Structured Electronic Design

Balancing: push-pull stage

Anton J.M. Montagne

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Complementary-parallel CS stage

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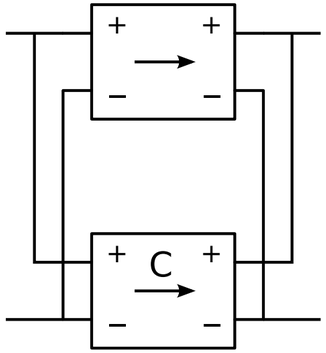
Complementary-parallel CS stage



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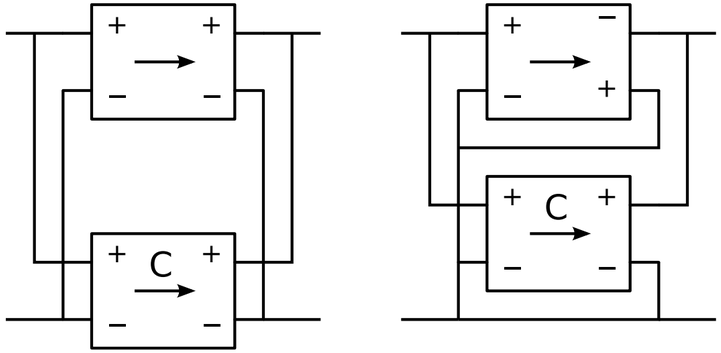

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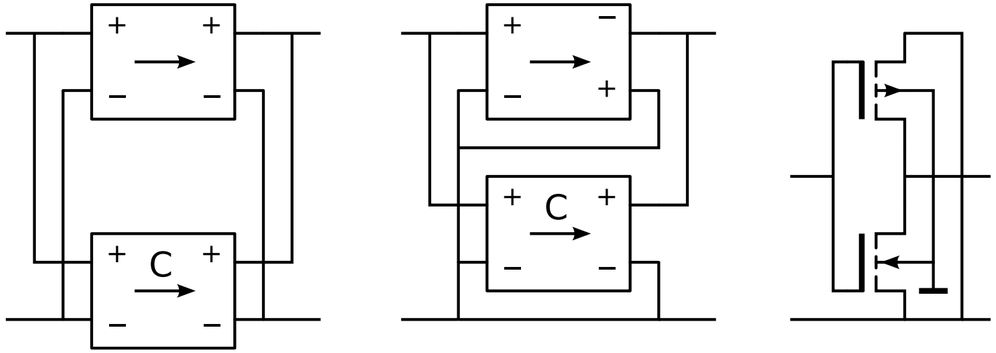

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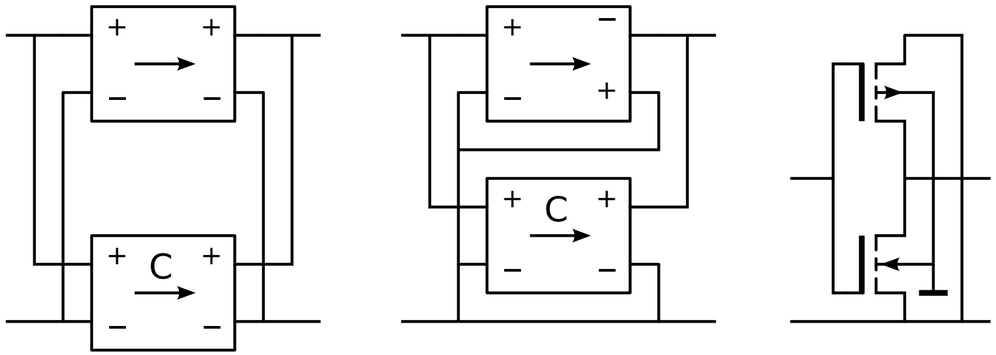

Complementary-parallel biased CS stages

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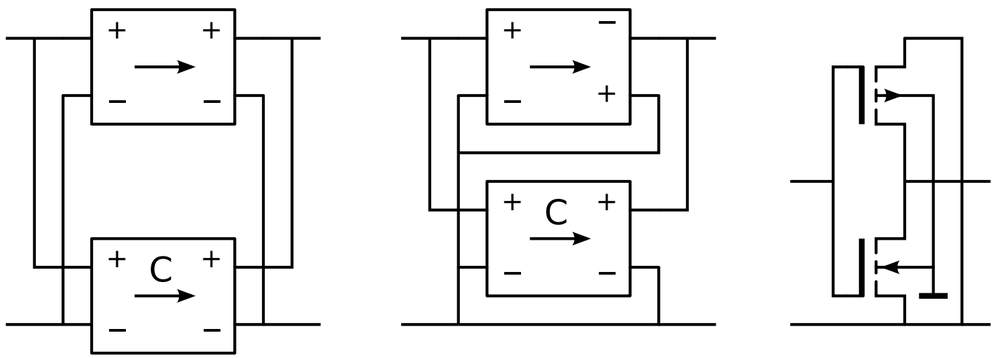

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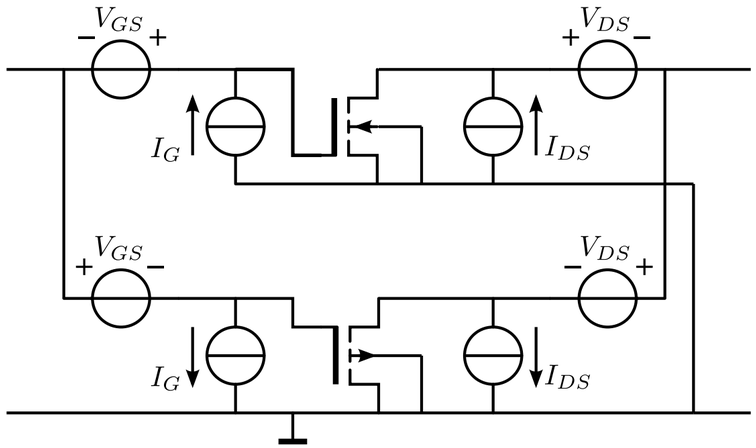

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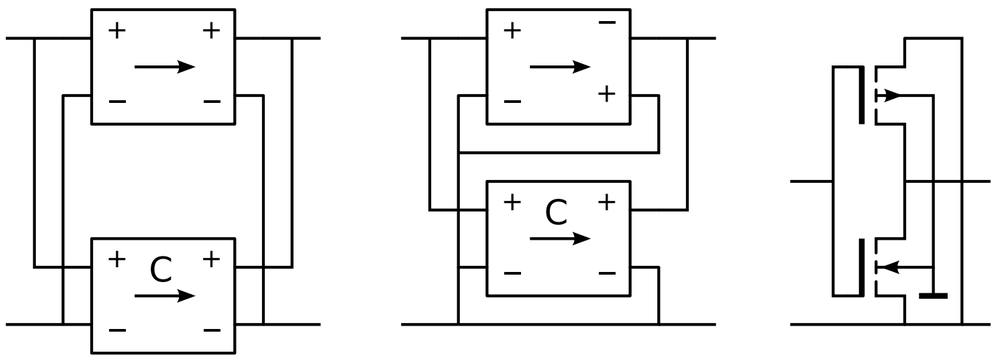

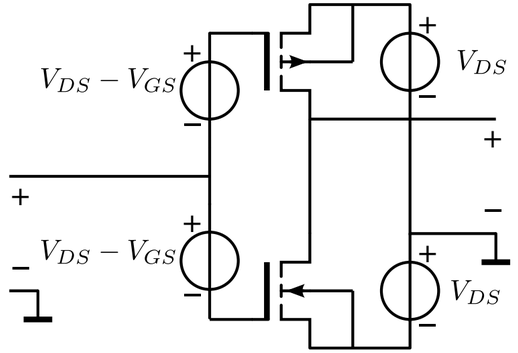

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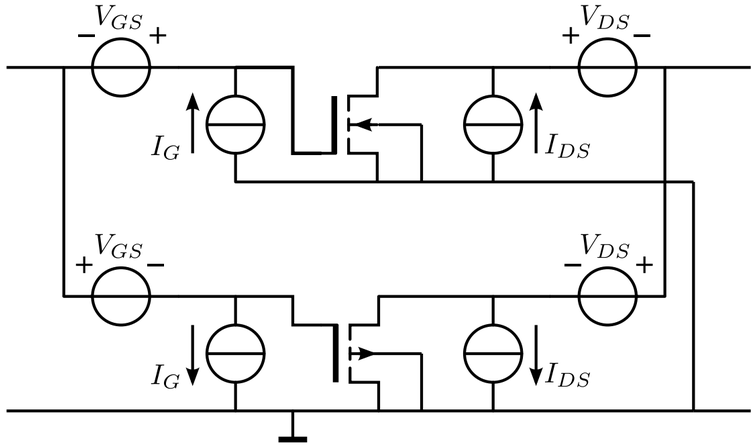

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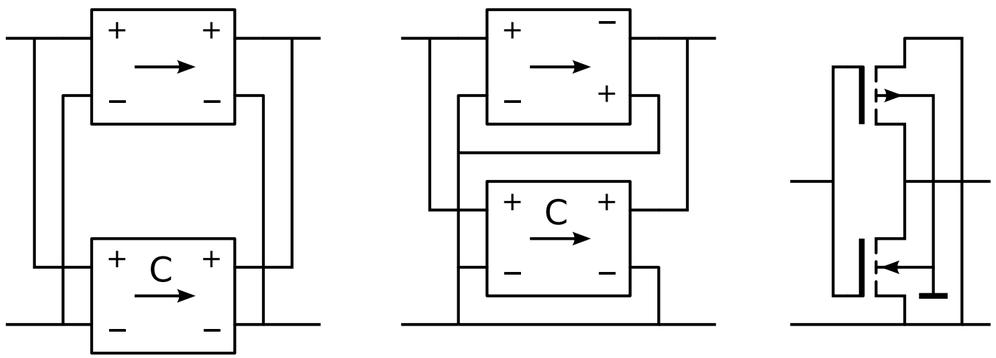

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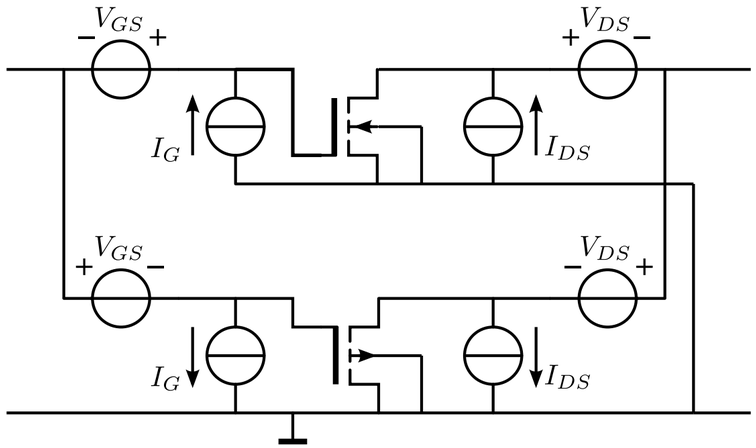

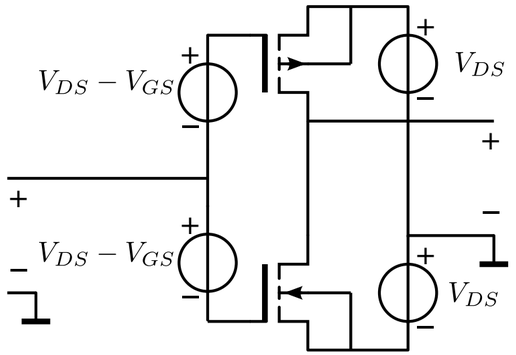

Common-mode currents
are defined by the bias voltages
and the device characteristics

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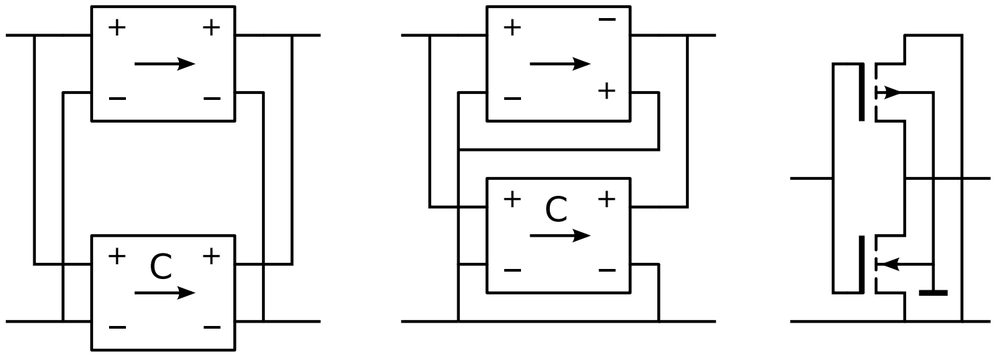

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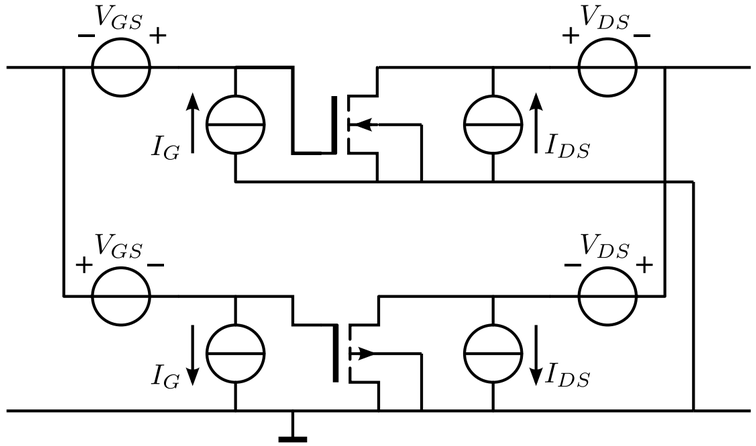

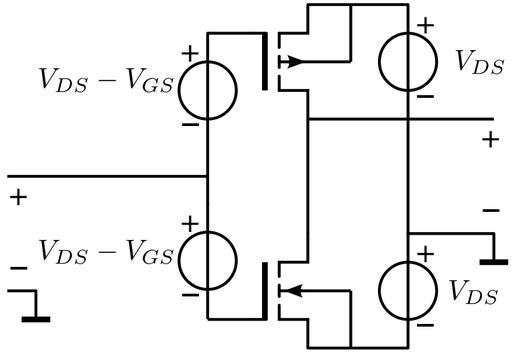

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Push-pull stage V-I transfer

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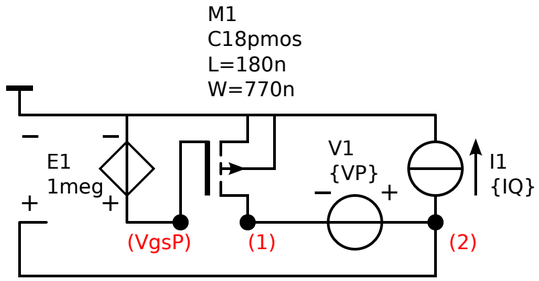

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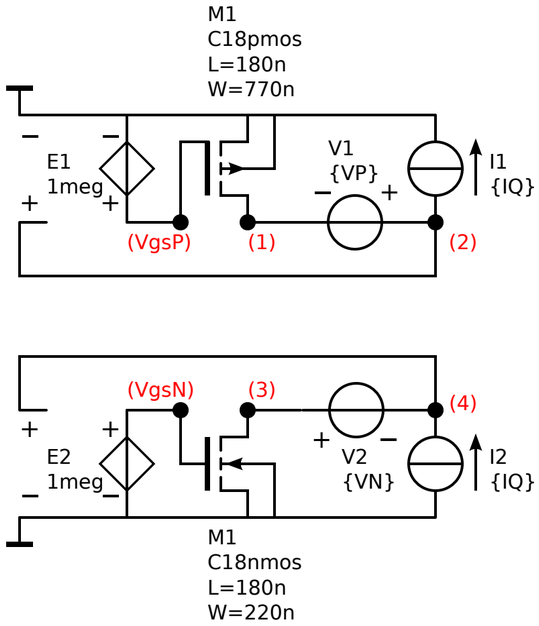

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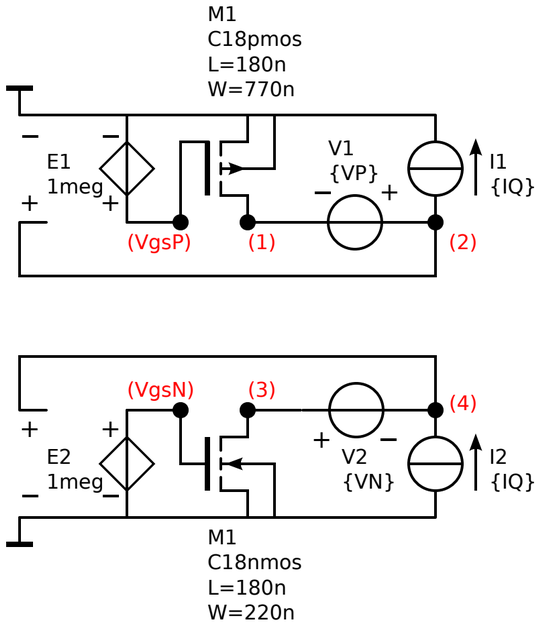

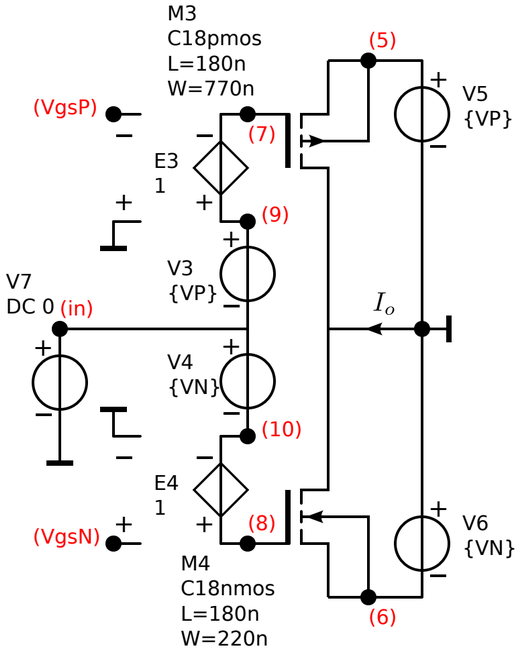

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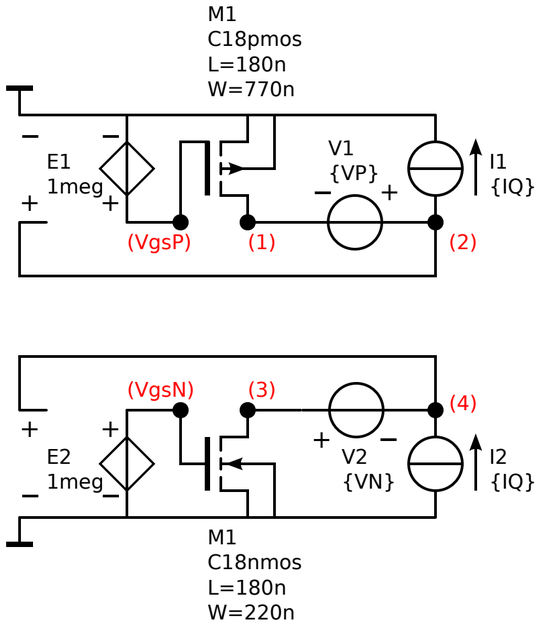

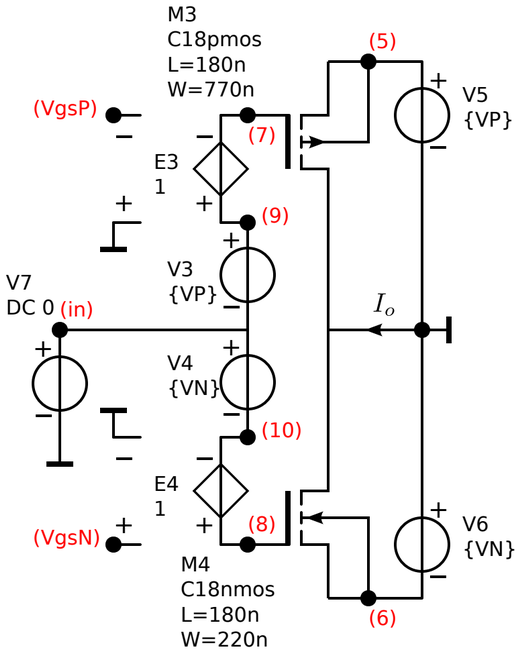

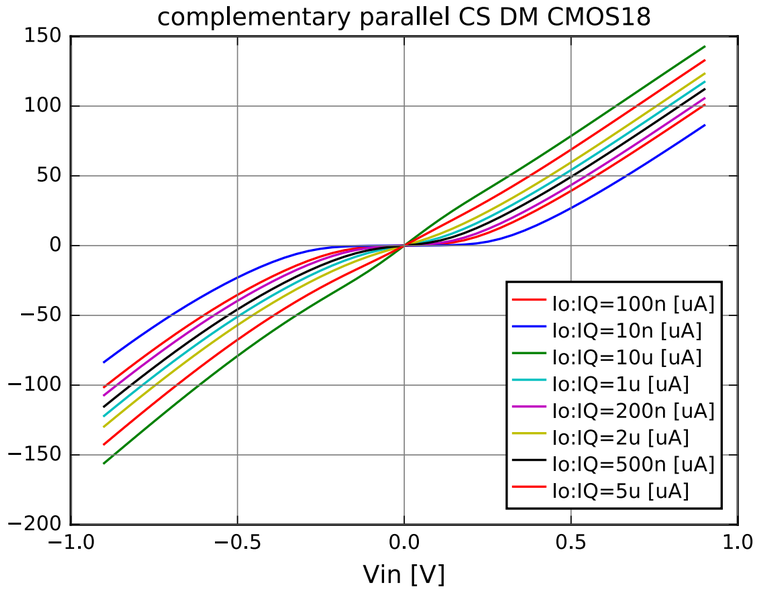

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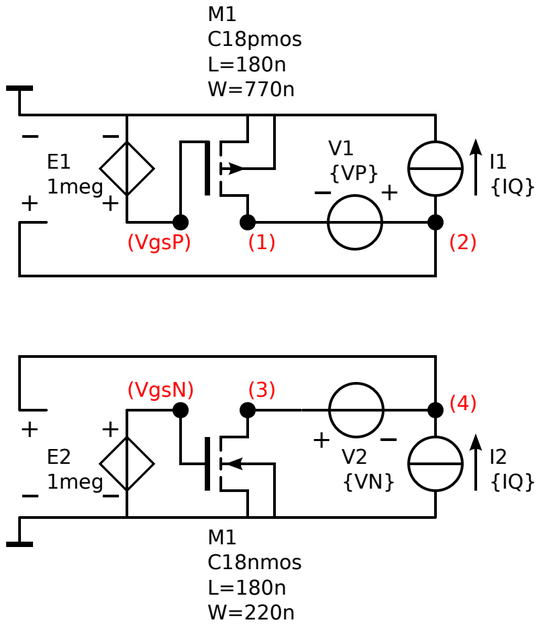

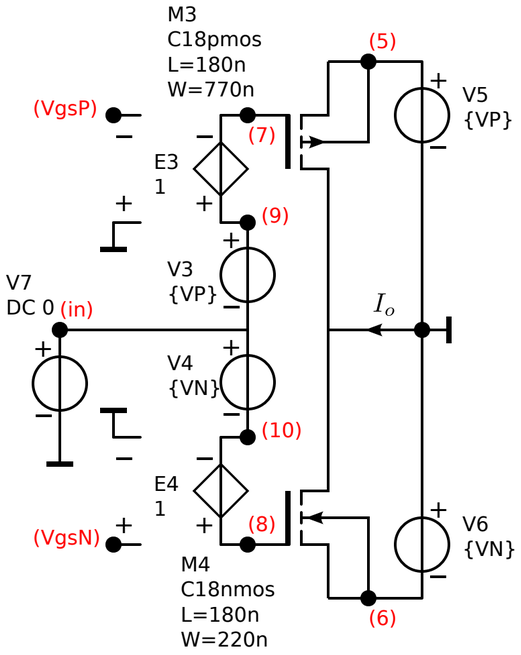

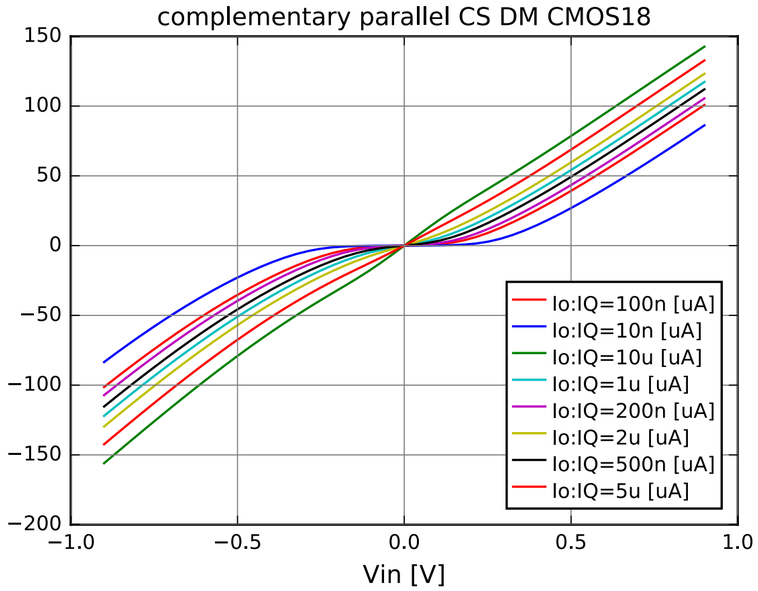

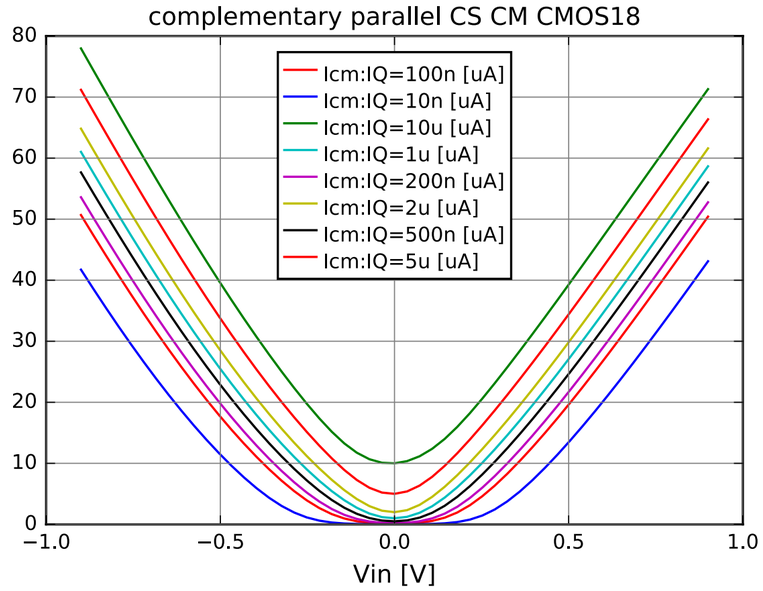

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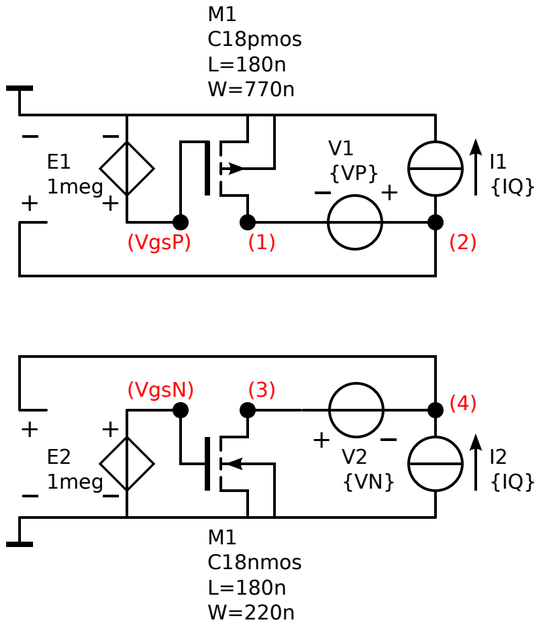

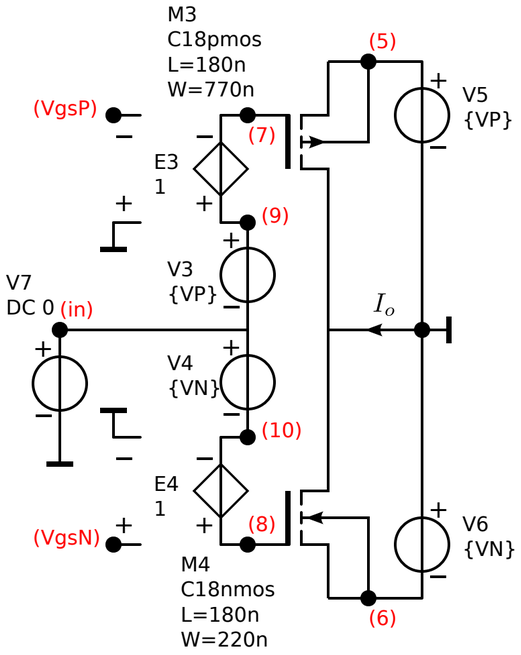

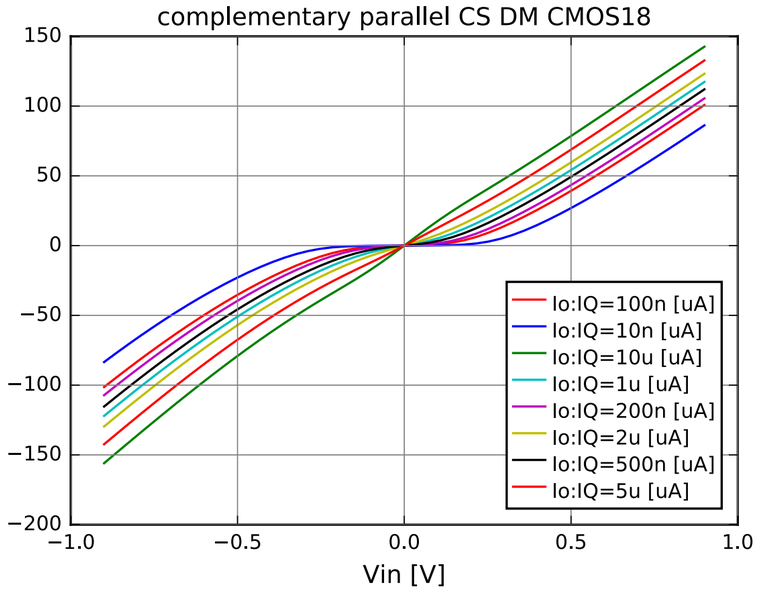

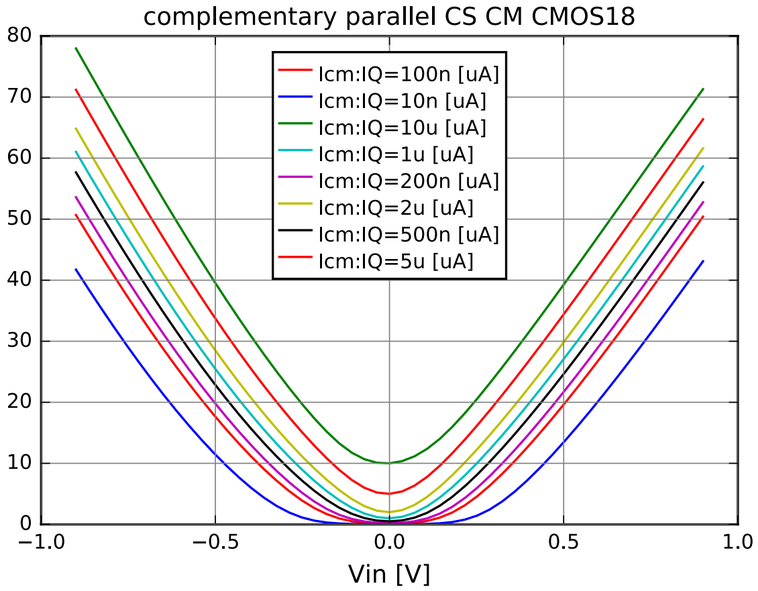

Class A operation: Sink and source devices conduct during push and pull phase

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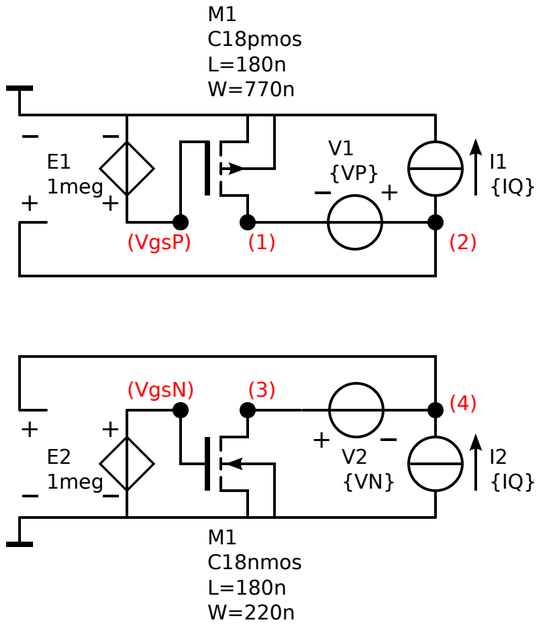
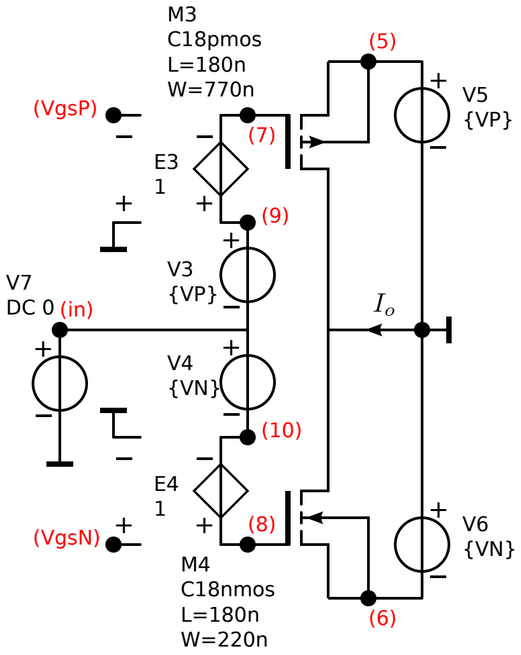
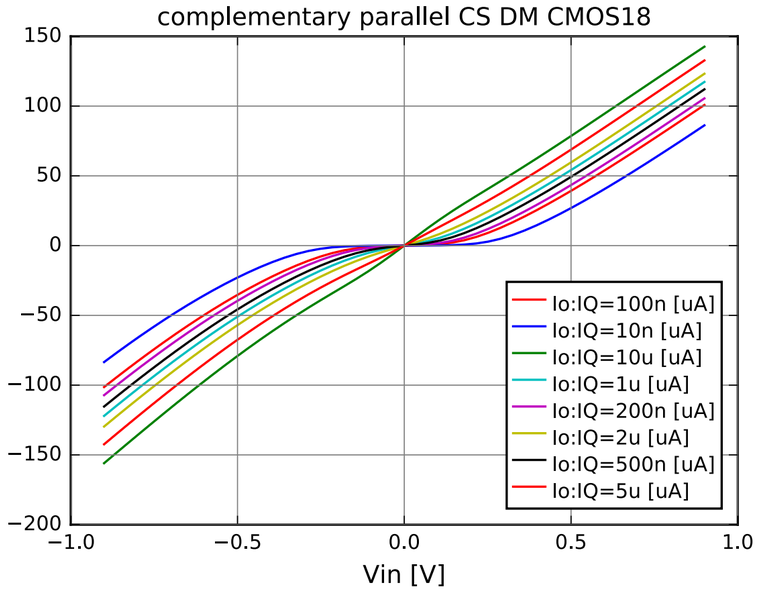
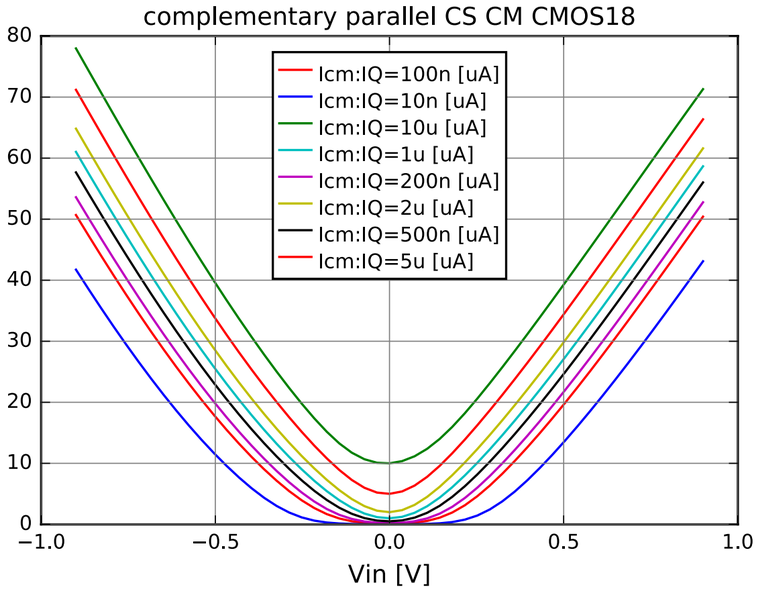
Push-pull stage V-I transfer









Class A operation: Sink and source devices conduct during push and pull phase

Class B operation: Sink device conducts during pull phase
Source device conducts during push phase

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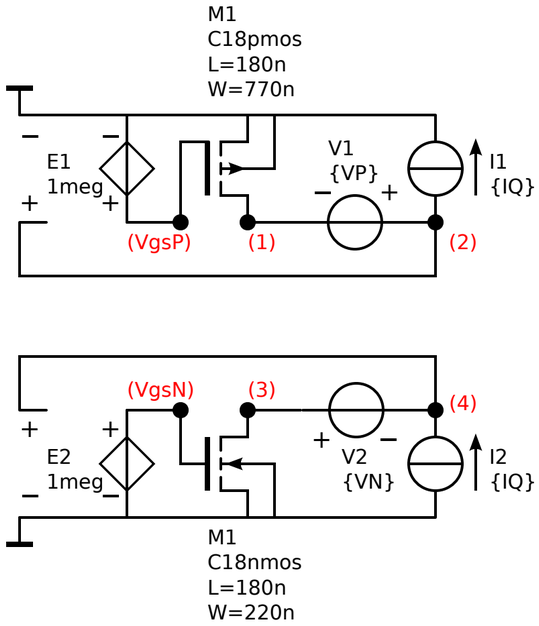
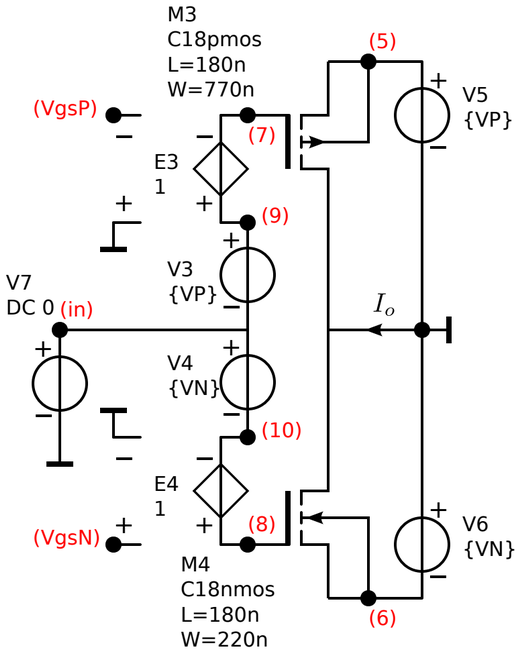
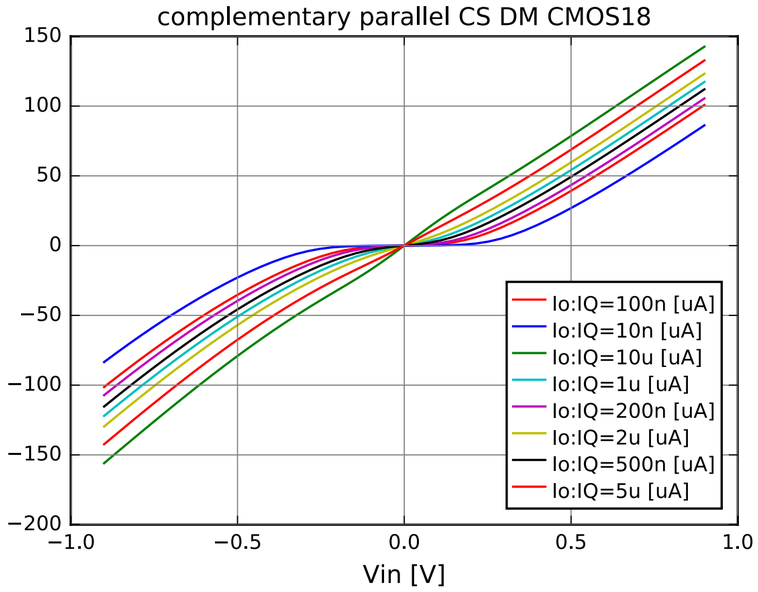
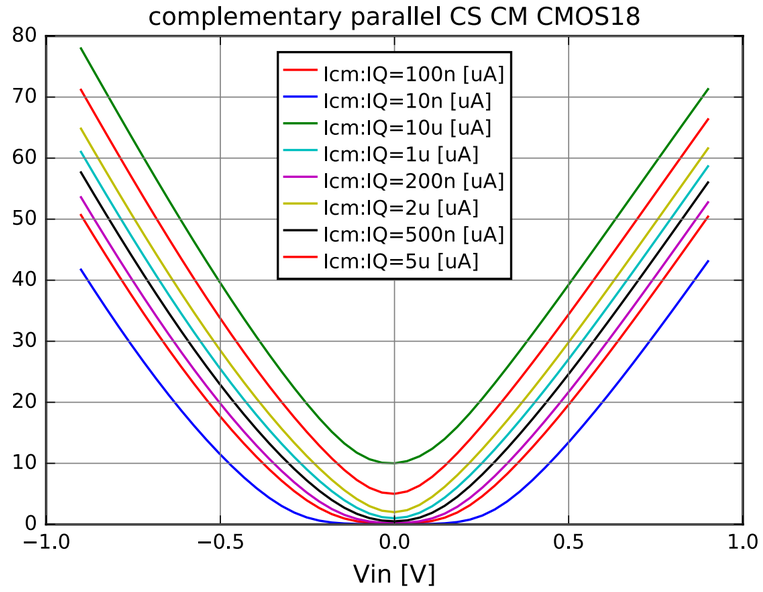
Push-pull stage V-I transfer









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Class B operation: Sink device conducts during pull phase
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Class AB operation: Between A and B: overlap

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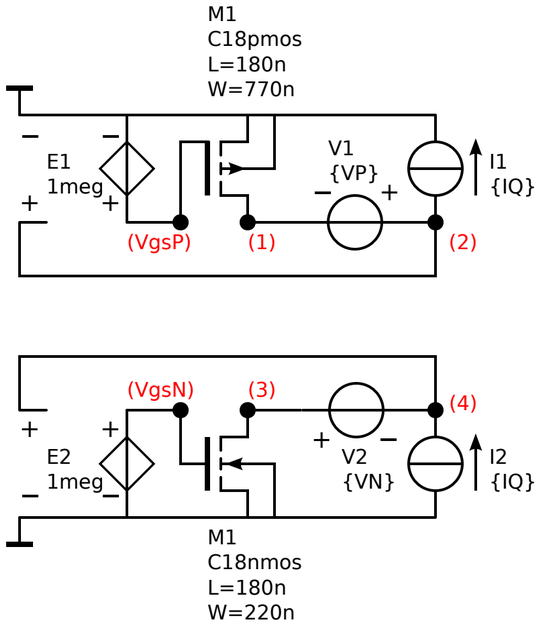
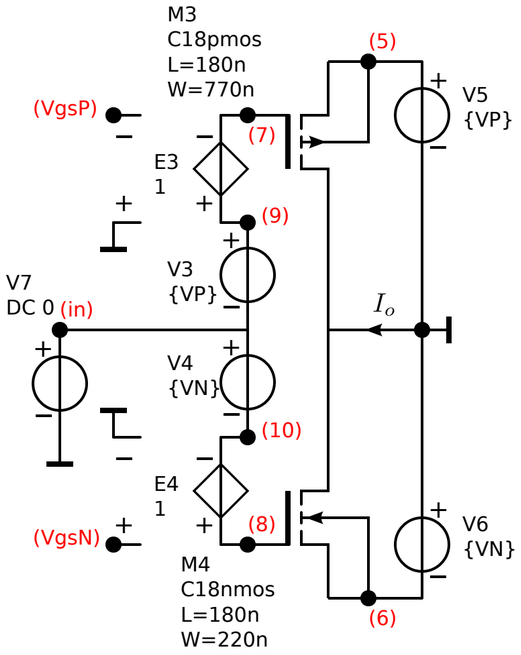
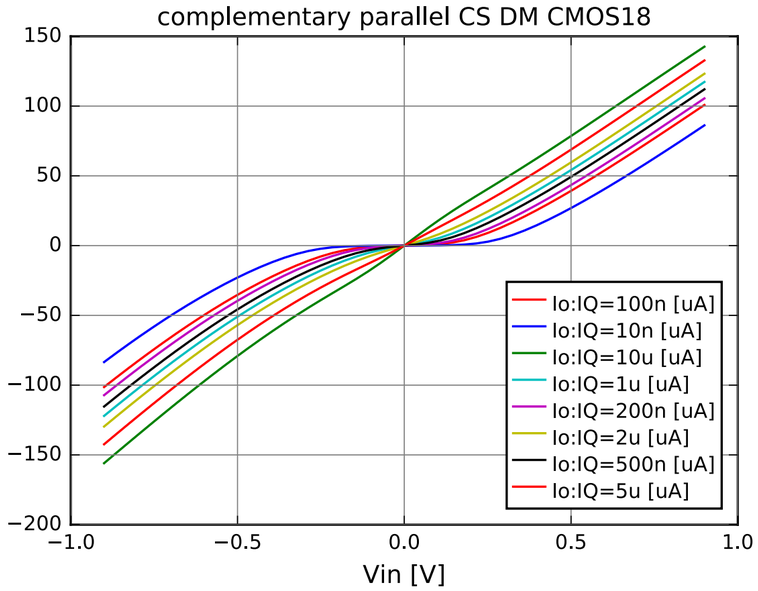
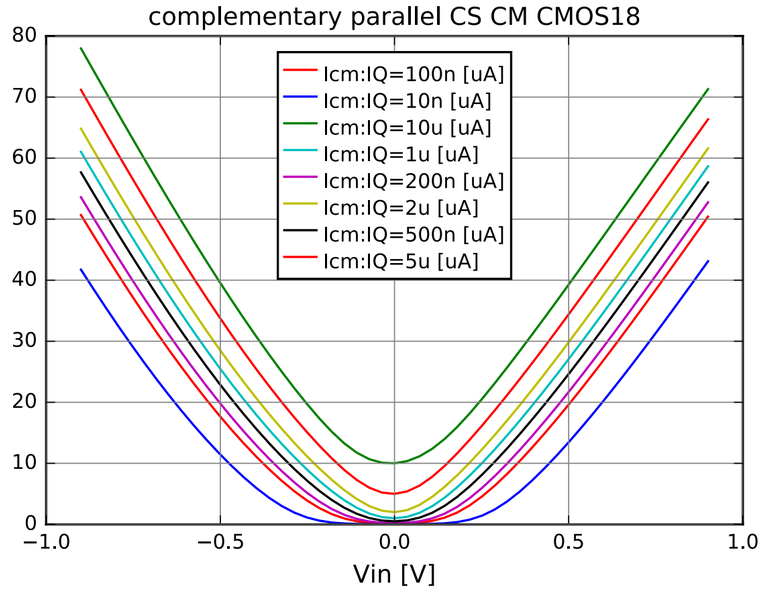
Push-pull stage V-I transfer









Class A operation: Sink and source devices conduct during push and pull phase

Class B operation: Sink device conducts during pull phase
Source device conducts during push phase

Class AB operation: Between A and B: overlap

Class C operation: Dead zone

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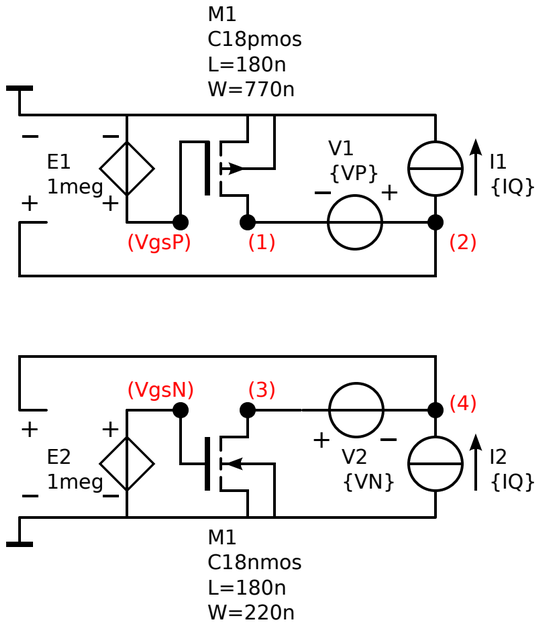
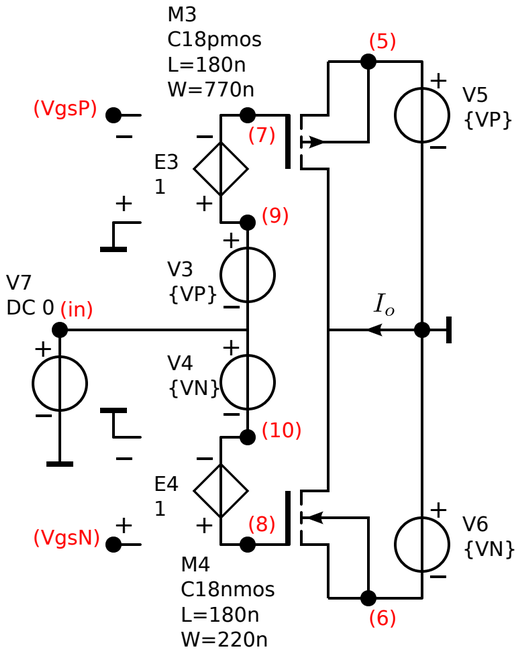
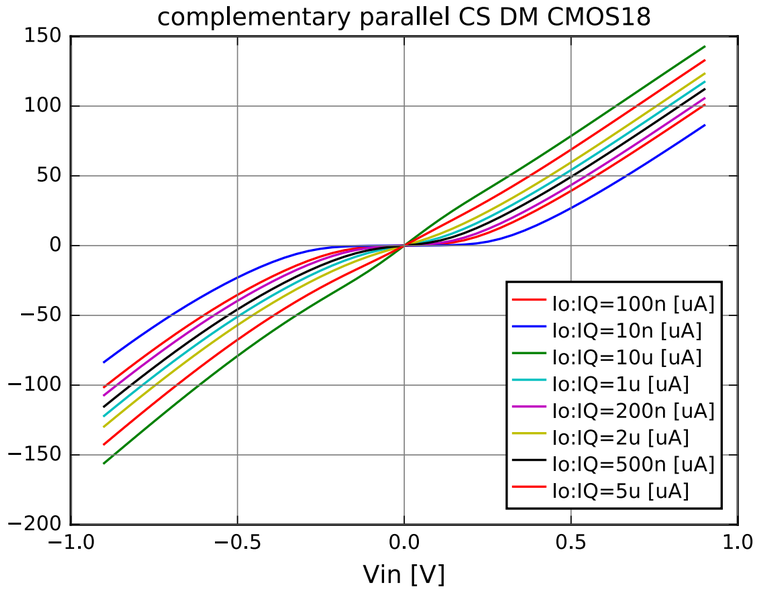
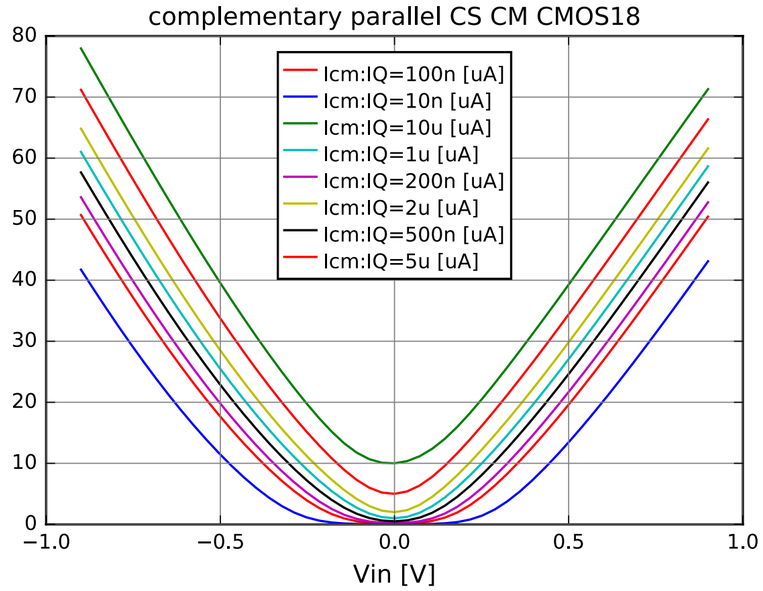
Push-pull stage V-I transfer









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Push-pull stage small-signal transfer

Push-pull stage small-signal transfer

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports

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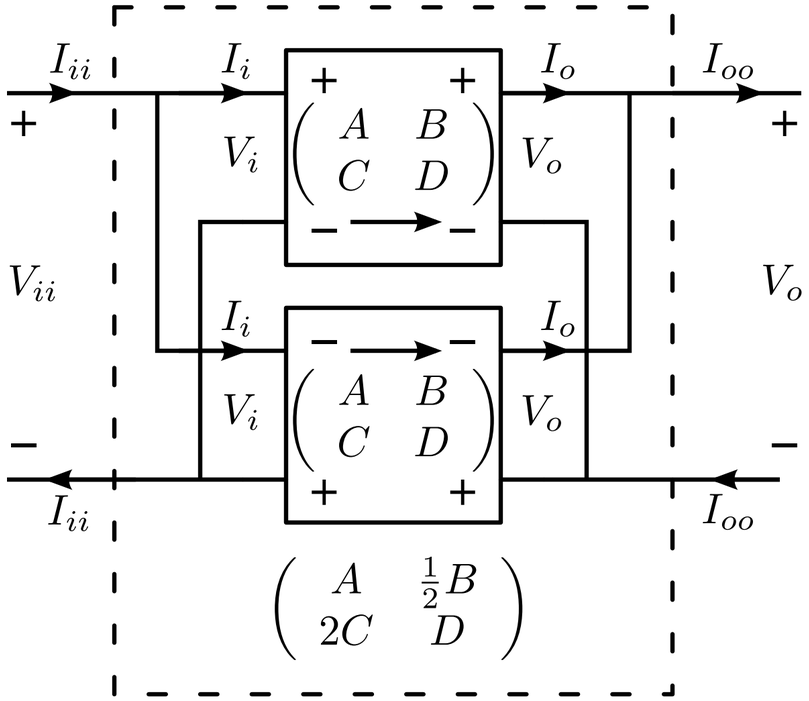
Push-pull stage small-signal transfer

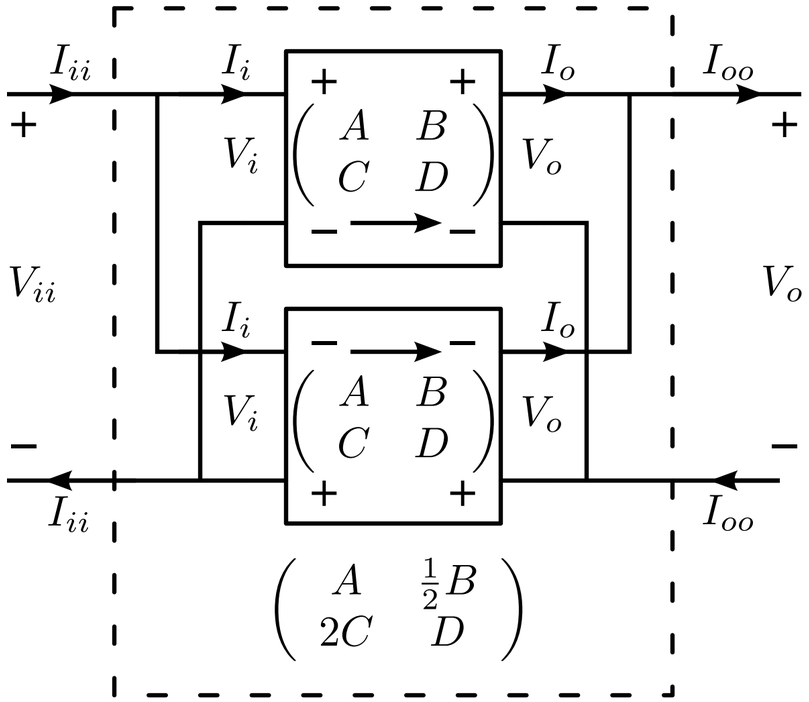
Behavioral modifications resulting from (anti)-parallel connection of linear two-ports



Push-pull stage small-signal transfer

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports

Small-signal diagram push-pull stage



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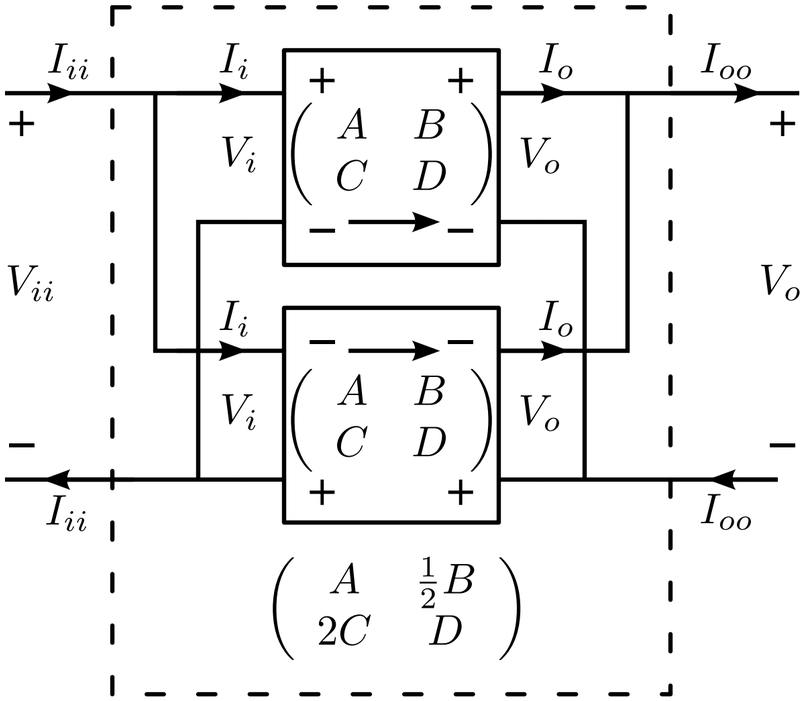

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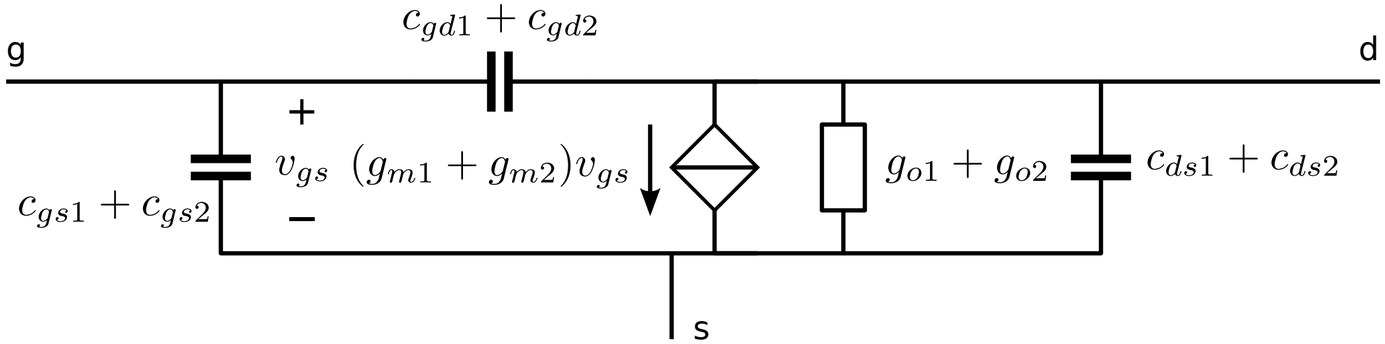

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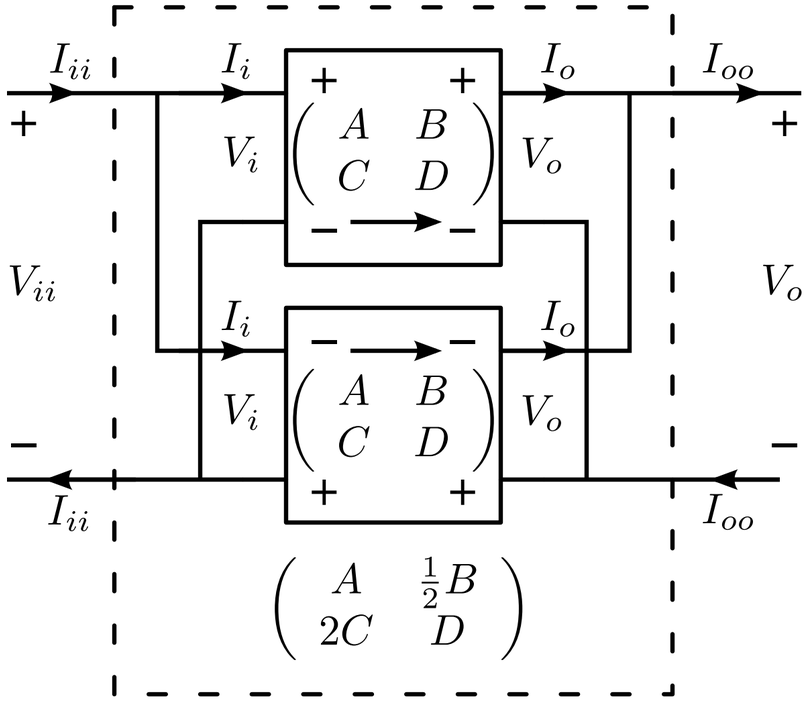
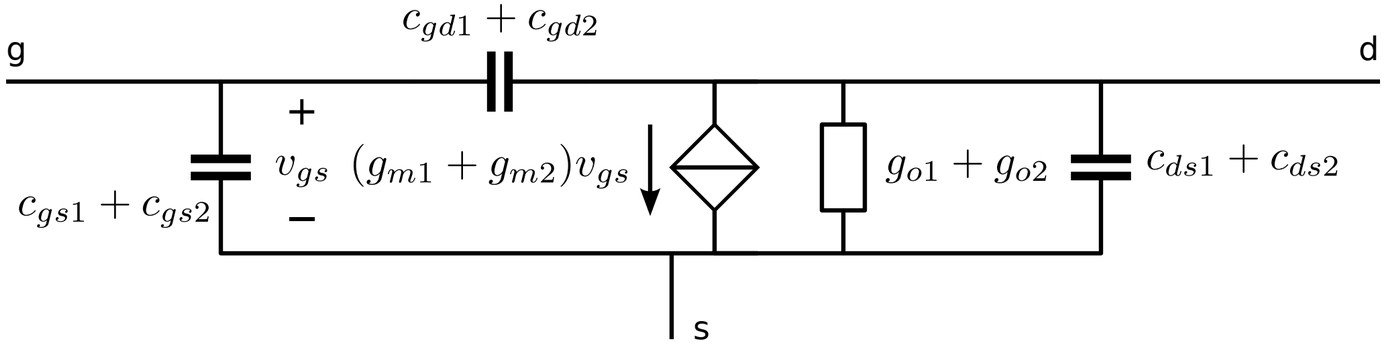
Push-pull stage small-signal transfer

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports



Small-signal diagram push-pull stage



Equivalent small-signal diagram in quiescent operating point

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Push-pull stage small-signal transfer

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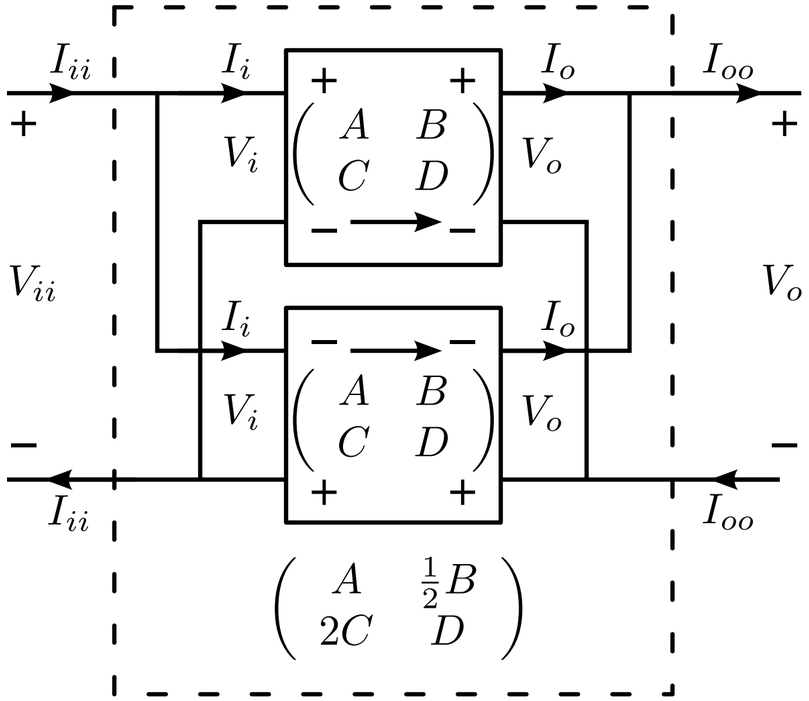

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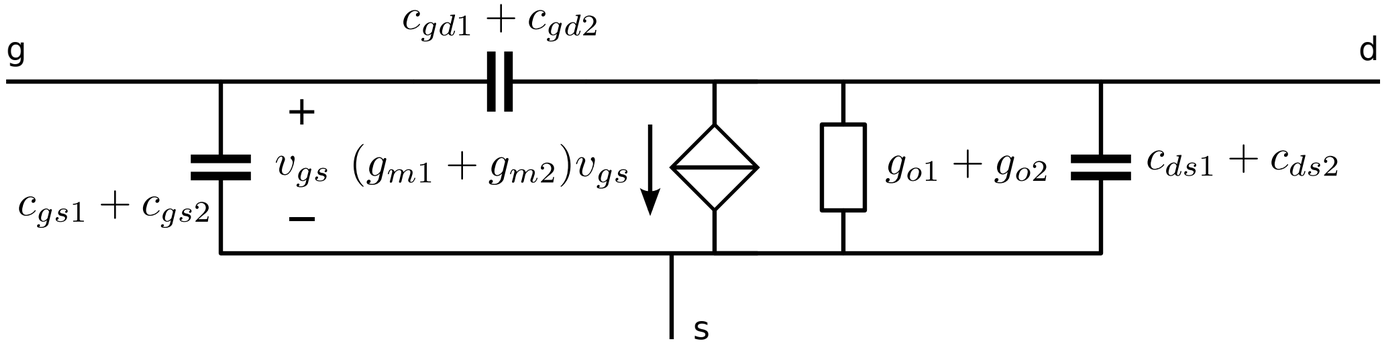

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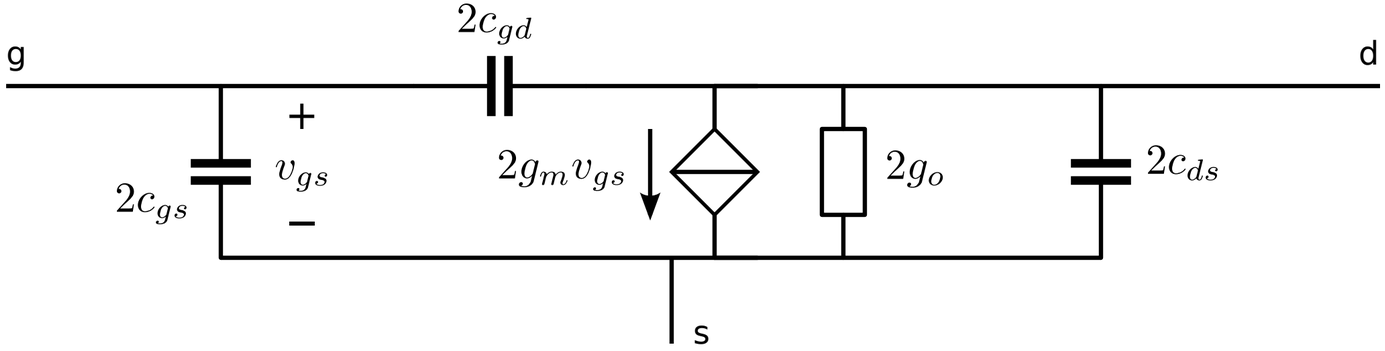

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Push-pull stage small-signal transfer

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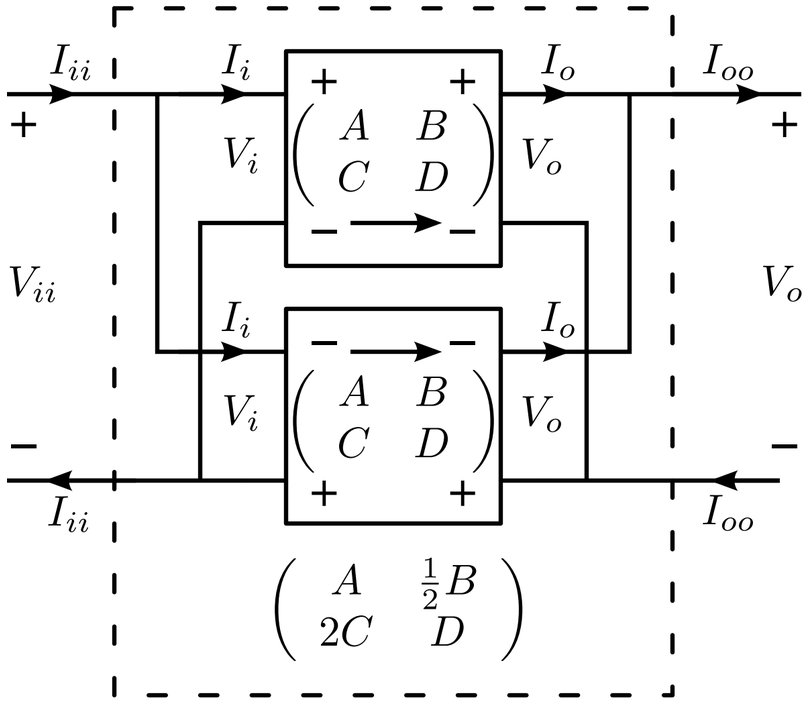

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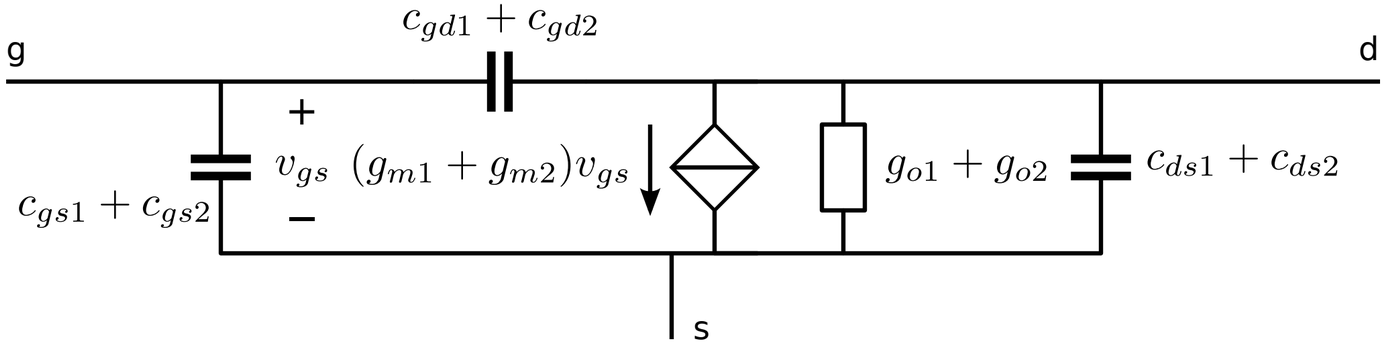

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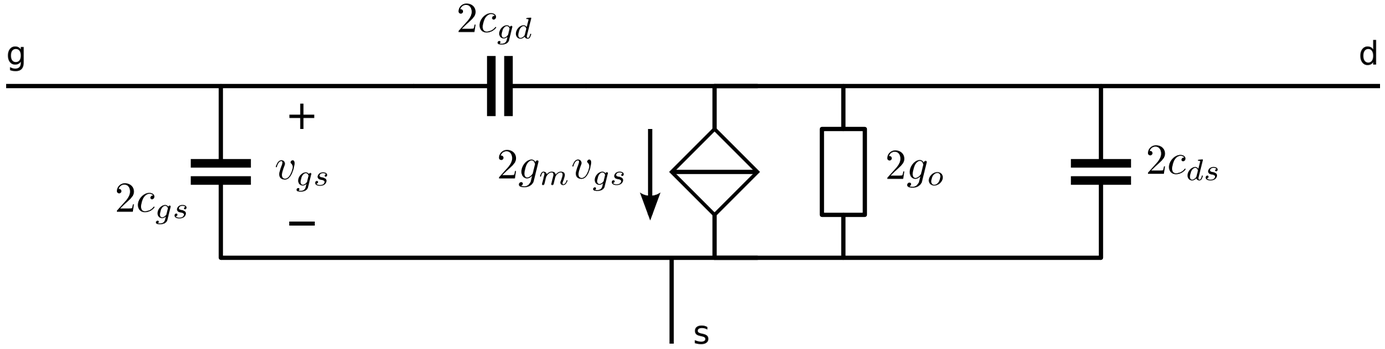

c_{gs}, c_{gd}, c_{ds}, g_m and g_o are the small-signal parameters of the CS stage.

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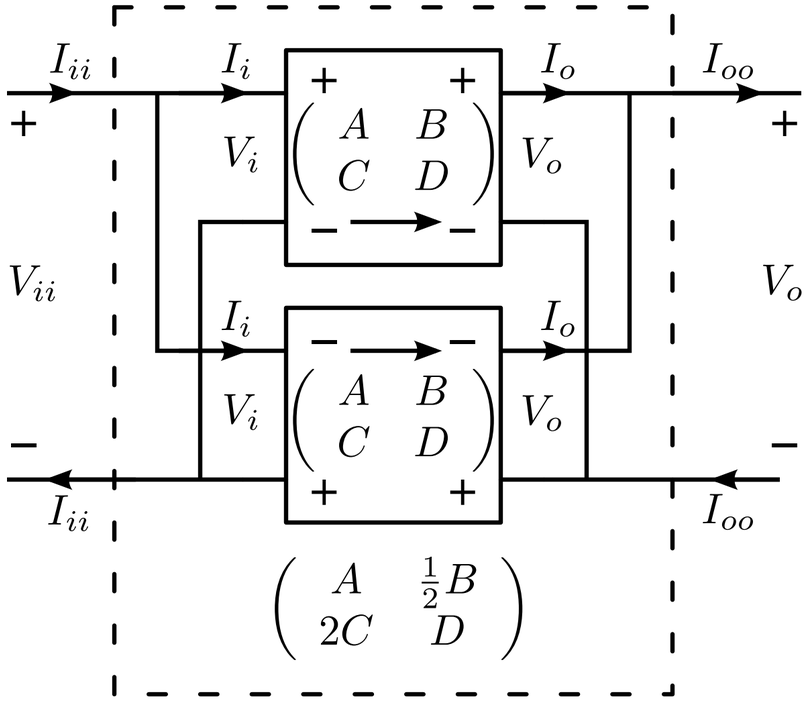
Push-pull stage small-signal transfer

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports



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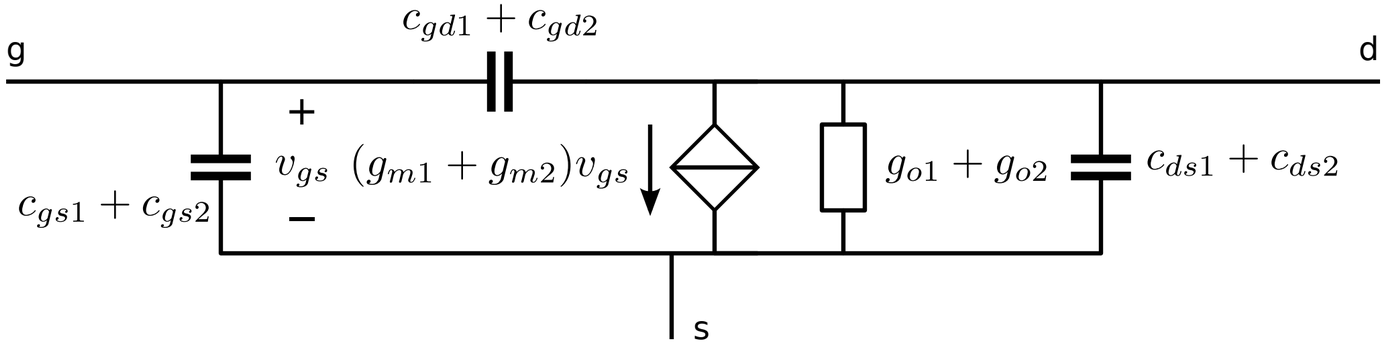

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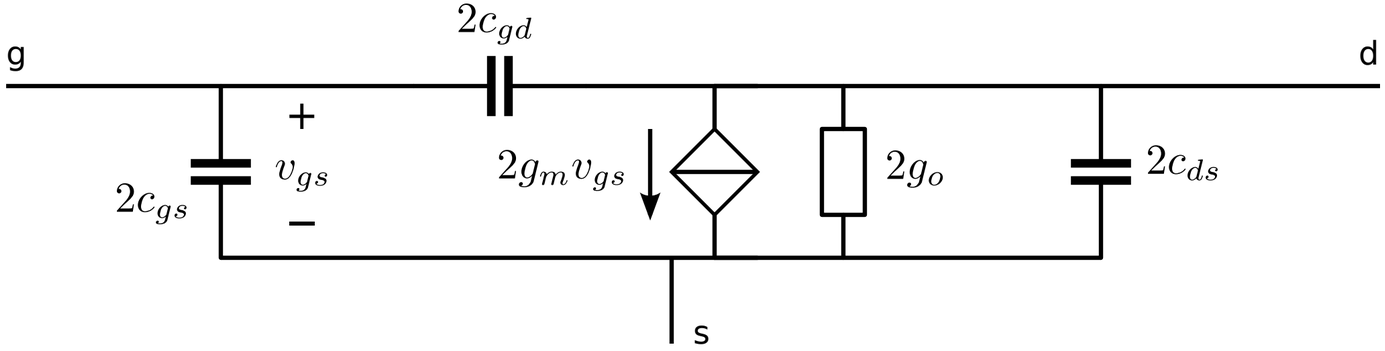

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Push-pull stage stationary noise

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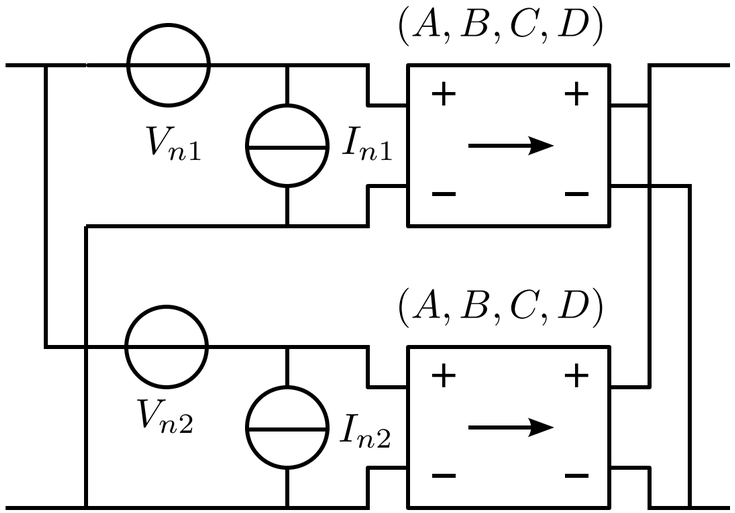
Push-pull stage stationary noise

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports

Push-pull stage stationary noise

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports



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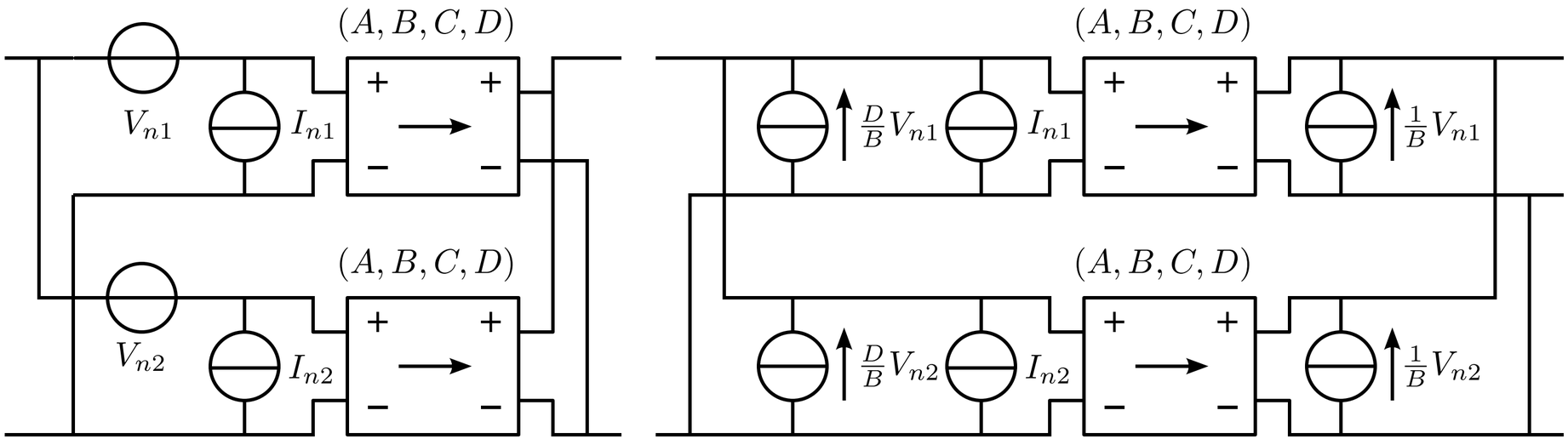
Push-pull stage stationary noise

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports



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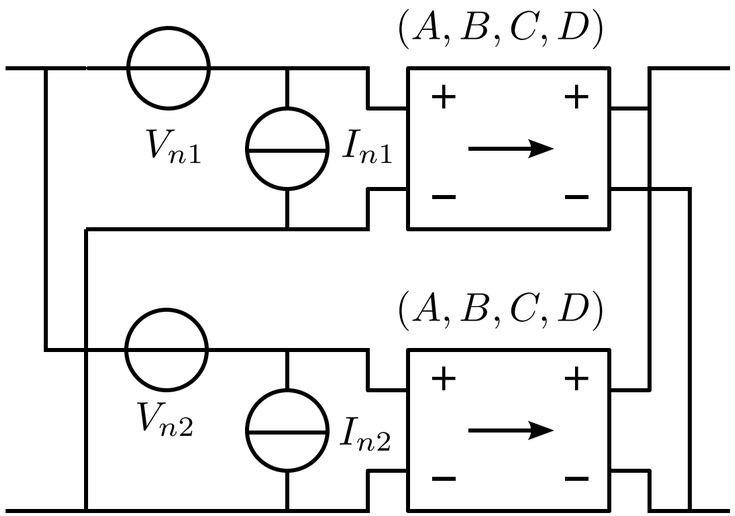
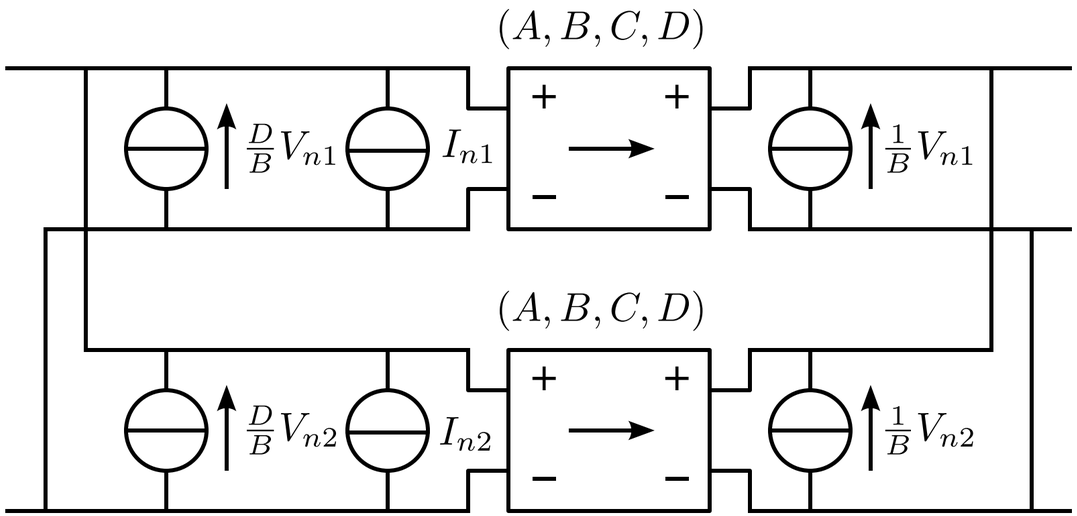
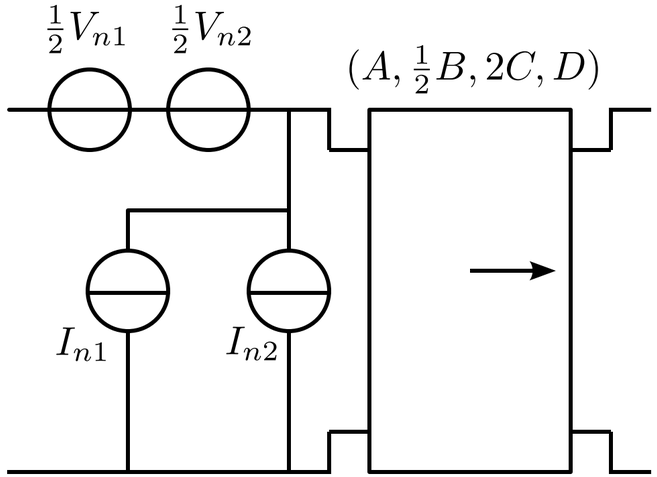
Push-pull stage stationary noise

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports







Result:

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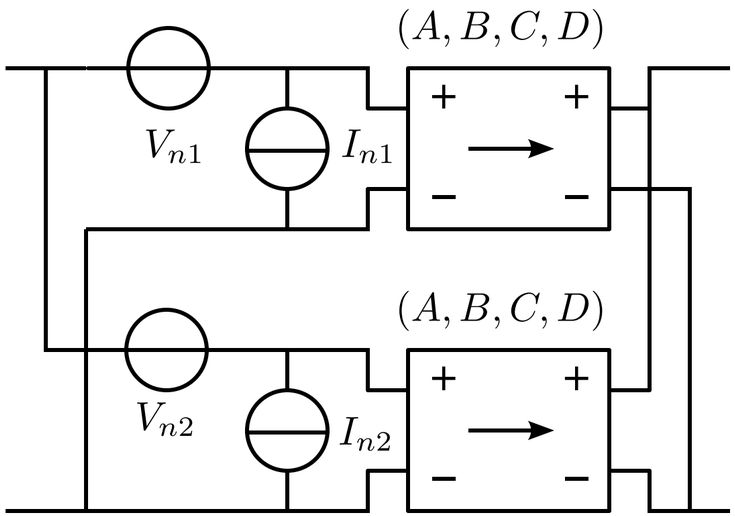
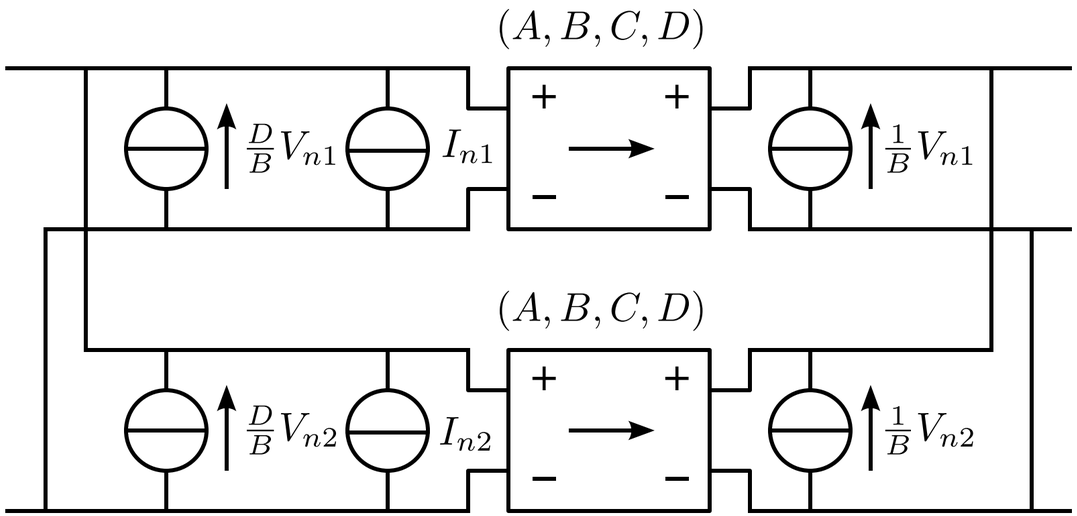
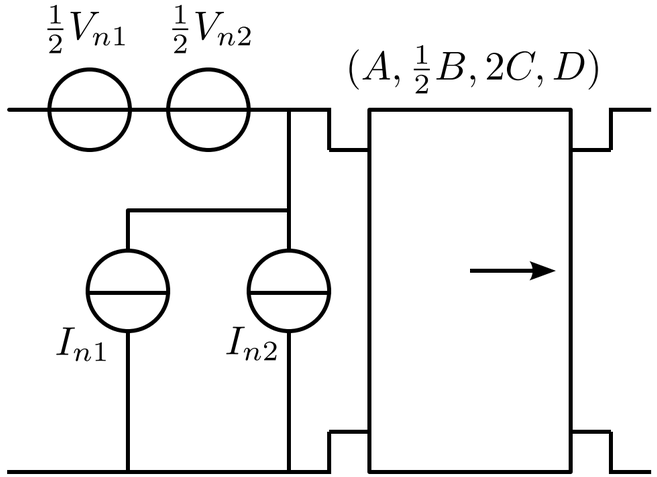
Push-pull stage stationary noise

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports







Result:

$S_v = \frac{1}{4} \left(S_{Vn1} + S_{Vn2} \right)$

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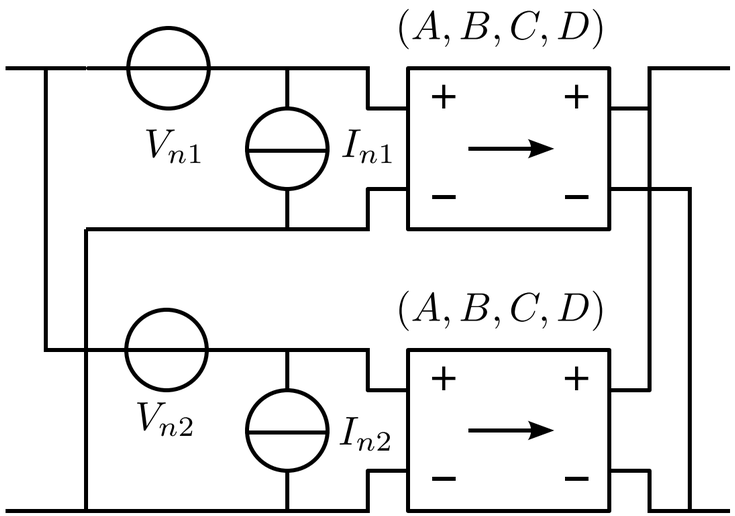
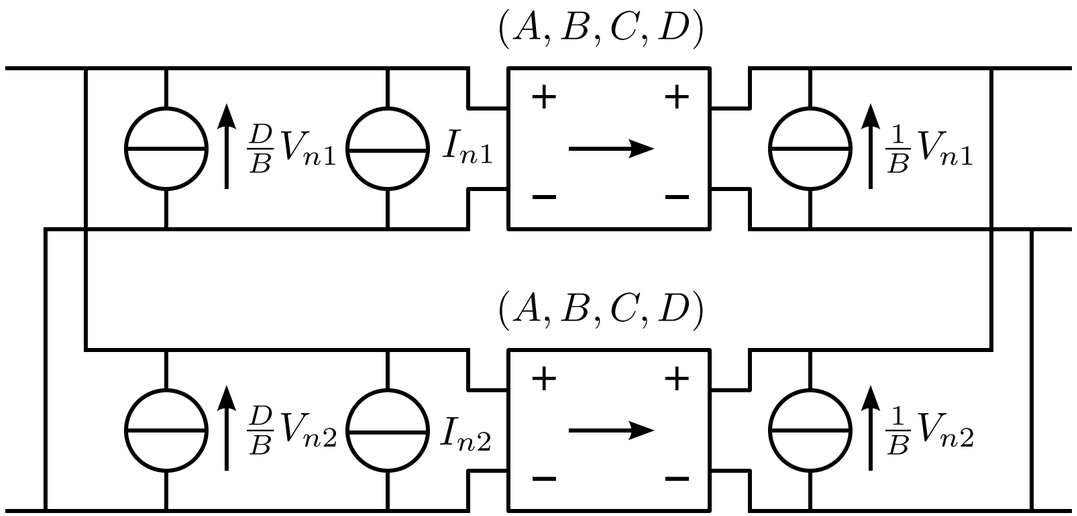
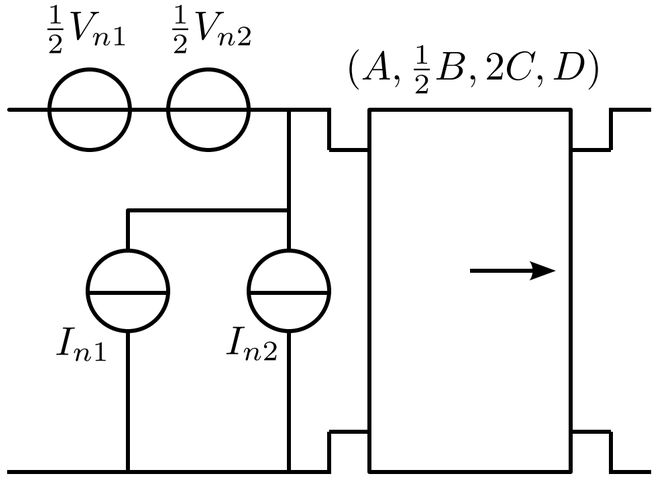
Push-pull stage stationary noise

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports







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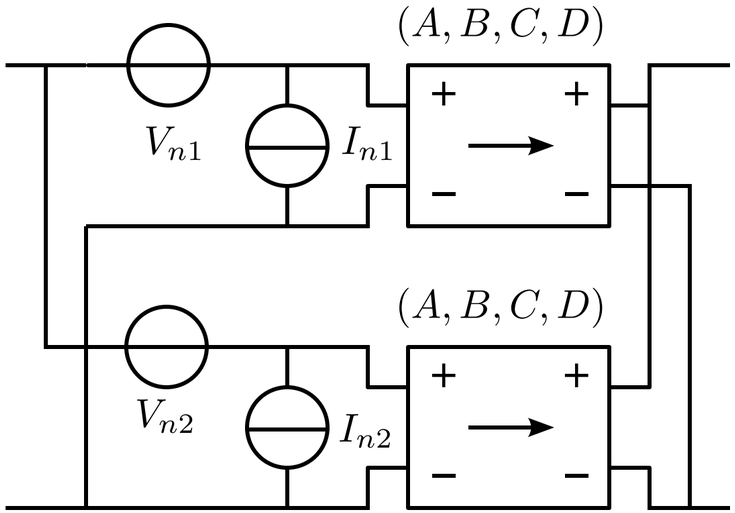
$S_v = \frac{1}{4} \left(S_{Vn1} + S_{Vn2} \right)$

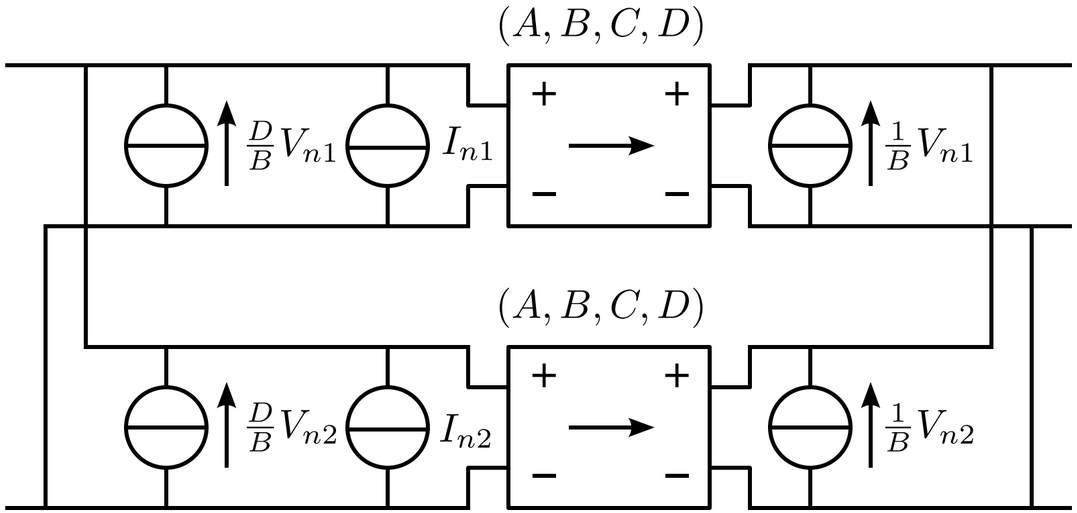
$S_i = S_{In1} + S_{In2}$

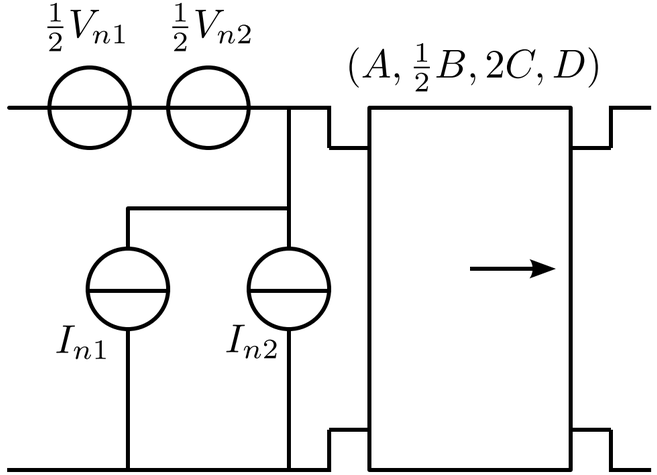
(c) 2020 A.J.M. Montagne

Push-pull stage stationary noise

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports







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Conclusion:

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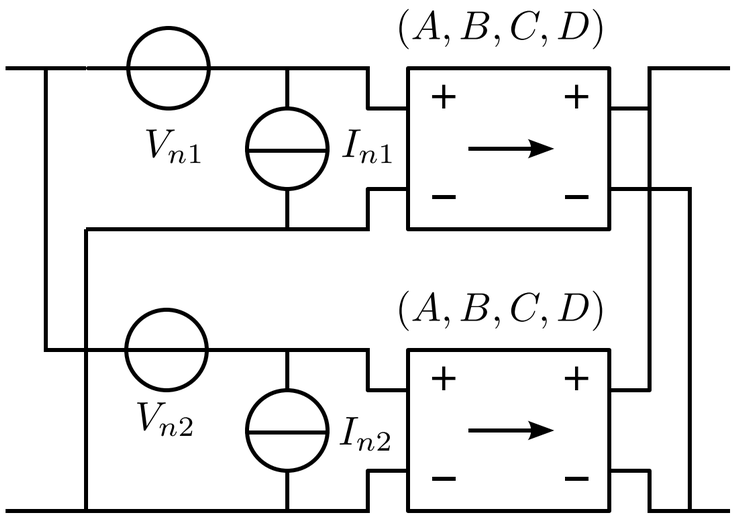
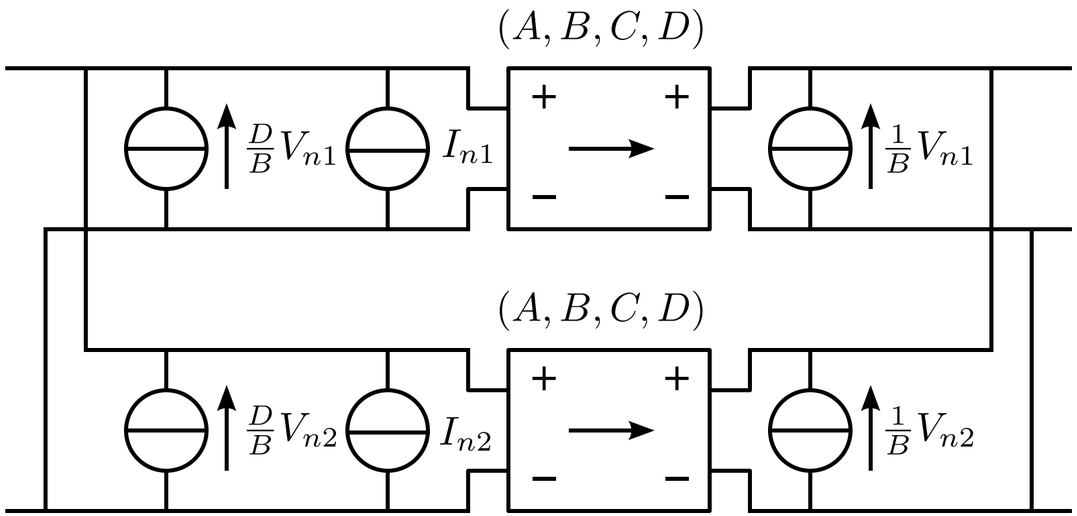
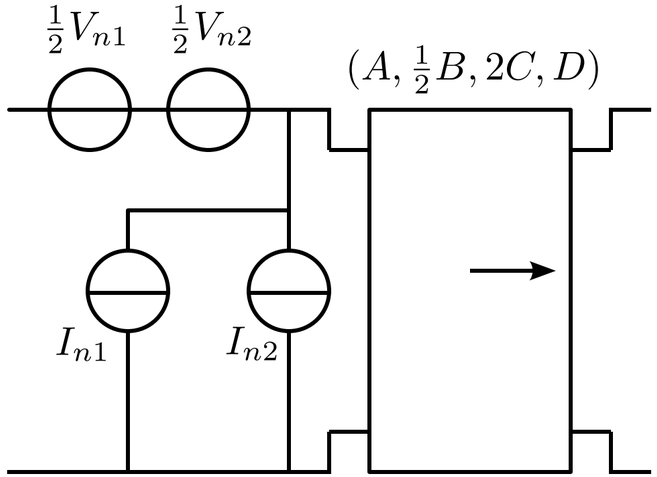
Push-pull stage stationary noise

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports







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$$S_v = \frac{1}{4}\left(S_{Vn1} + S_{Vn2}\right)$$
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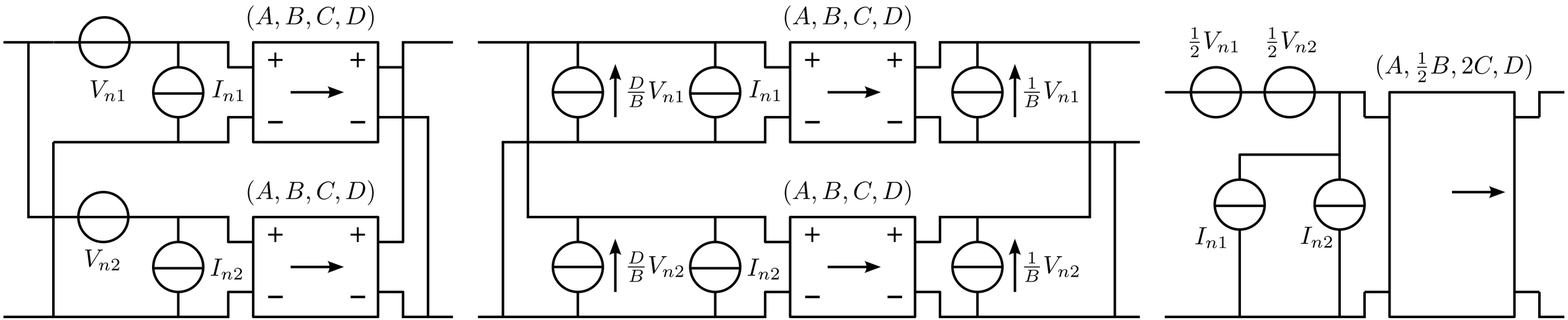
Conclusion: Equivalent input noise sources of a push-pull stage equal those of of a single CS stage if:

Push-pull stage stationary noise

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports



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Width and drain current of the transistors of the differential pair are half the values of those of the single CS stage

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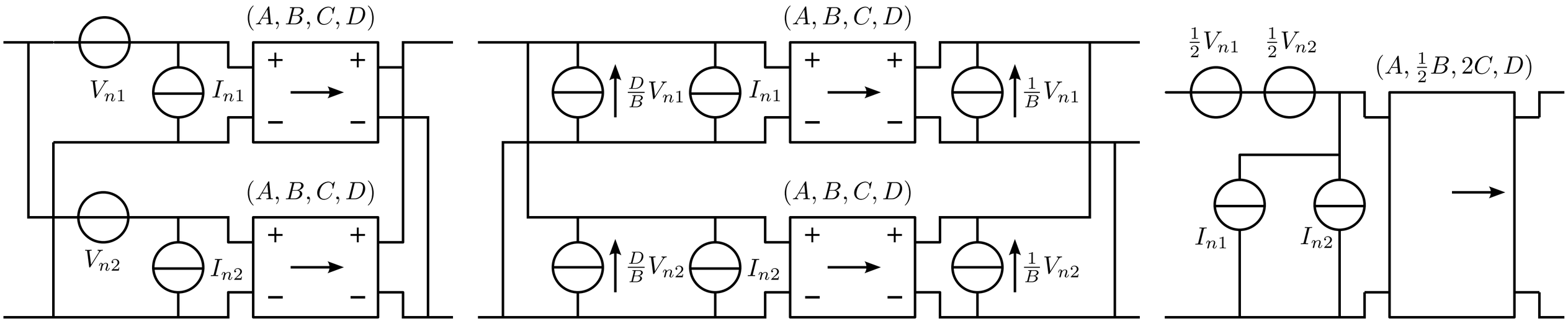
Push-pull stage stationary noise

Behavioral modifications resulting from (anti)-parallel connection of linear two-ports



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Same performance: equal area, equal current (complementary devices)

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Push-pull stage stationary noise

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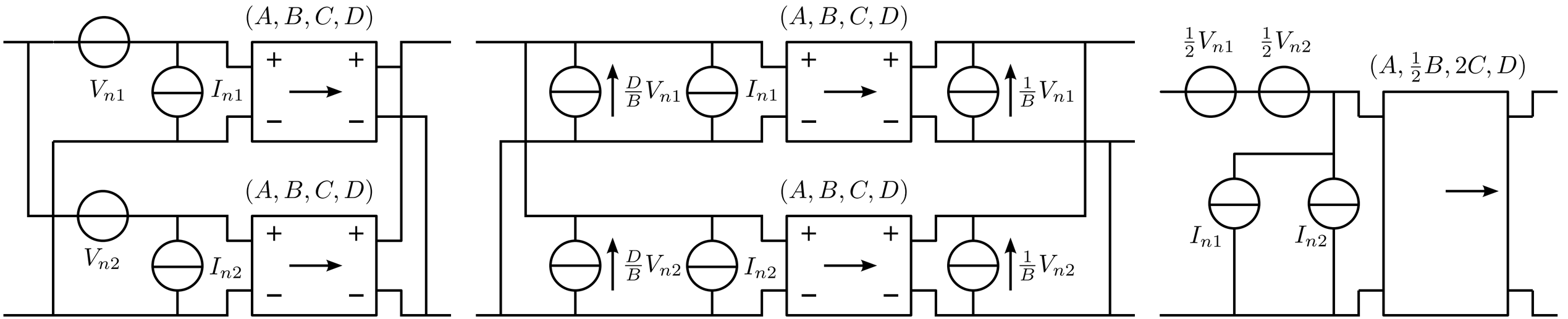

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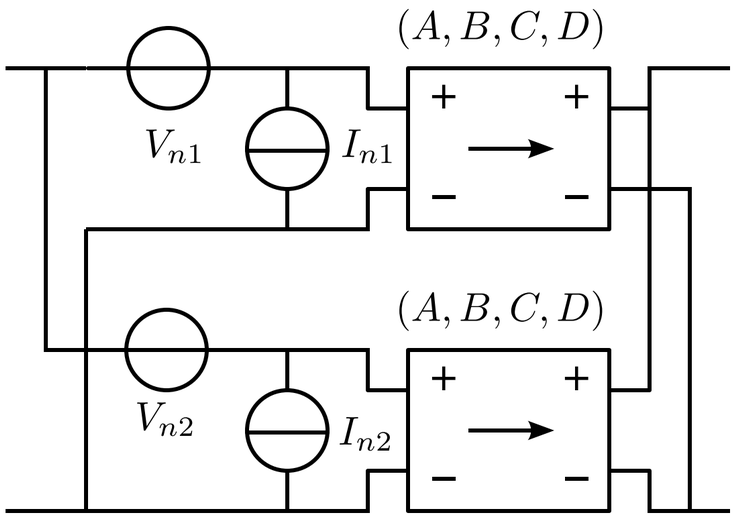

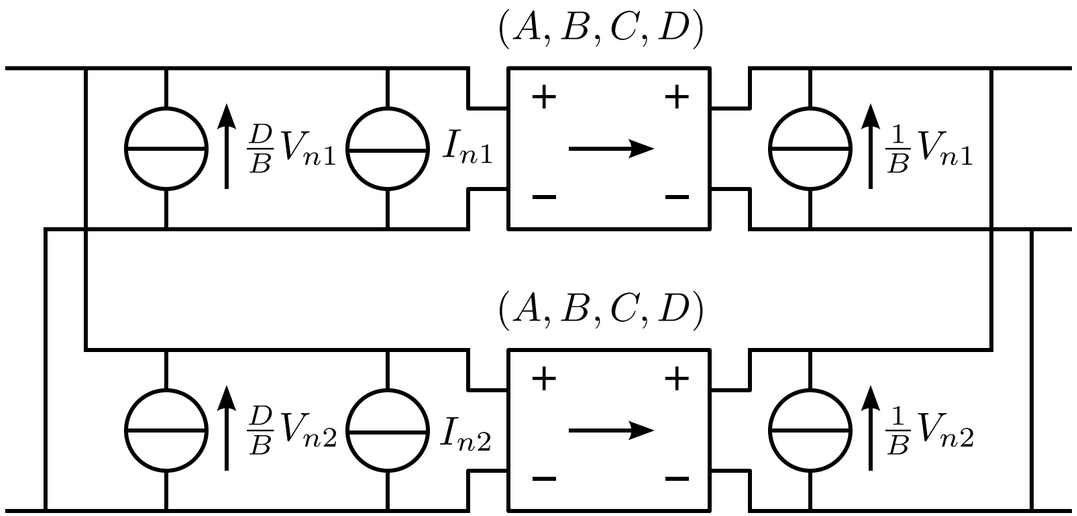

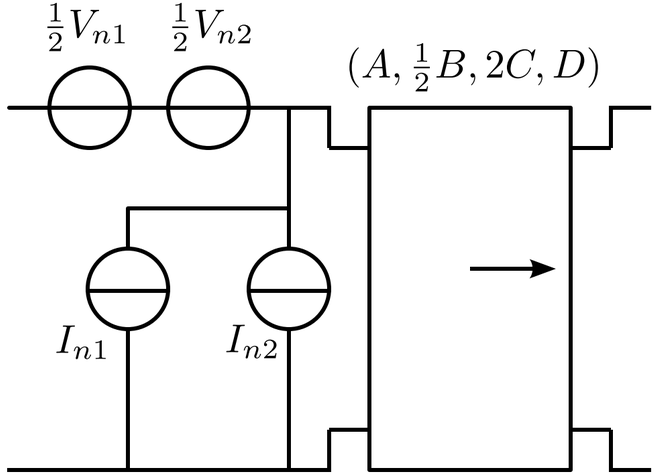

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Carrier mobility in PMOS devices a factor 4 times lower

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Push-pull stage stationary noise

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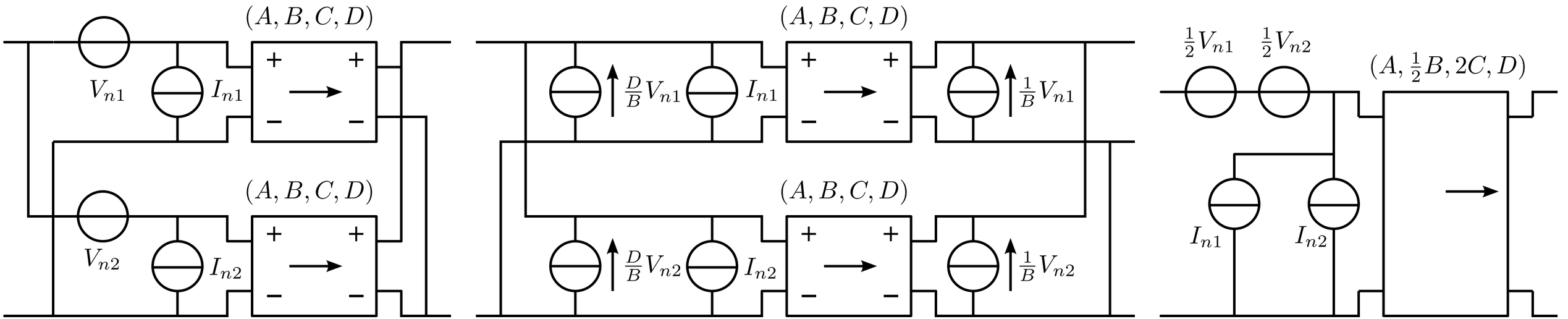

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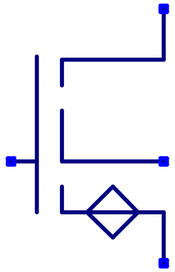
Push-pull stage SLiCAP model

LTspice symbol for SLiCAP:
SLXMPN



SLiCAP subcircuit for this symbol:
CMOS18PN

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