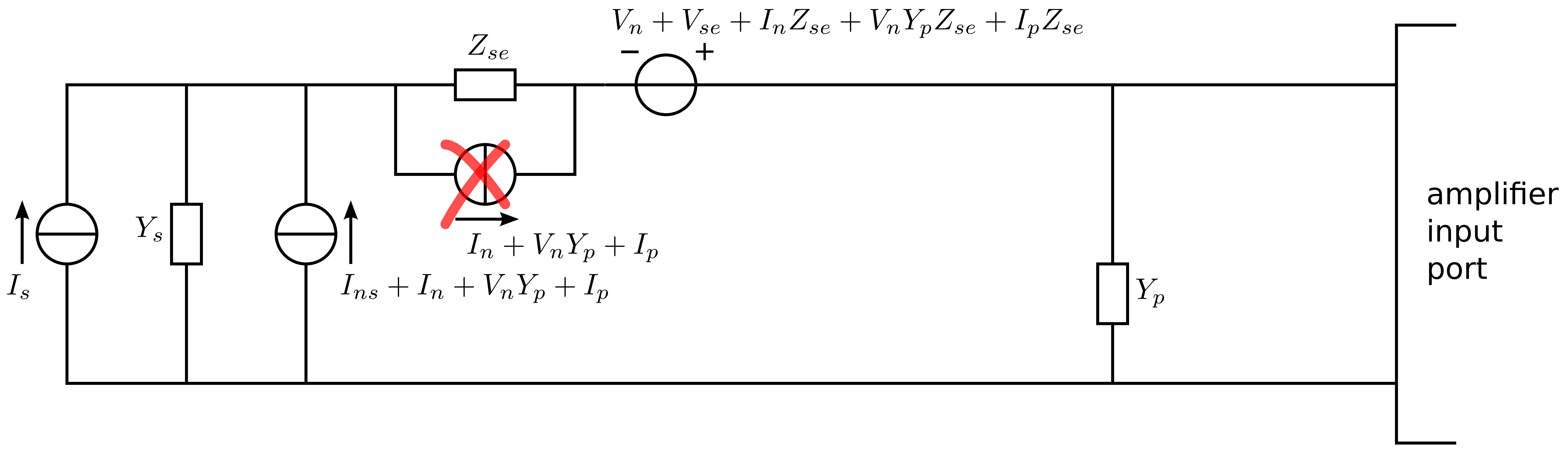

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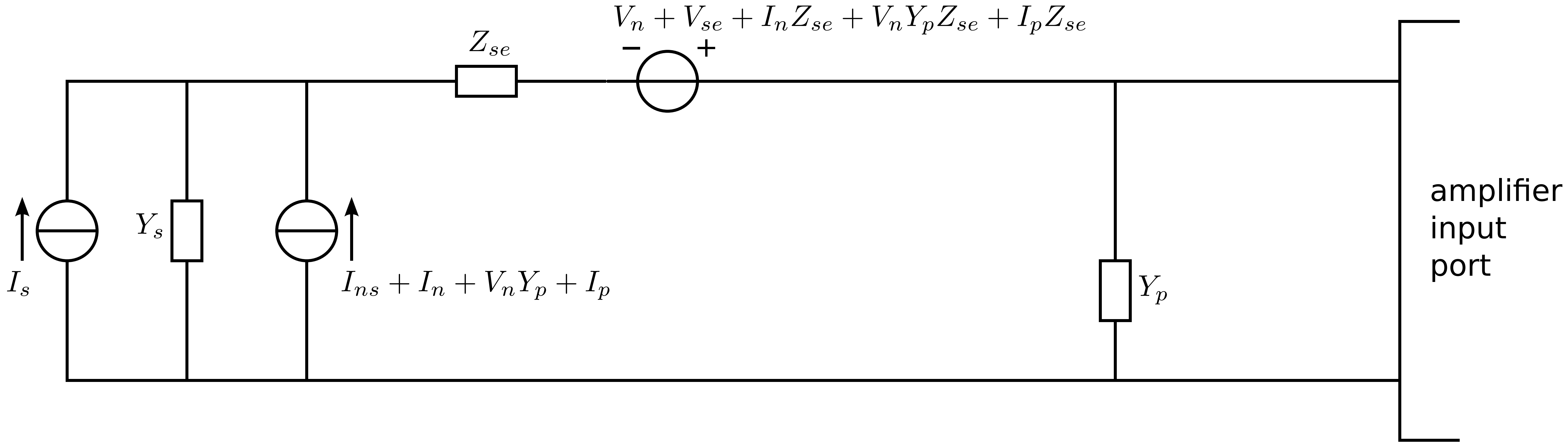

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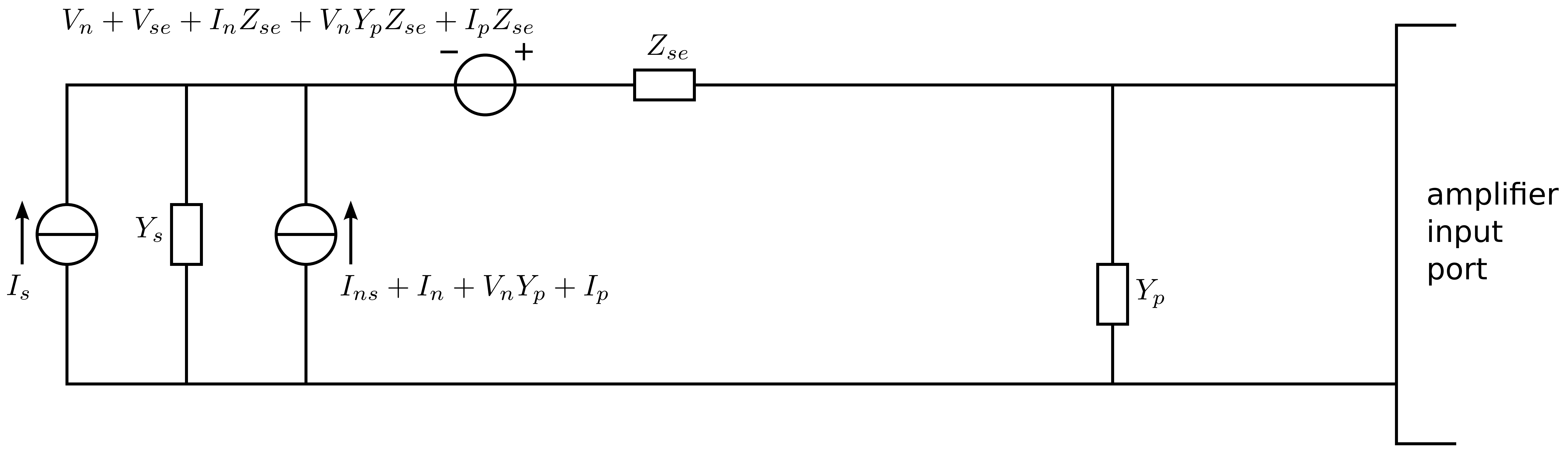

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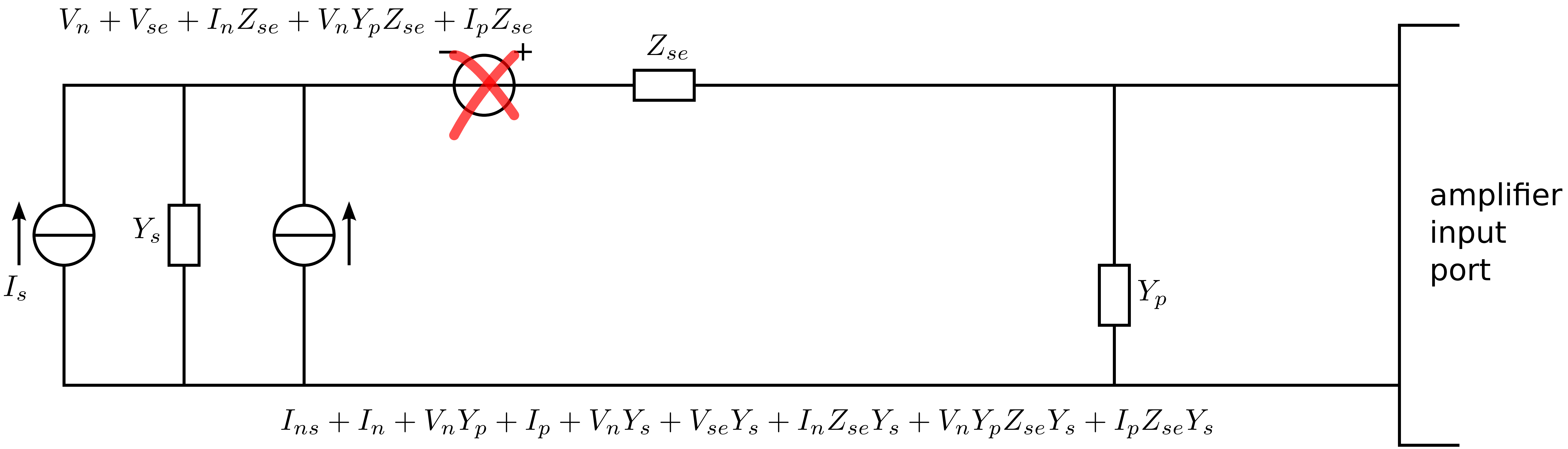

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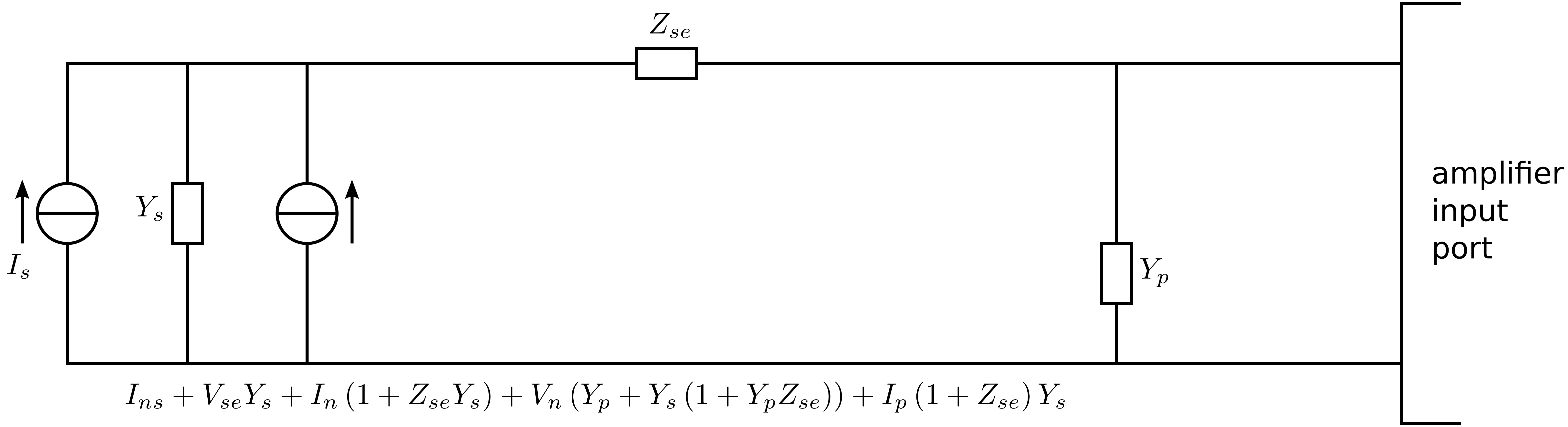
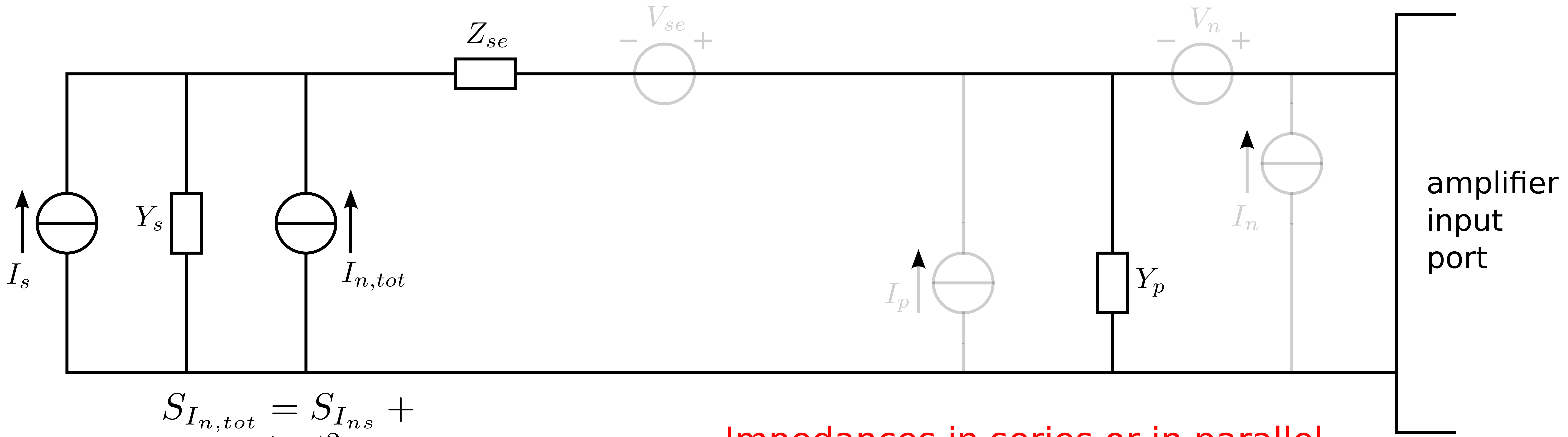


$$I_{ns} + V_{se}Y_s + I_n\left(1 + Z_{se}Y_s\right) + V_n\left(Y_p + Y_s\left(1 + Y_pZ_{se}\right)\right) + I_p\left(1 + Z_{se}\right)Y_s$$

Impedances in the signal path



$$
\begin{aligned}
S_{I_{n,tot}} &= S_{I_{ns}} + \\
&+ S_{V_{se}} |Y_s|^2 + \\
&+ S_{I_n} |1 + Z_{se} Y_s|^2 + \\
&+ S_{V_n} |Y_p + Y_s (1 + Y_p Z_{se})|^2 + \\
&+ S_{I_p} |1 + Z_{se} Y_s|^2
\end{aligned}
$$

Impedances in series or in parallel with the signal path increase the influence of noise sources further in the signal path

Design conclusions

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Insertion of impedances in series or in parallel with the signal path should be avoided

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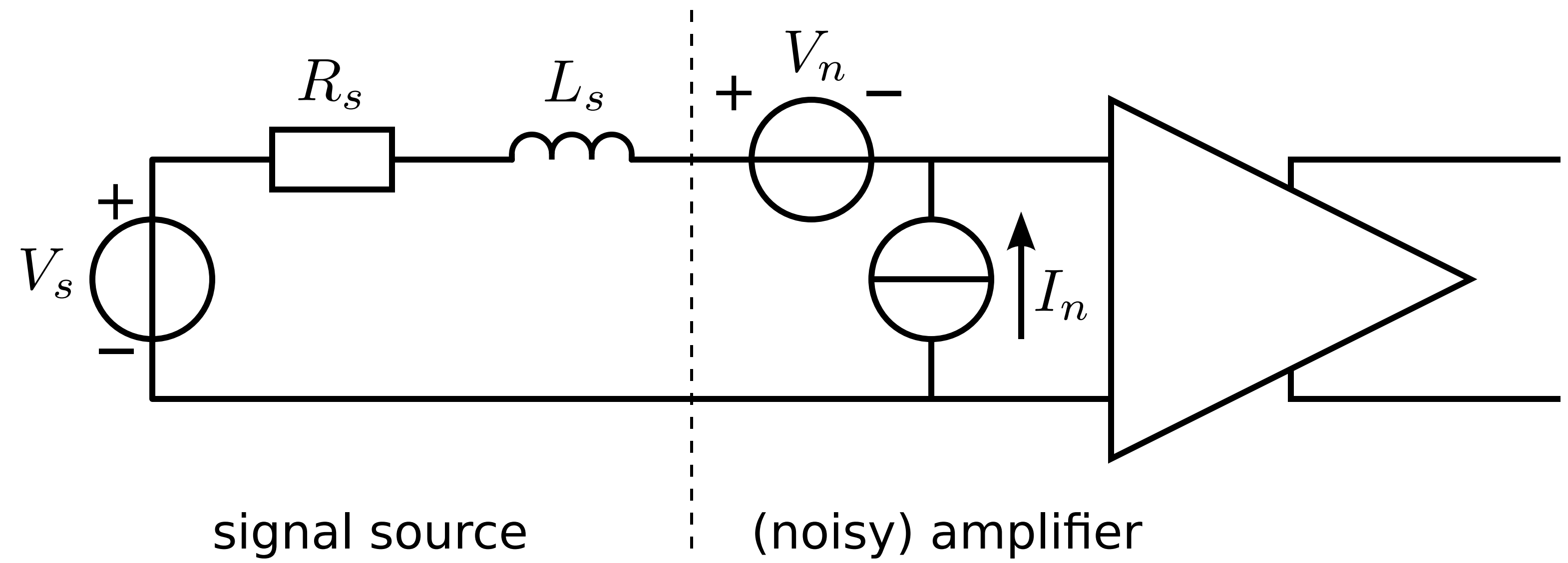

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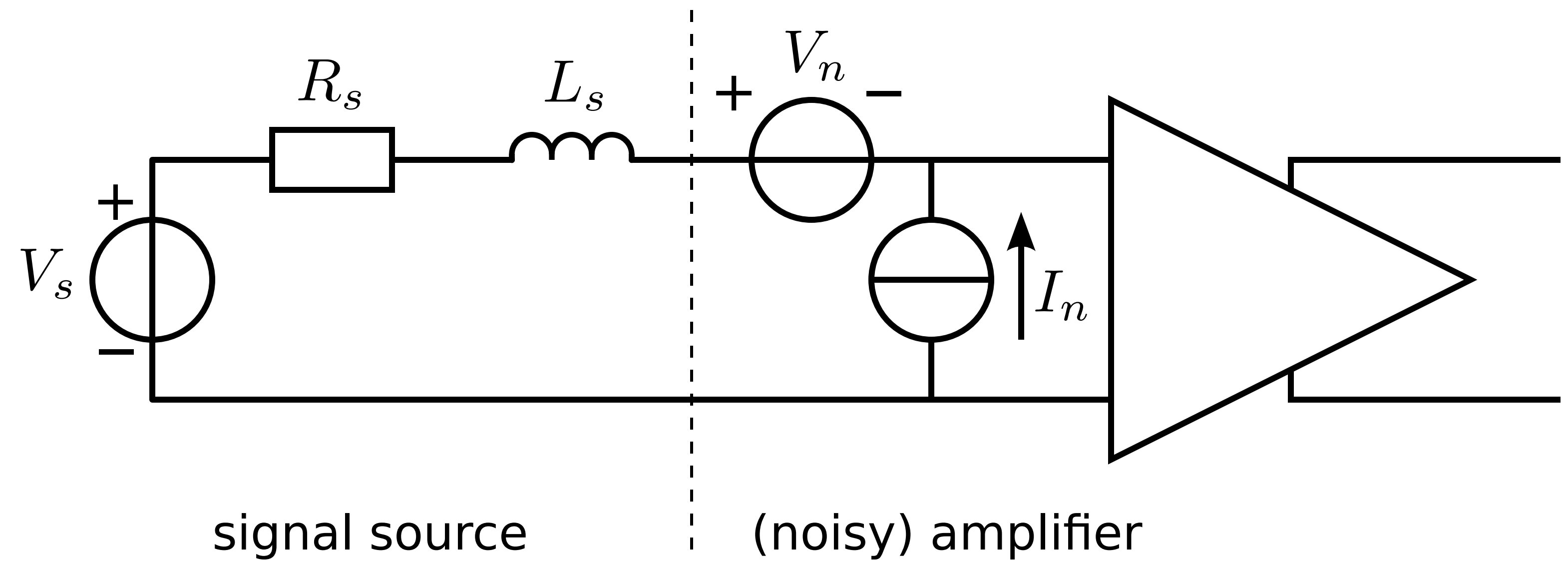

$$S_{V n_{tot}} = 4kTR_s + S_{V_n} + S_{I_n}\left(R_s^2 + (\omega L_s)^2\right)$$

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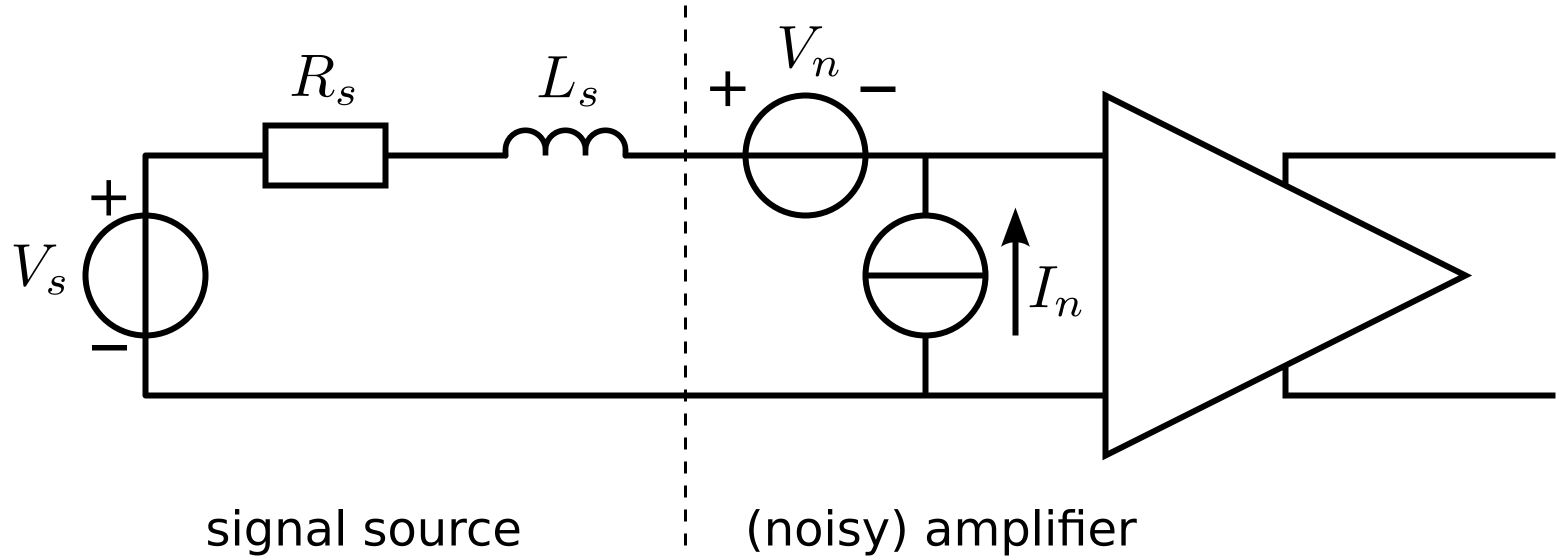

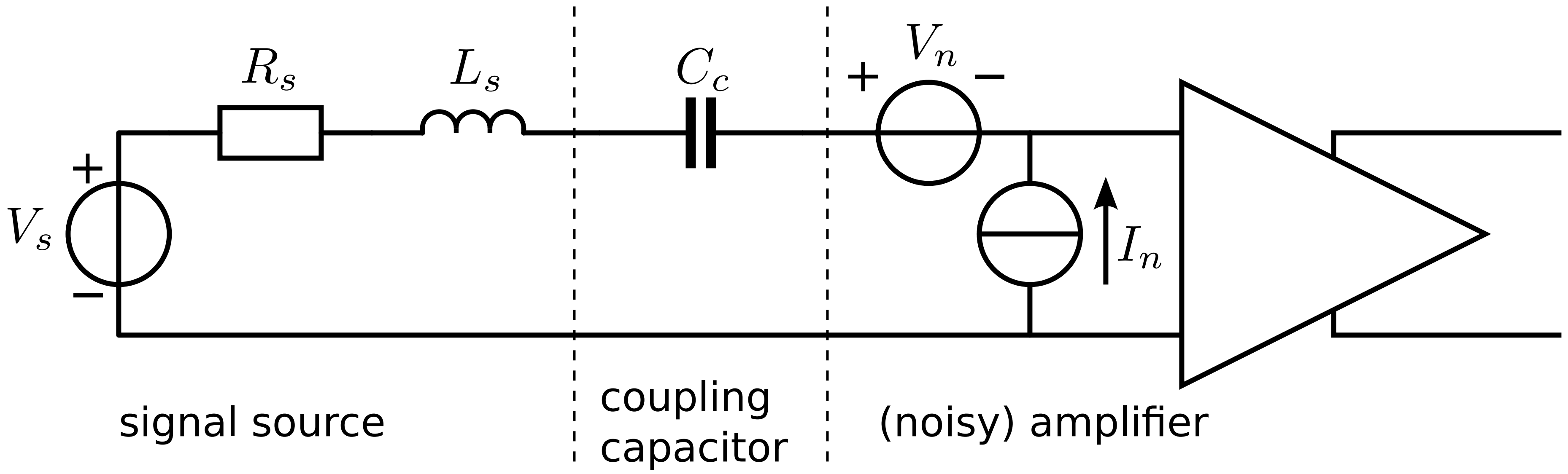

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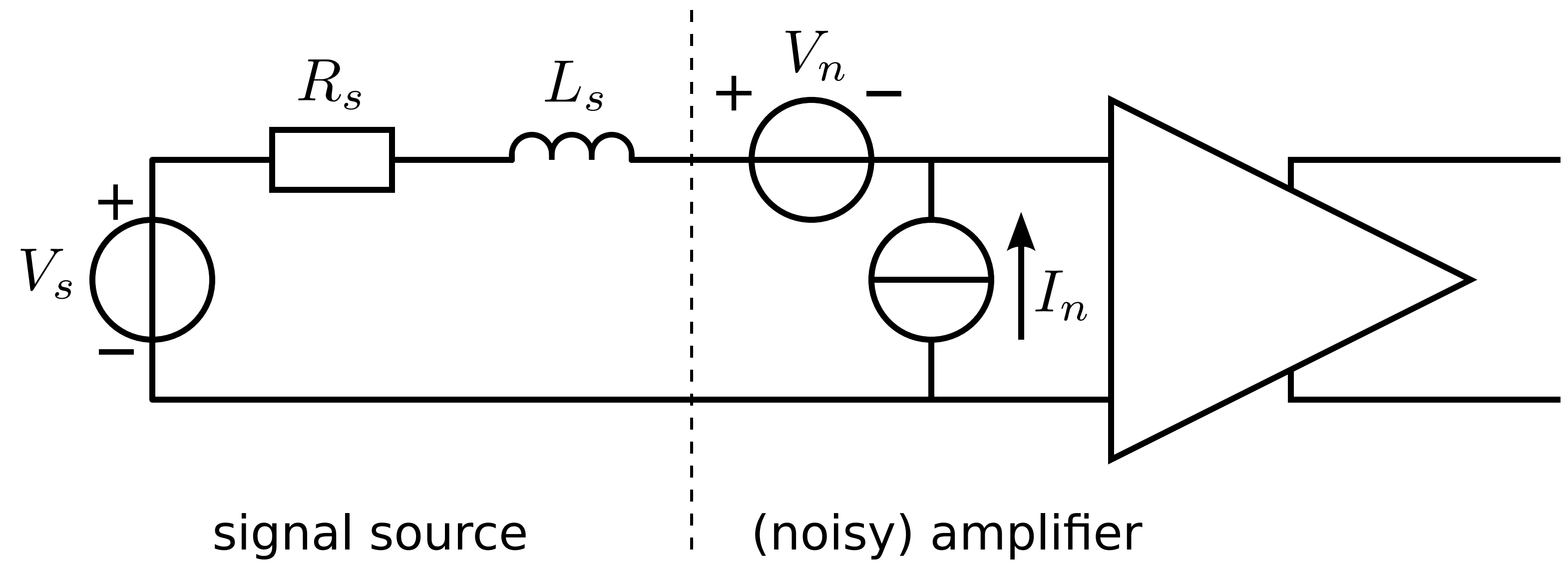

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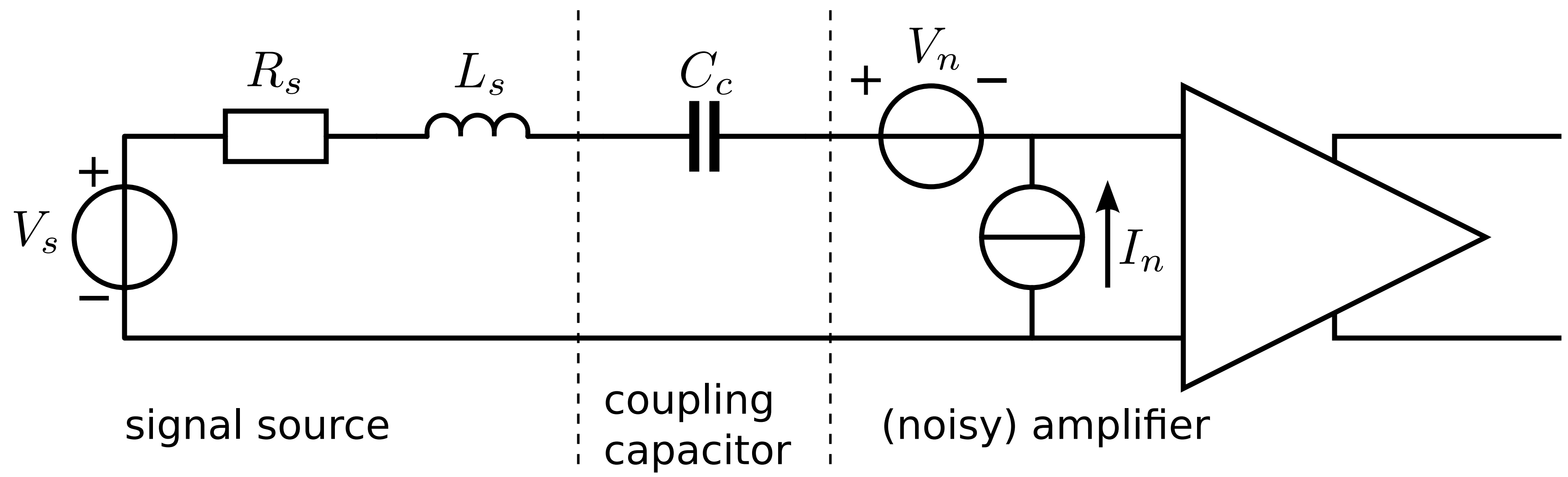

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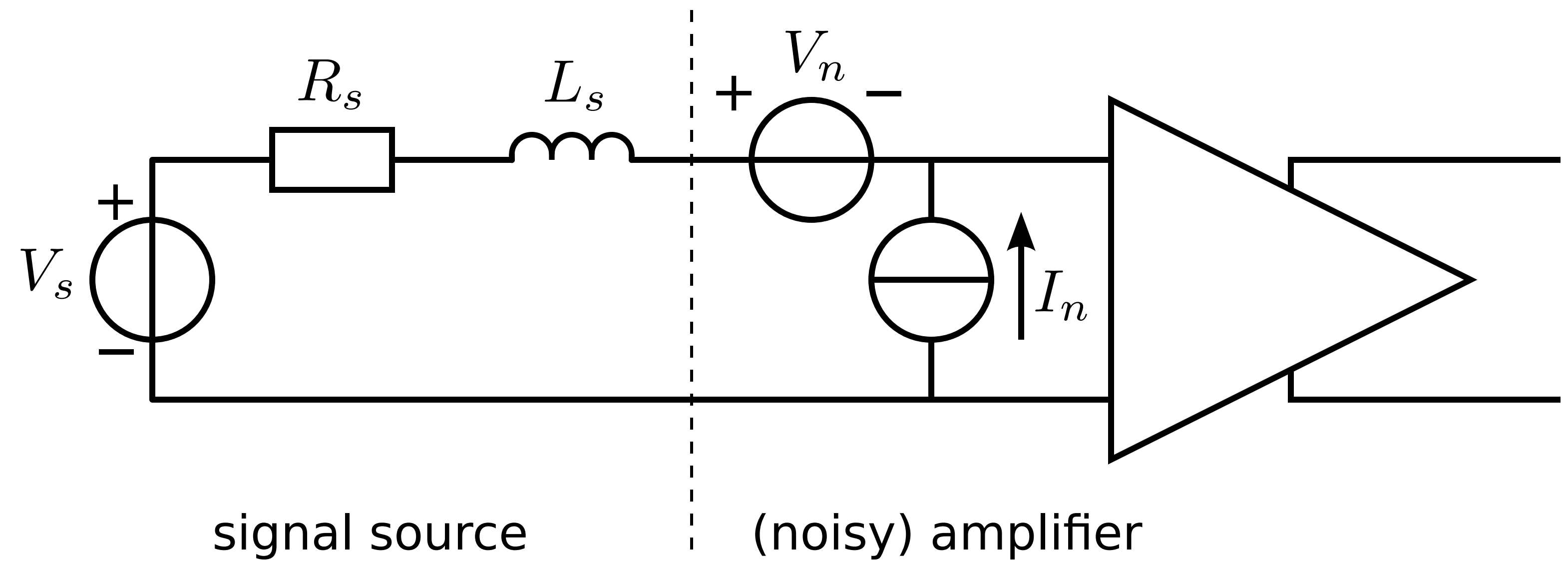

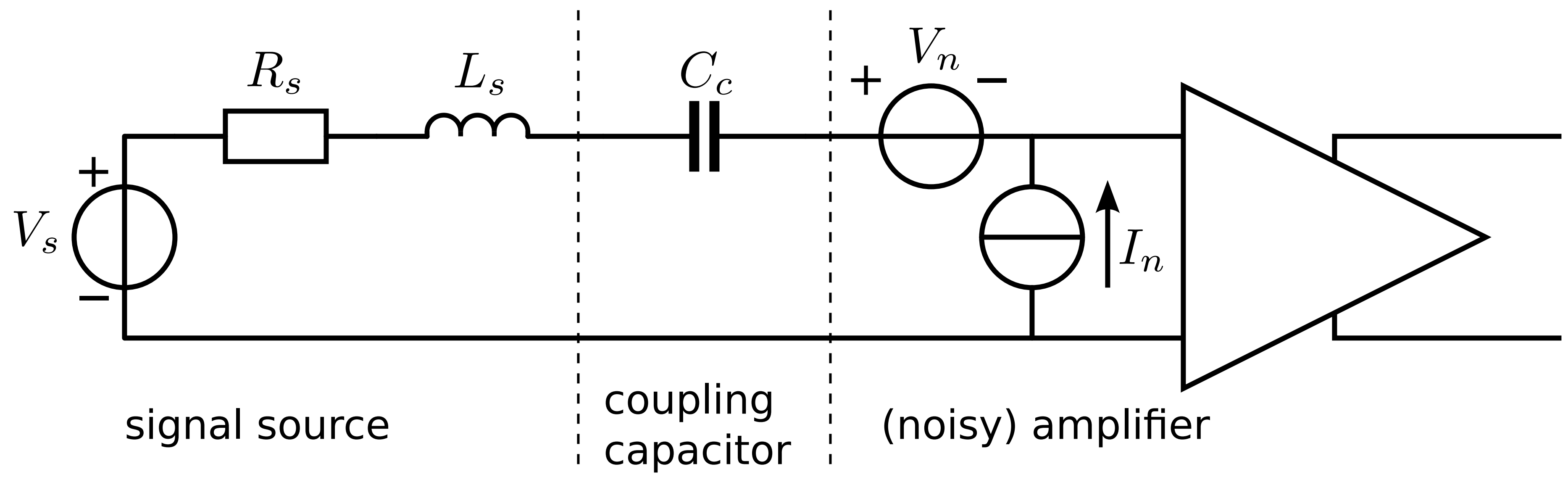

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Strong reduction of contribution of I_n
to the total source-referred noise if $\omega L_s \approx \frac{1}{\omega C_c}$

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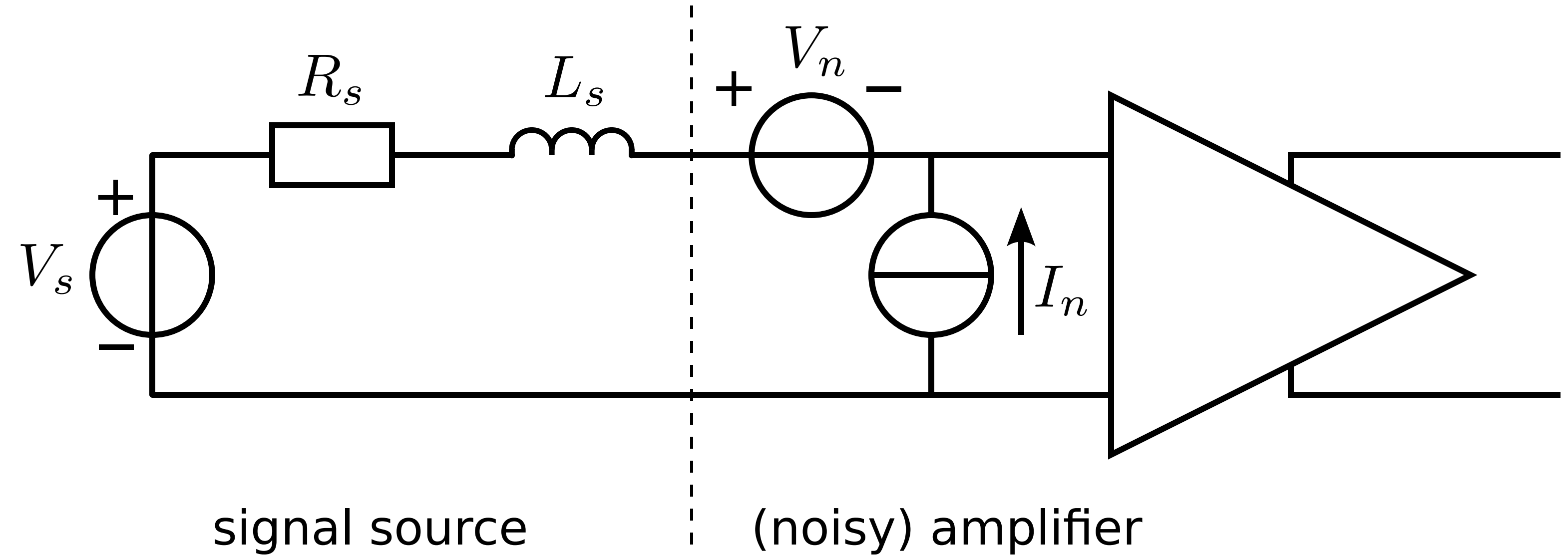

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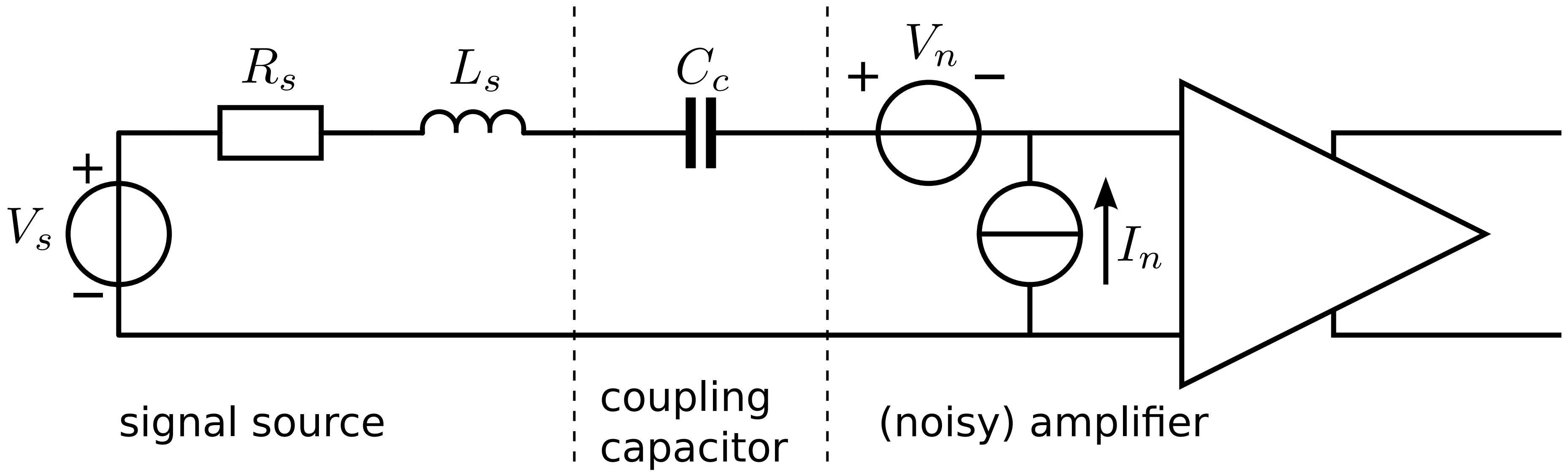

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