Balanced Stages

Balancing of two-terminal devices

Odd function synthesis with anti-series and complementary series connection

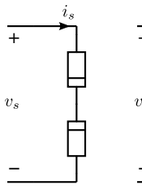
Element relation:

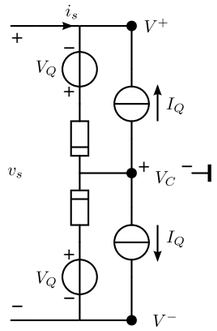
$$v(i) = a_o + a_1 i + a_2 i^2 + a_3 i^3 + \ldots$$

Balancing technique with series connection:

$$v_s = v(i_s) - v(-i_s)$$

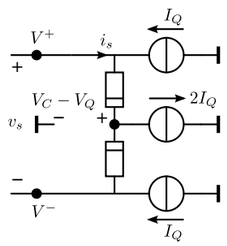
Circuit synthesis
- anti-series connection of equal elements
- series connection of complementary elements

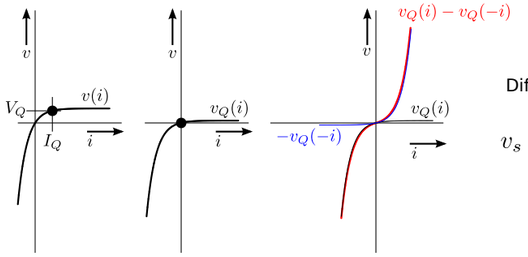




Biased anti-series connection

Biased with current sources





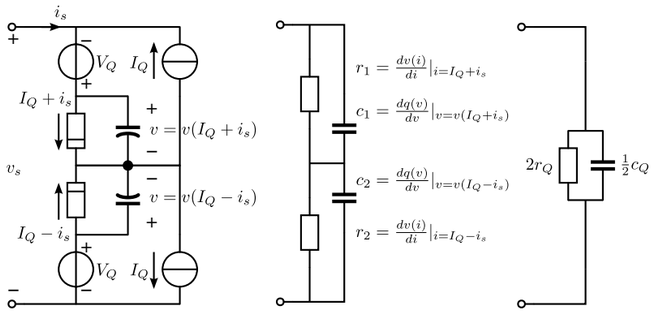
Differential-mode: odd transfer

$$\begin{aligned} v_s = v(i_s) - v(-i_s) = \\ + a_0 + a_1 i_s + a_2 i_s^2 + a_3 i_s^3 + \ldots \\ - a_0 + a_1 i_s - a_2 i_s^2 + a_3 i_s^3 - \ldots \\ = 2\left(a_1 i_s + a_3 i_s^3 + \ldots\right) \end{aligned}$$

Common-mode: even transfer

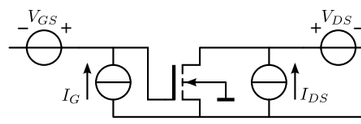
$$\begin{aligned} v_{cm} = \frac{1}{2}\left(v(i_s) + v(-i_s)\right) = \\ + a_0 + a_1 i_s + a_2 i_s^2 + a_3 i_s^3 + \ldots \\ + a_0 - a_1 i_s + a_2 i_s^2 - a_3 i_s^3 + \ldots \\ = a_0 + a_2 i_s^2 + \ldots \end{aligned}$$

Small-signal equivalent circuit



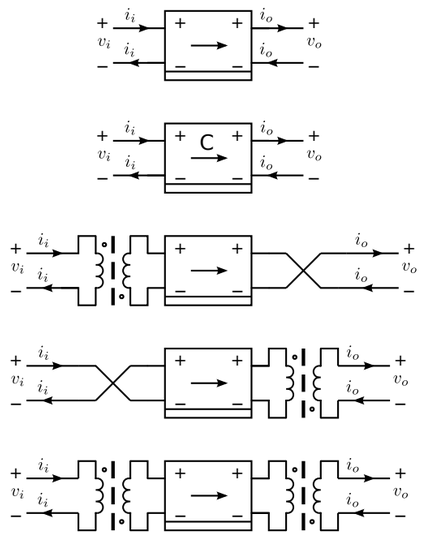
Noise

In quiescent operating point: Voltage noise spectrum twice that of the single element

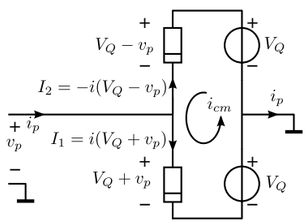


Balancing of two-ports

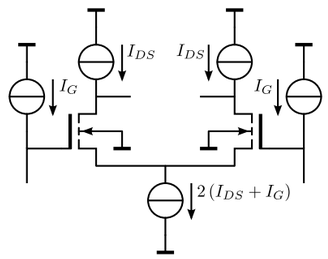
Two-ports and complementary two-ports



Biased with voltage sources



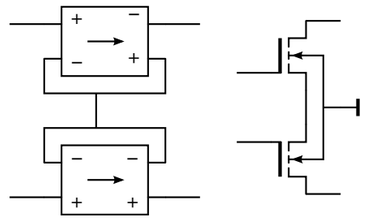
Anti-series stage



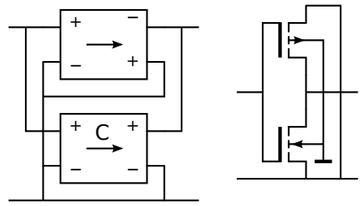
Eight possible interconnections with odd transfer

Two possible connections with three-terminal devices

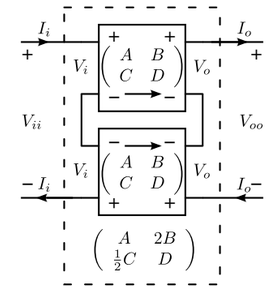
Anti-series connection of equal devices

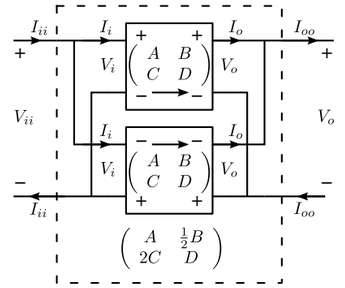


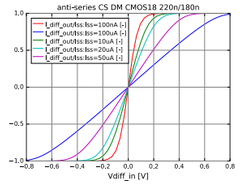
Parallel connection of complementary devices

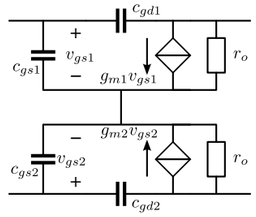


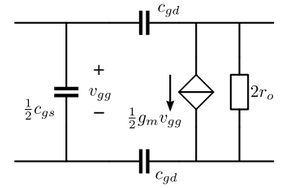
Small-signal models



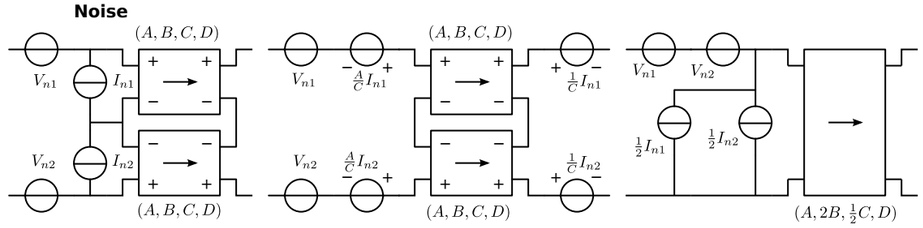




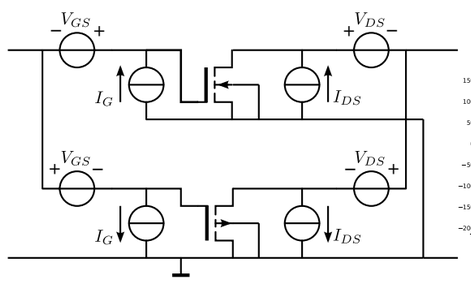


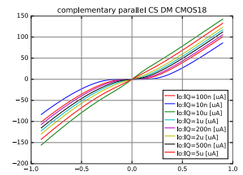


Noise

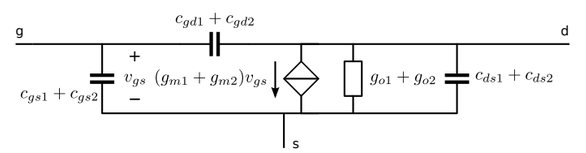


Complementary-parallel stage





In quiescent operating point: Voltage noise spectrum twice that of the single element, current noise spectrum half of that of the single element



In quiescent operating point: Current noise spectrum twice that of the single element, voltage noise spectrum half of that of the single element

Odd function synthesis with anti-parallel and complementary parallel connection

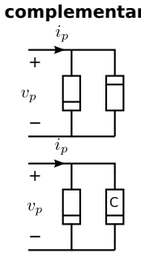
Element relation:

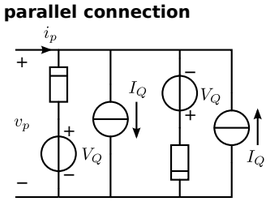
$$i(v) = a_o + a_1 v + a_2 v^2 + a_3 v^3 + \ldots$$

Balancing technique with parallel connection:

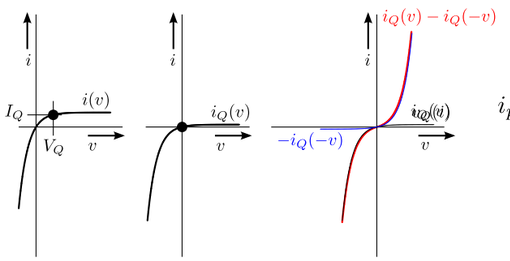
$$i_p = i(v_p) - i(-v_p)$$

Circuit synthesis
- anti-parallel connection of equal elements
- parallel connection of complementary elements





Biased anti-parallel connection



Differential-mode: odd transfer

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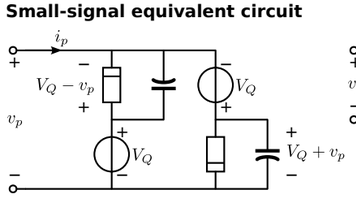
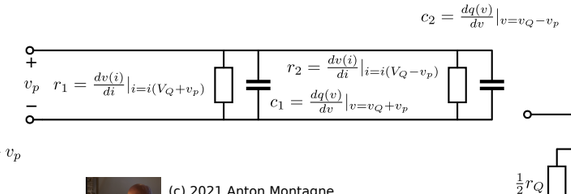
Common-mode: even transfer

$$\begin{aligned} i_{cm} = \frac{1}{2}\left(i(v_p) + i(-v_p)\right) = \\ + a_o + a_1 v_p + a_2 v_p^2 + a_3 v_p^3 + \ldots \\ + a_o - a_1 v_p + a_2 v_p^2 - a_3 v_p^3 + \ldots \\ = 2\left(a_o v_p + a_2 v_p^2 + \ldots\right) i_{cm} \end{aligned}$$

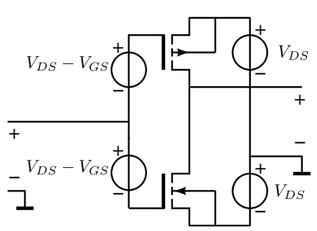
Small-signal equivalent circuit



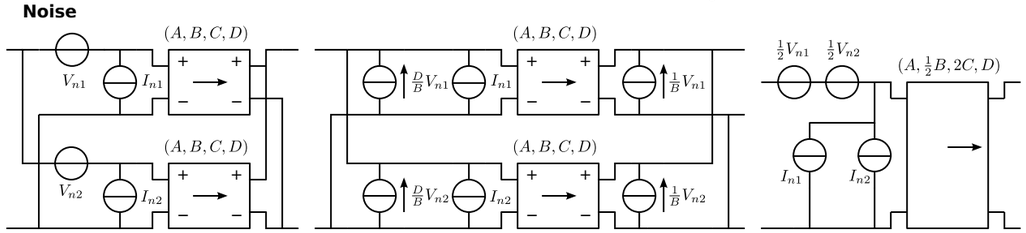


Noise

In quiescent operating point: Current noise spectrum twice that of the single element



Noise



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