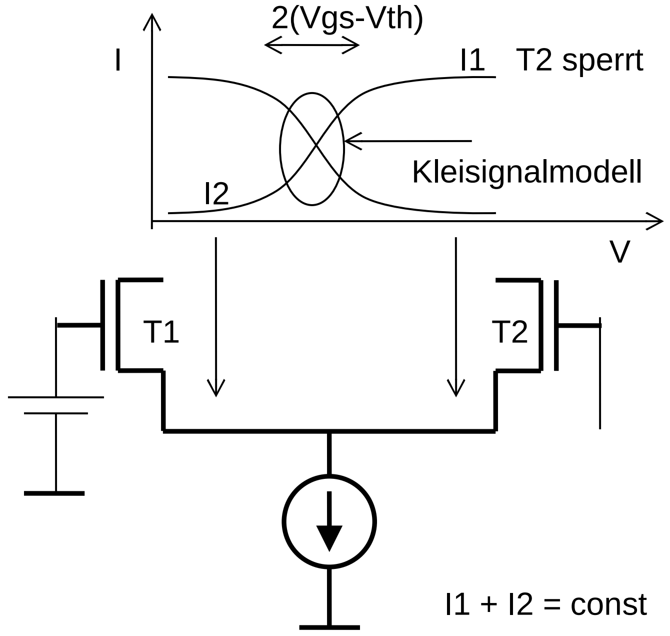
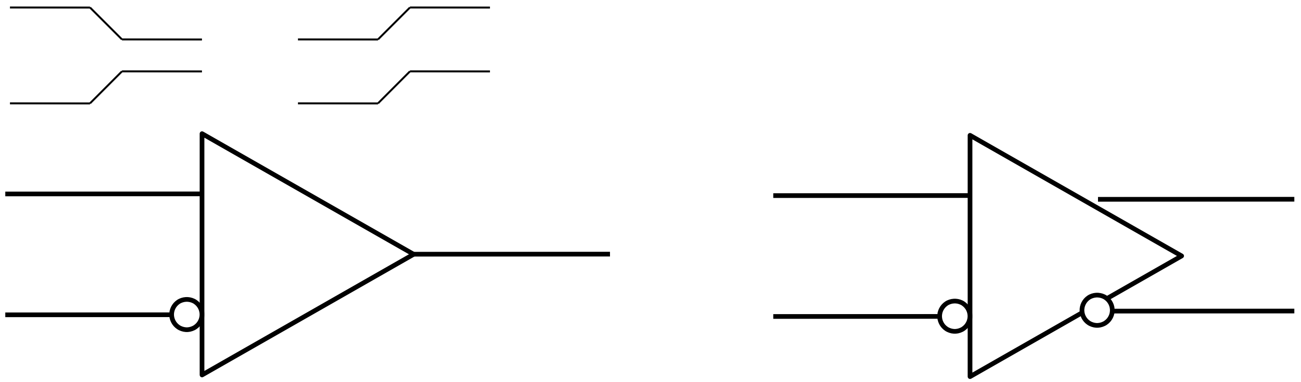
Differenzverstärker

- Vorlesung 8
- Differenz- und Gleichtaktverstärkung
- Operations- und Differenzverstärker
- Vorlesung 9
- AC – Analyse von Differenzverstärker



I1 + I2 = const

ΔI1 = -ΔI2



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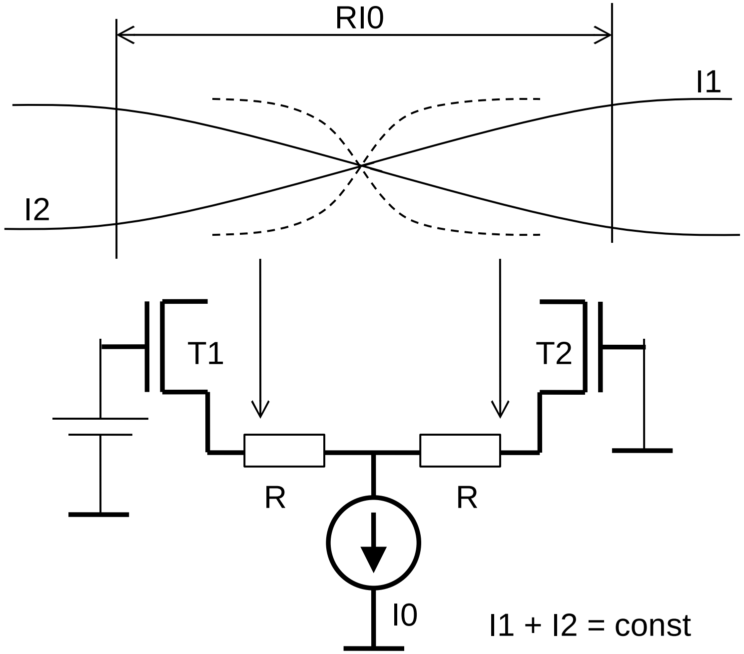

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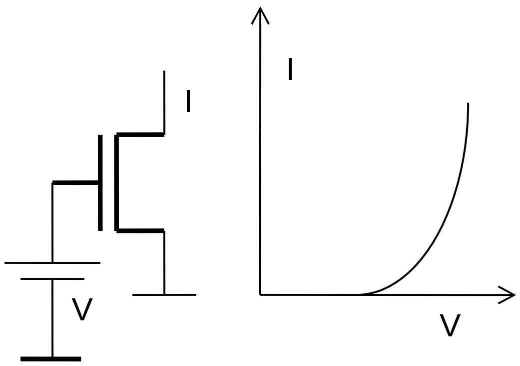
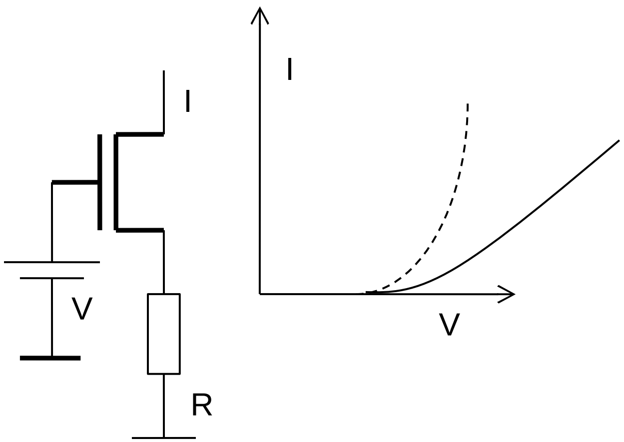
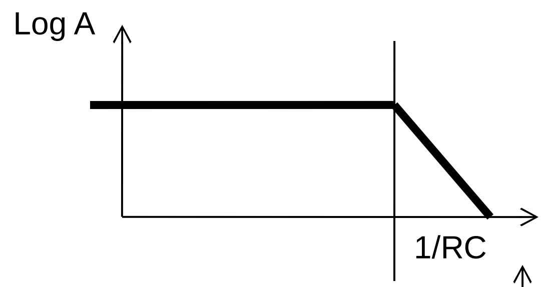
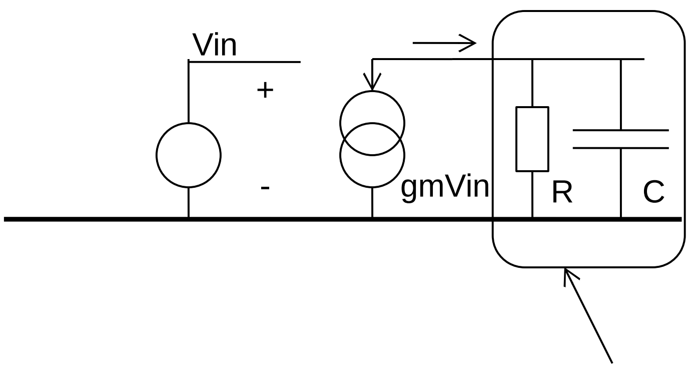




Spannungsverstärker

- Einfaches Beispiel
- Stromquelle angeschlossen an die Parallelschaltung von R und C
- Tiefpass Z





$$Z = \frac{R}{1 + sRC}$$

$$V_{out} = IZ = -g_m V_{in} \frac{R}{1 + sRC}$$

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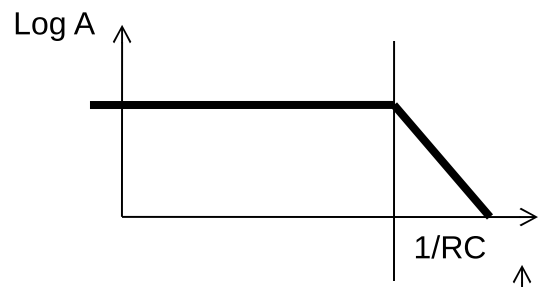
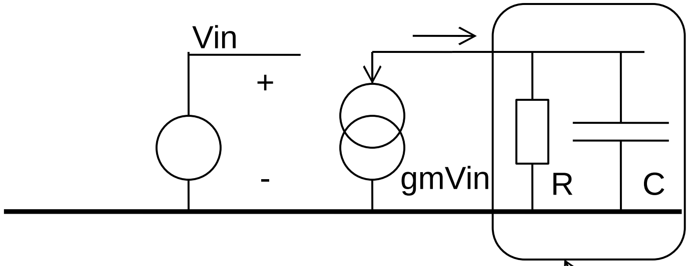
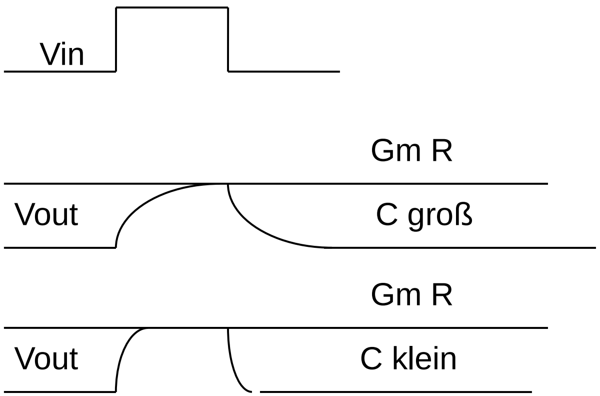


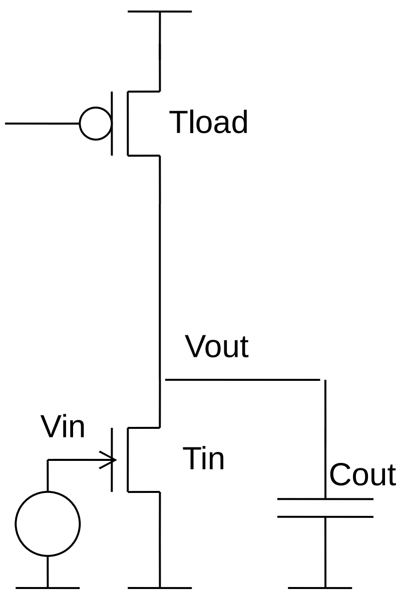


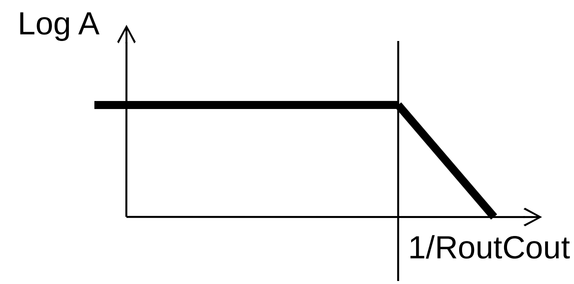


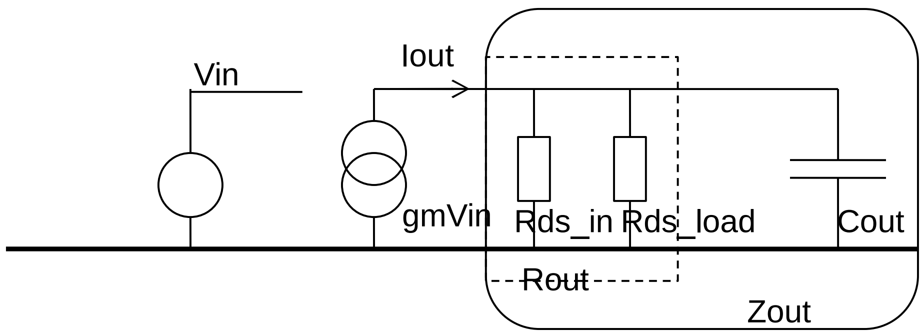
$$Z = \frac{R}{1 + sRC}$$

$$V_{out} = IZ = -g_m V_{in} \frac{R}{1 + sRC}$$

- Reale Schaltung: Single-Ended Spannungsverstärker (vereinfacht)
- Ausgangsstrom Iout
- Ausgangsimpedanz Zout







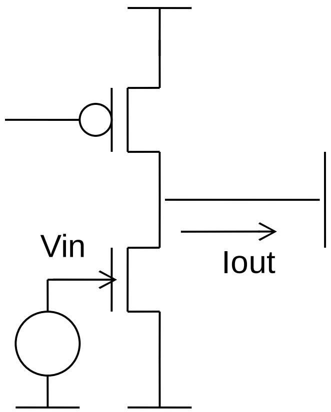
$$R_{out} = r_{ds\_in} \,||\, r_{ds\_out}$$

$$Z_{out} = \frac{R_{out}}{1 + sR_{out}C_{out}}$$

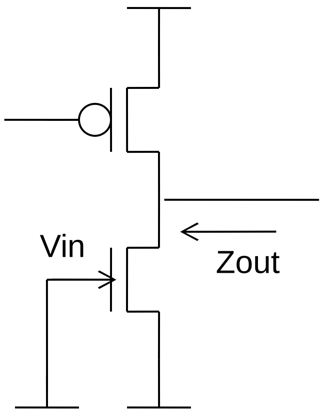
$$V_{out} = I_{out} Z_{out} = -g_m V_{in} \frac{R_{out}}{1 + sR_{out}C_{out}}$$

- **Norton‘sche**-Ersatzstromquelle

Schaltung 1

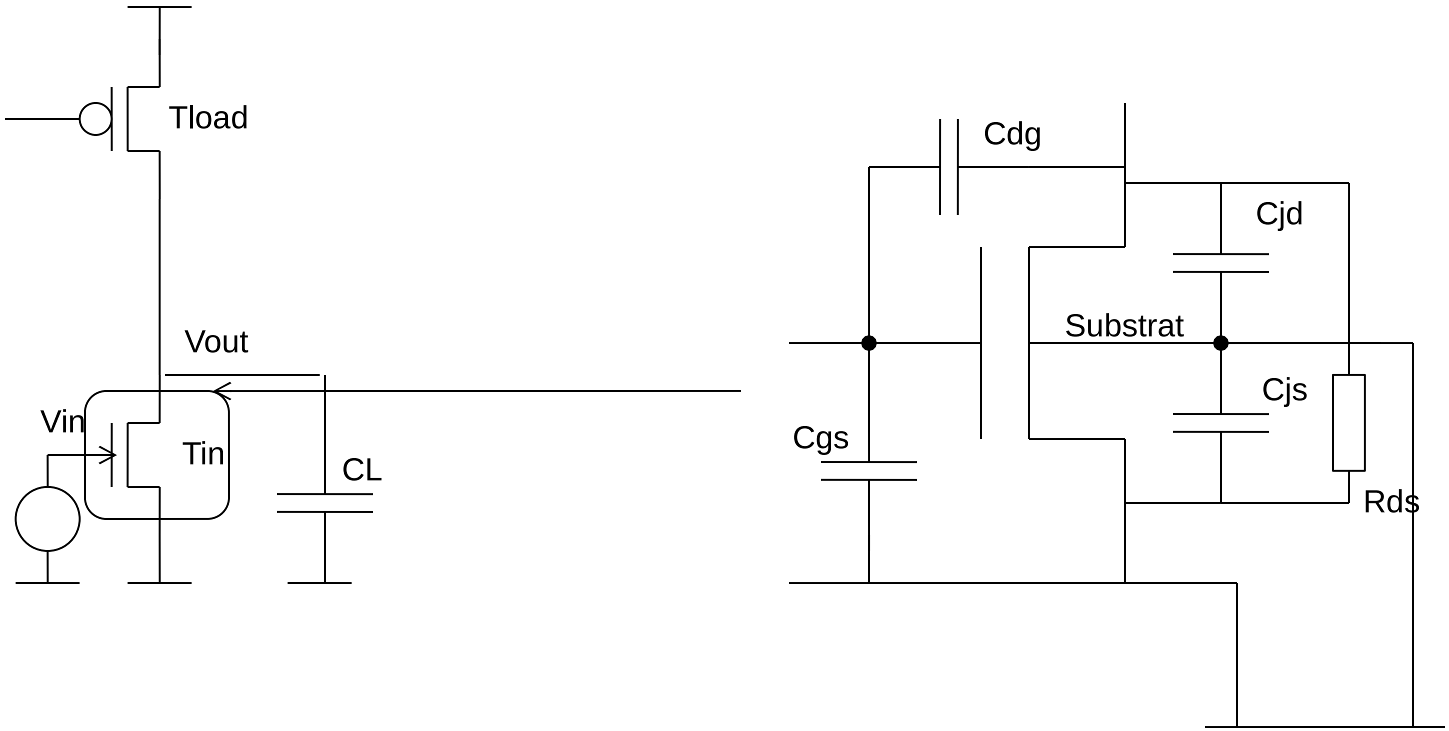


Schaltung 2



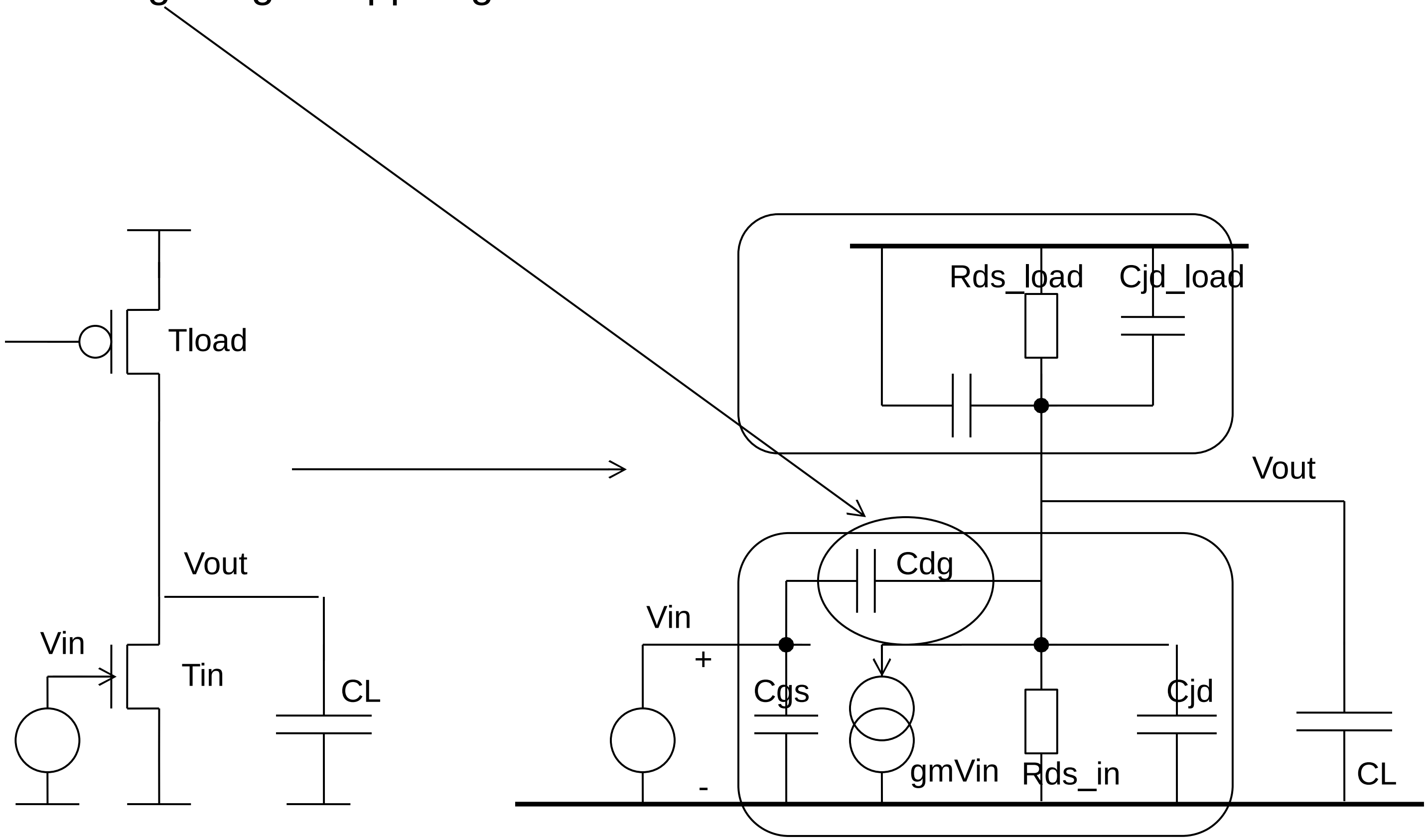
Vout = Zout Iout

- Single-Ended Spannungsverstärker (detailliert)
- Kapazitäten eines MOSFETS

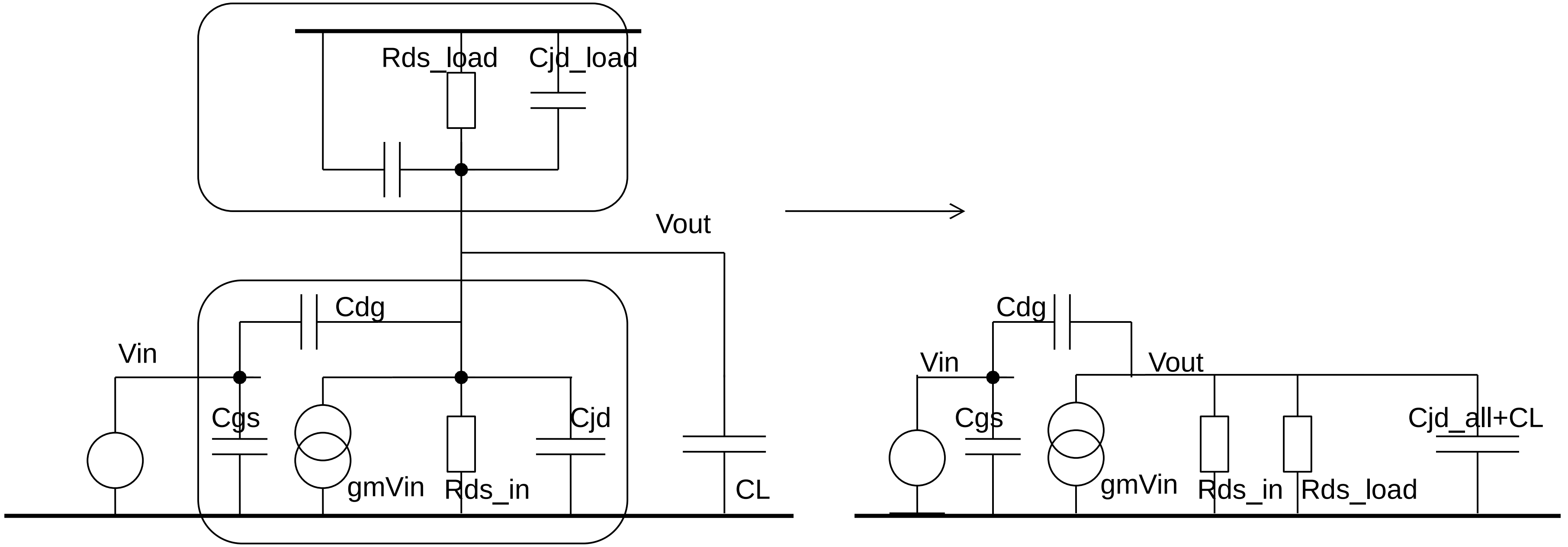


Spannungsverstärker

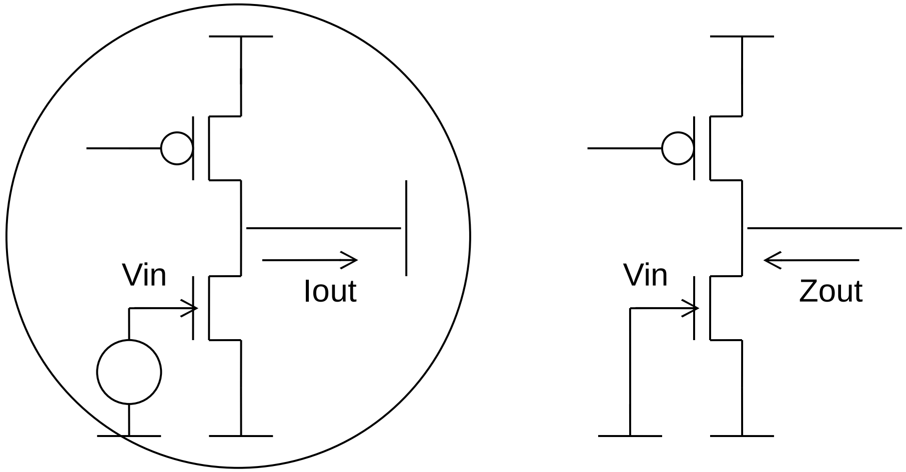
- Kapazität Cdg: Gegenkopplung und feed-forward



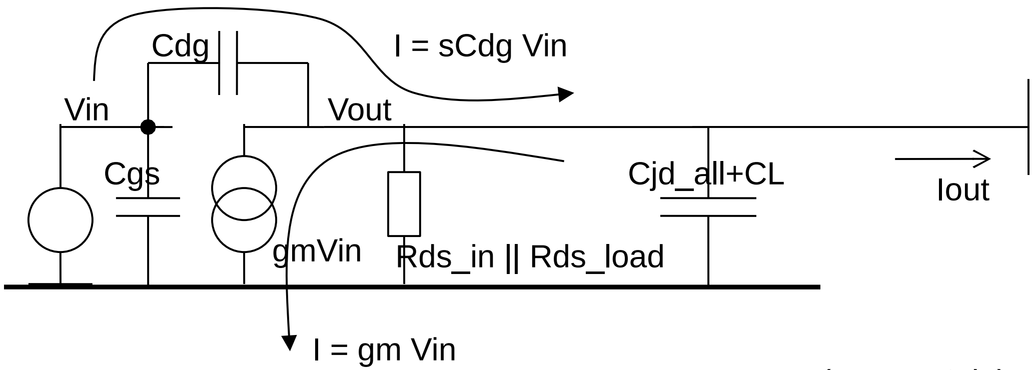
- Parallele Kapazitäten werden zusammengeführt
- Effekt von Cdg



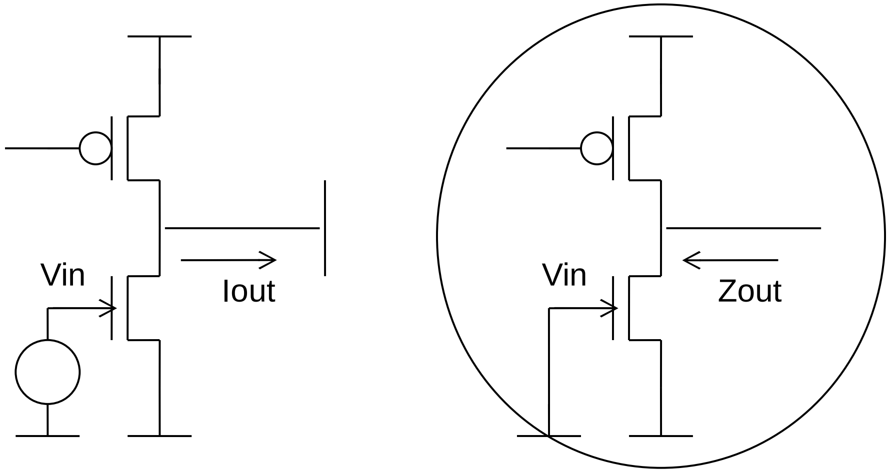
Spannungsverstärker



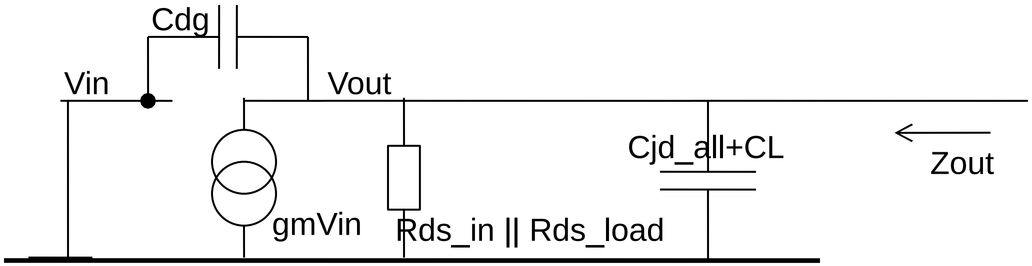
Vout = Zout Iout



Iout = (-gm + sCdg) Vin



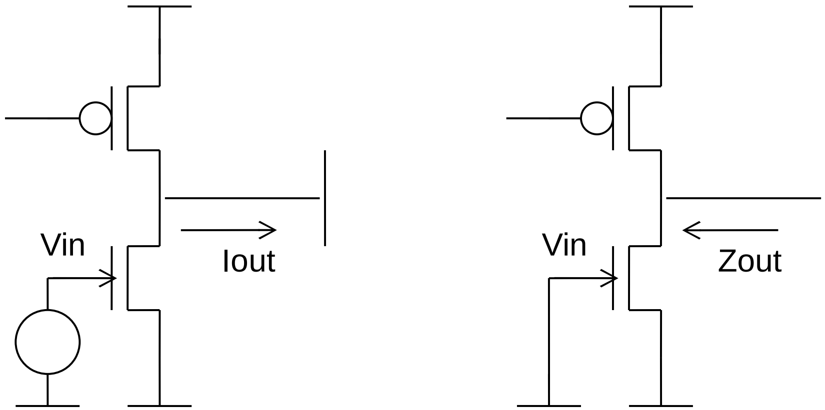
Vout = Zout Iout



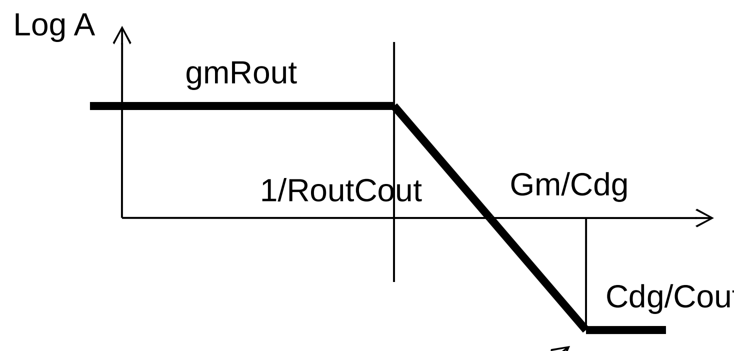
Zout = Rout Cout / (1 + s Rout Cout)

Rout = Rds_in || Rds_load

Cout = Cjd_all + CL + Cdg



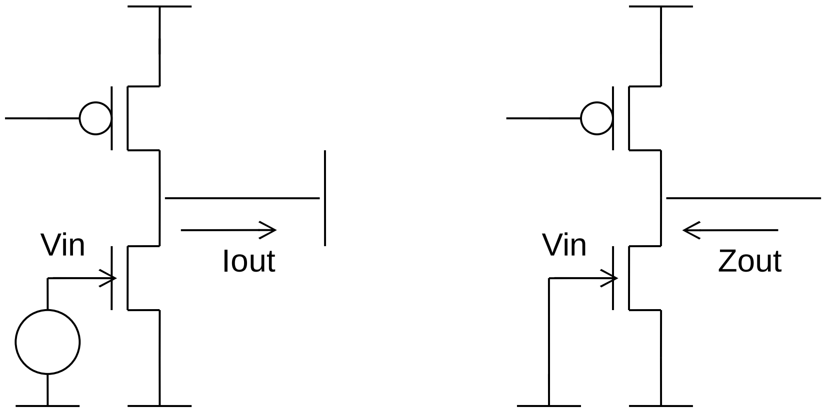
Vout = Zout Iout



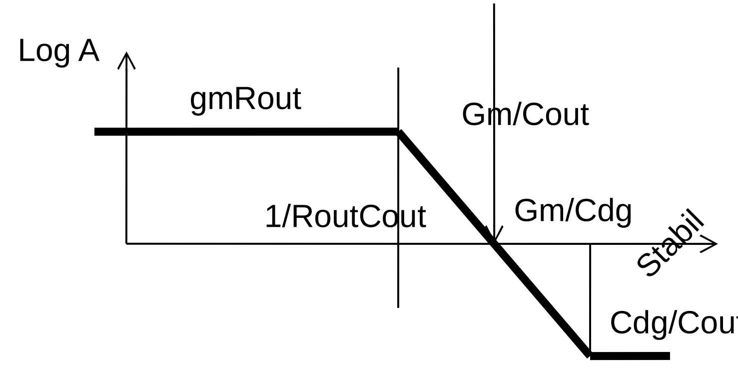
Zout = Rout Cout / (1 + s Rout Cout)

Iout = (-gm + sCdg) Vin

$$V_{out} = \frac{-g_m(1 - sC_{dg}/g_m)V_{in}R_{out}}{1 + sR_{out}C_{out}}$$



Vout = Zout Iout



Zout = Rout Cout / (1 + s Rout Cout)

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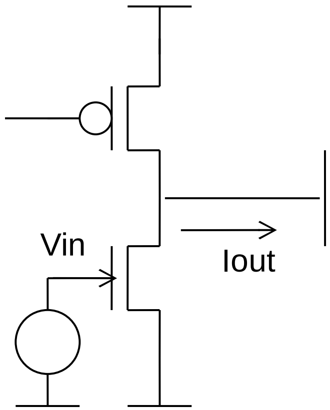
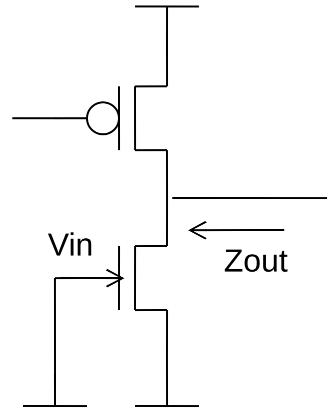
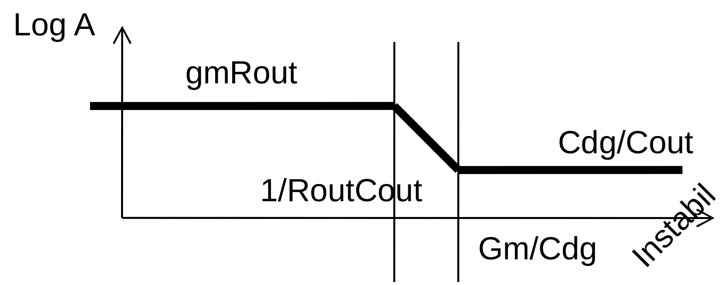
Spannungsverstärker





Vout = Zout Iout



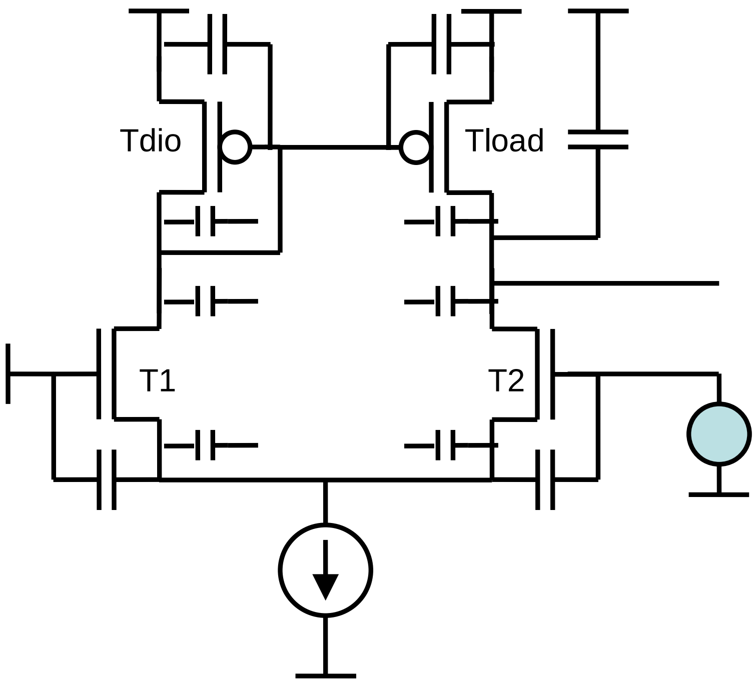
Zout = Rout Cout / (1 + s Rout Cout)

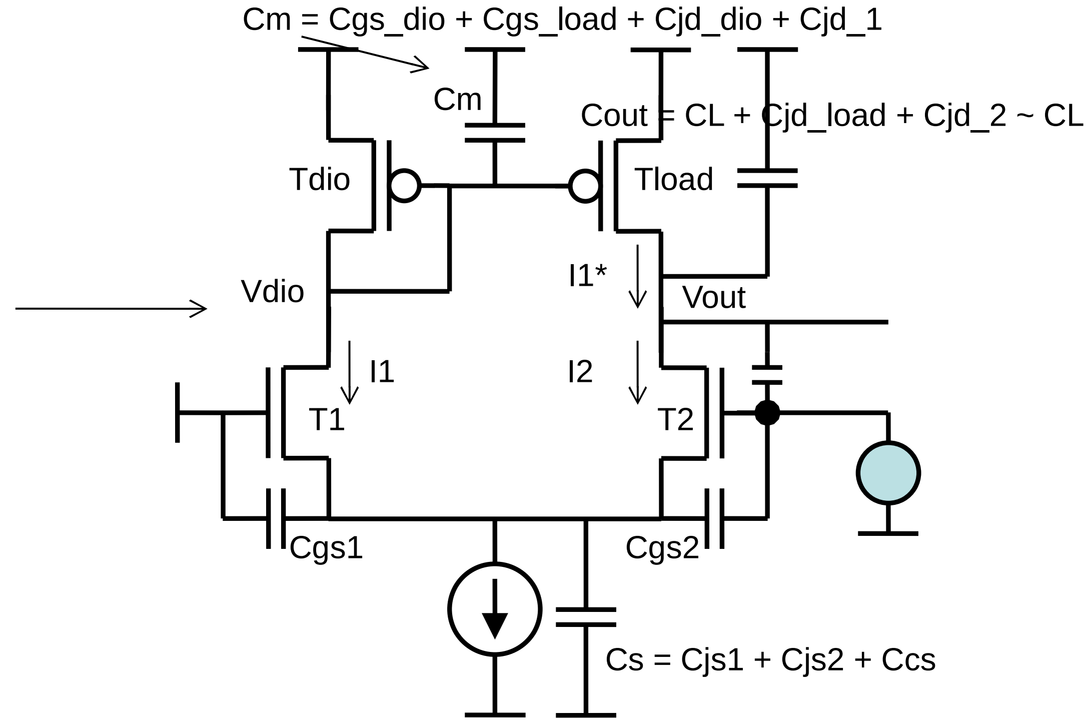
Iout = (-gm + sCdg) Vin

$$V_{out} = \frac{-g_m(1 - sC_{dg}/g_m)V_{in}R_{out}}{1 + sR_{out}C_{out}}$$

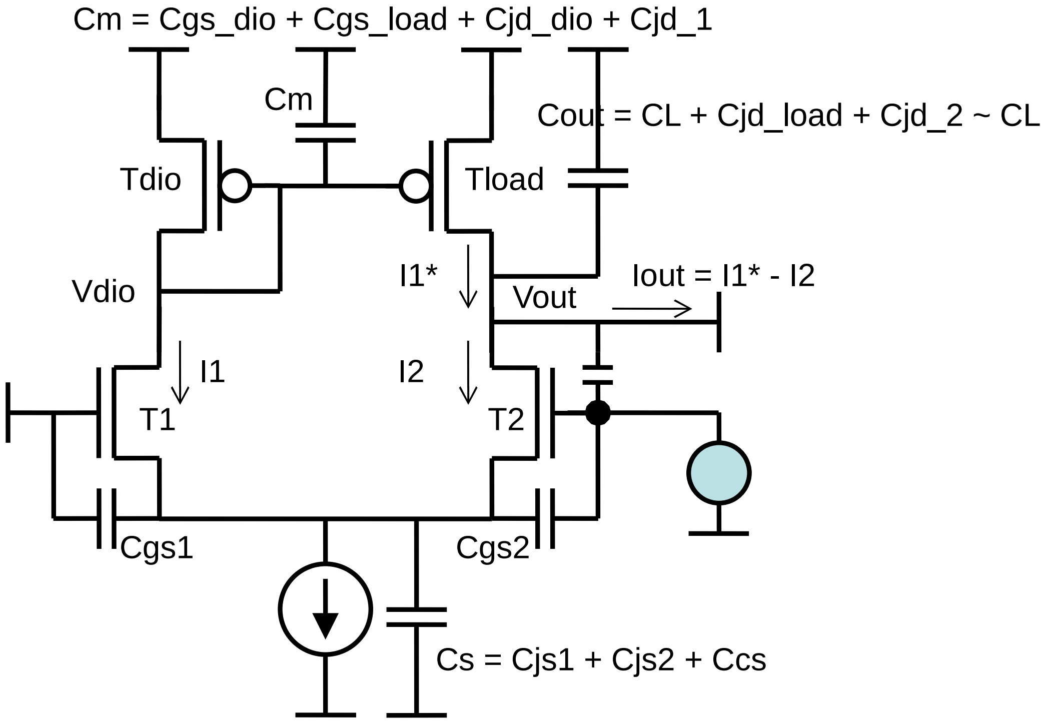
AC-Übertragungsfunktion des Operationsverstärkers

Differentieller Verstärker

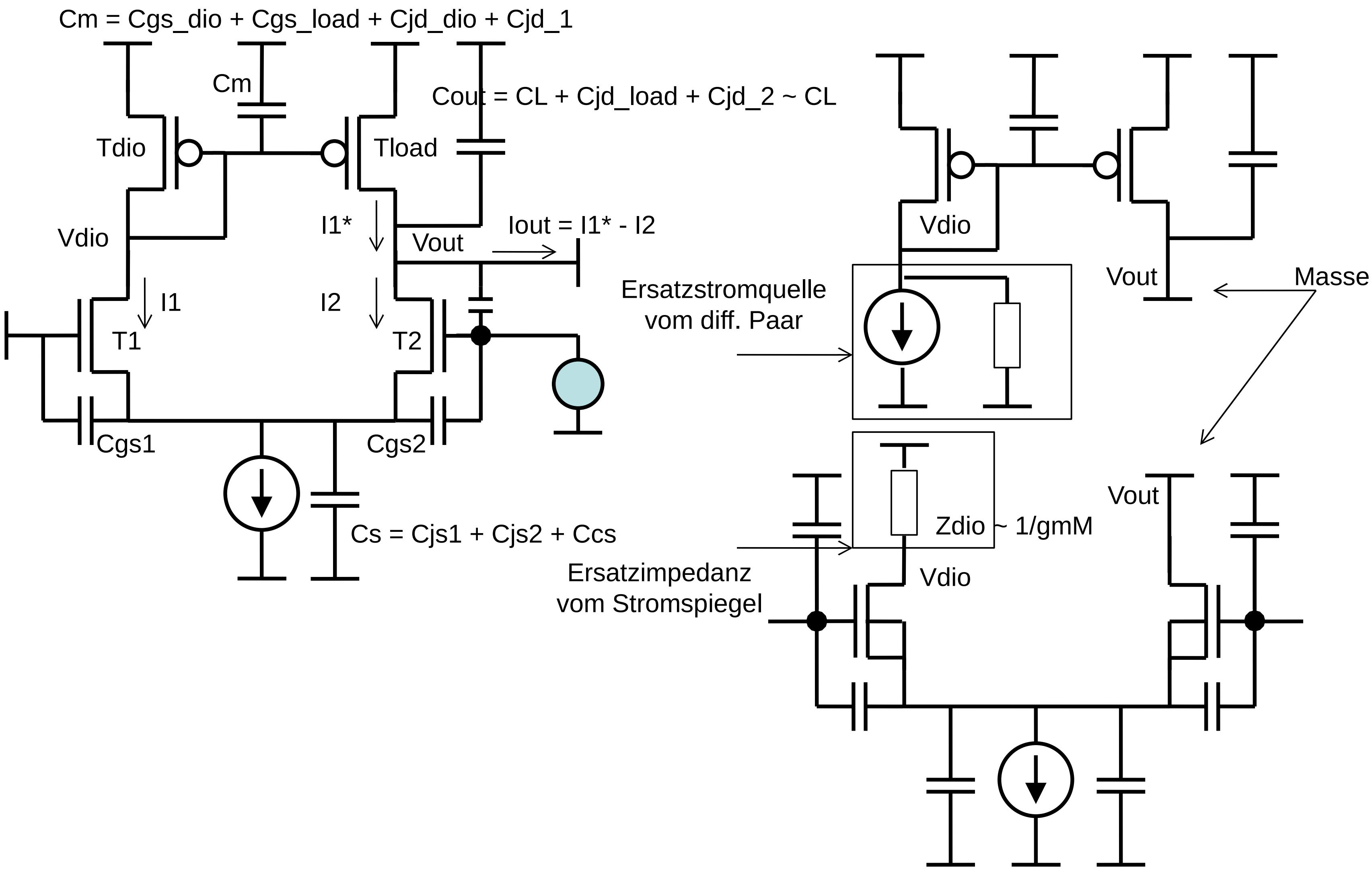




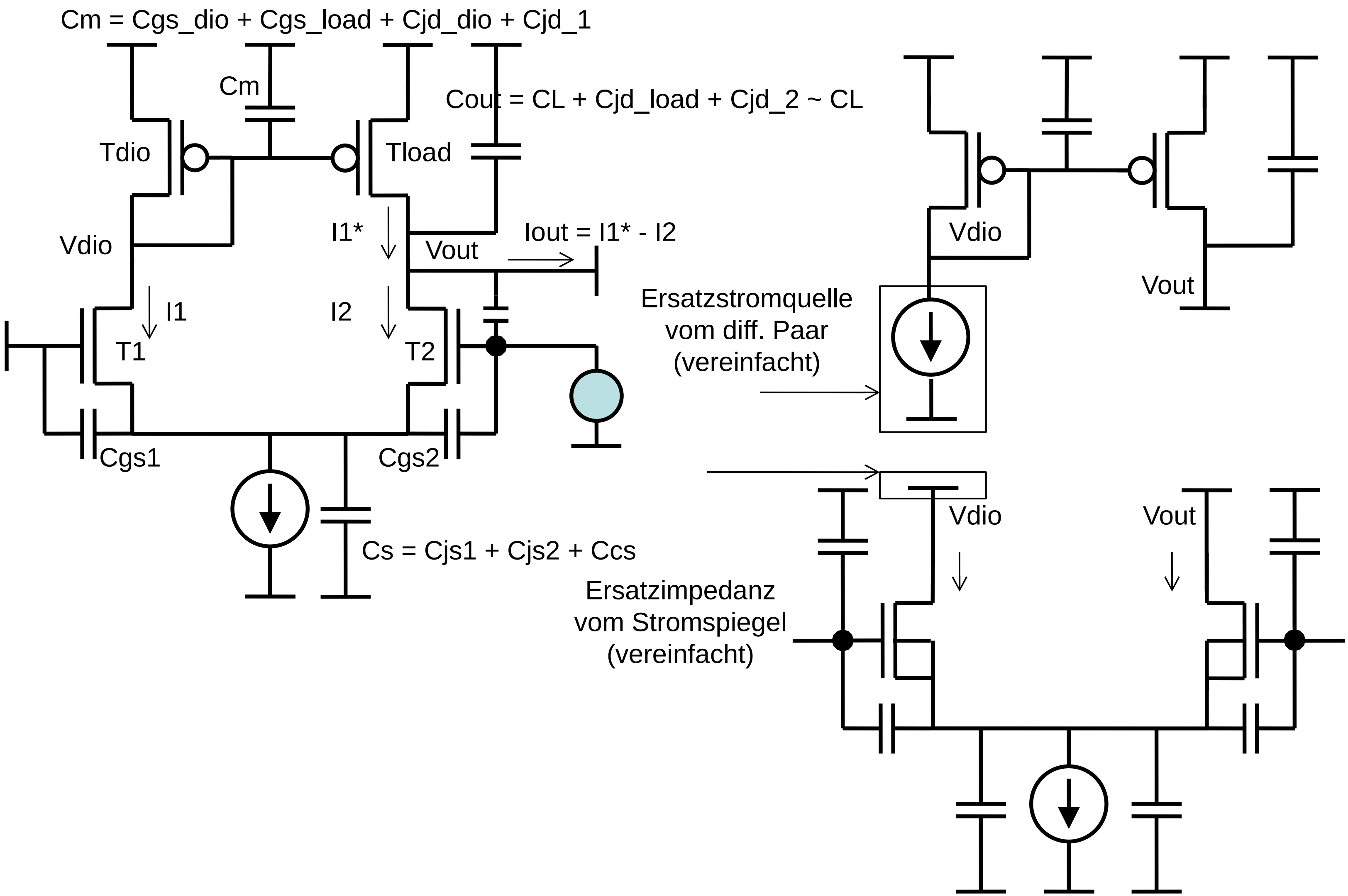
Ersatzstromquelle



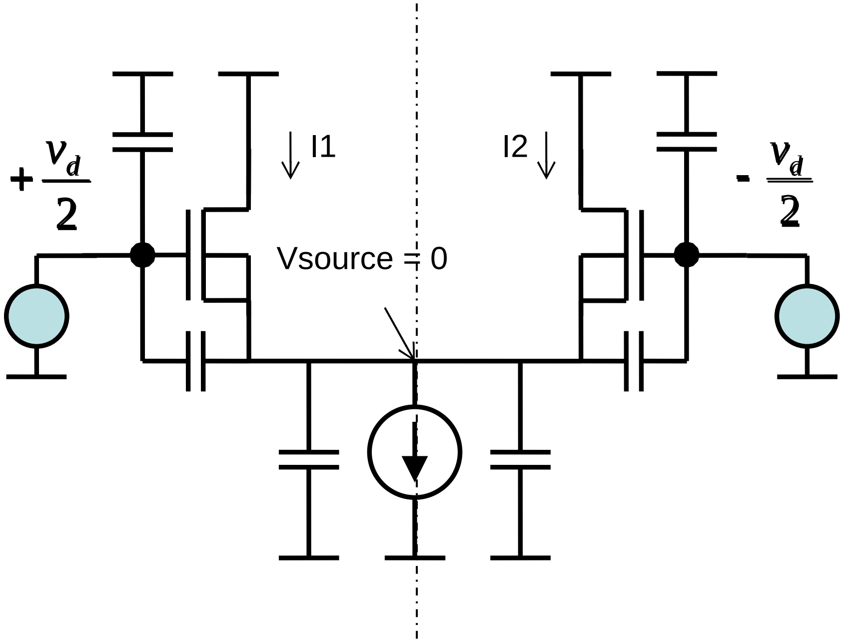
Ersatzstromquelle



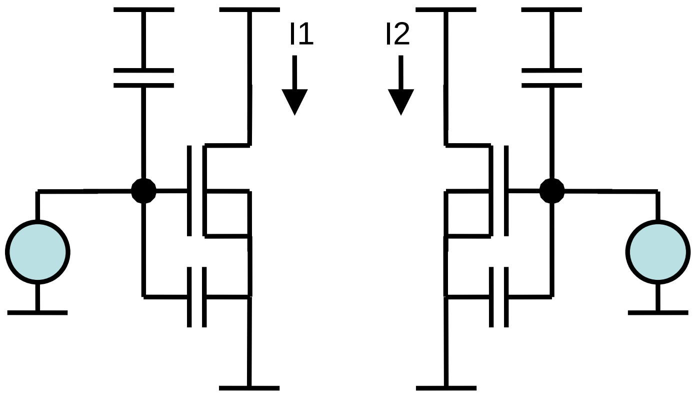
Ersatzstromquelle



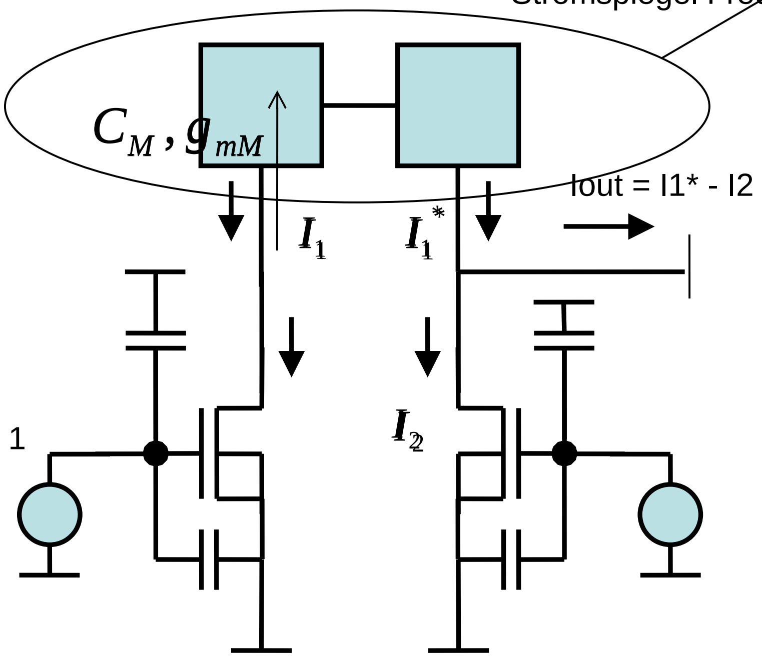
Ersatzstromquelle



I1 = -I2 = gm Vd/2



$$g_{mM} = g_m(T_{Load}, T_{Dio})$$



Stromspiegel Frequenzgang

$$I_1^* = I_1 \frac{1}{(C_M / g_{mM})s + 1}$$

$$-I_2 = I_1 = g_m \frac{V_d}{2}$$

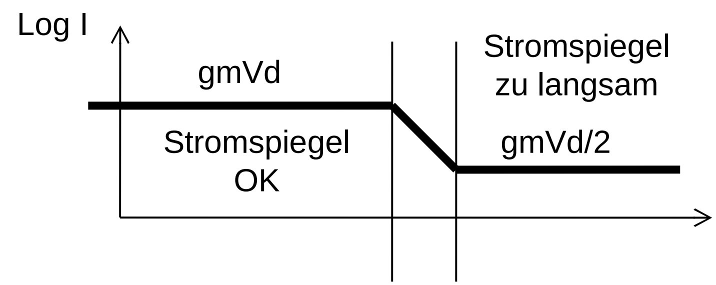
Vorherige Folie

$$I_{out} = I_1^* - I_2 = g_m \frac{V_d}{2}\left(\frac{1}{(C_M / g_{mM})s + 1} + 1\right)$$

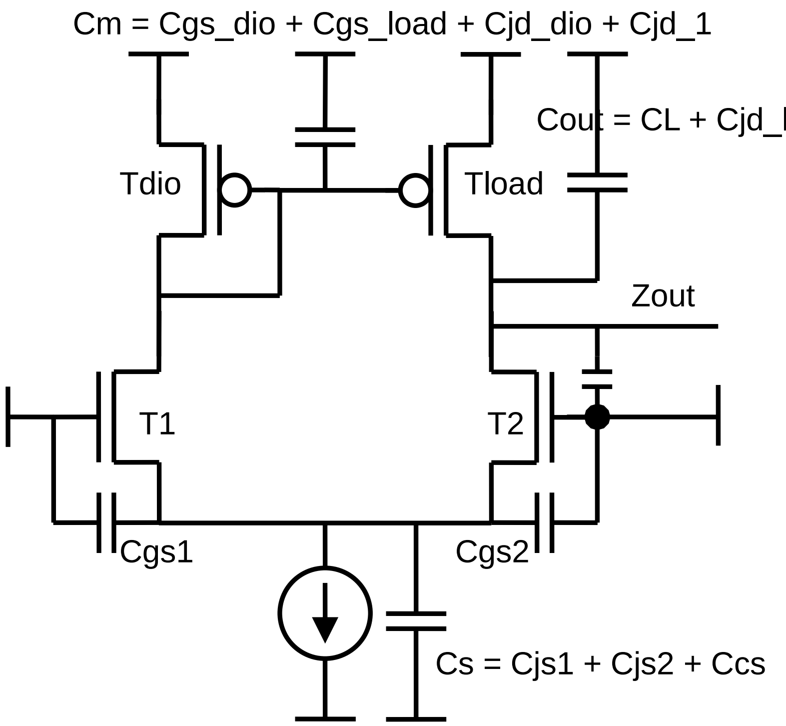
$$I_{out} = V_d g_m \left(\frac{(C_M / 2g_{mM})s + 1}{(C_M / g_{mM})s + 1}\right)$$

$$I_{out}(0) = V_d g_m$$

$$I_{out}(\infty) = \frac{1}{2} V_d g_m$$



Zout

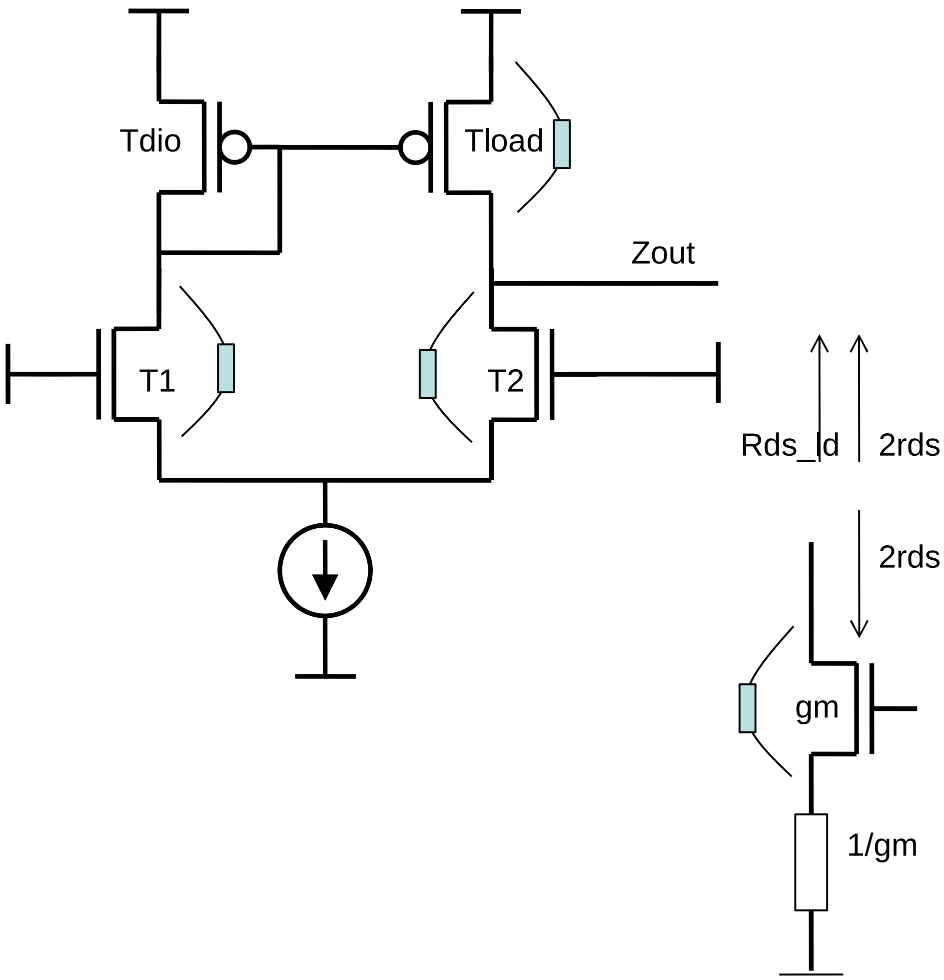


Zout ~ 1/sCout || Rout

Cout = CL + Cjd_load + Cjd_2 ~ CL

Rout = rds_load || rds2

Zout



Zout ~ 1/sCout || Rout

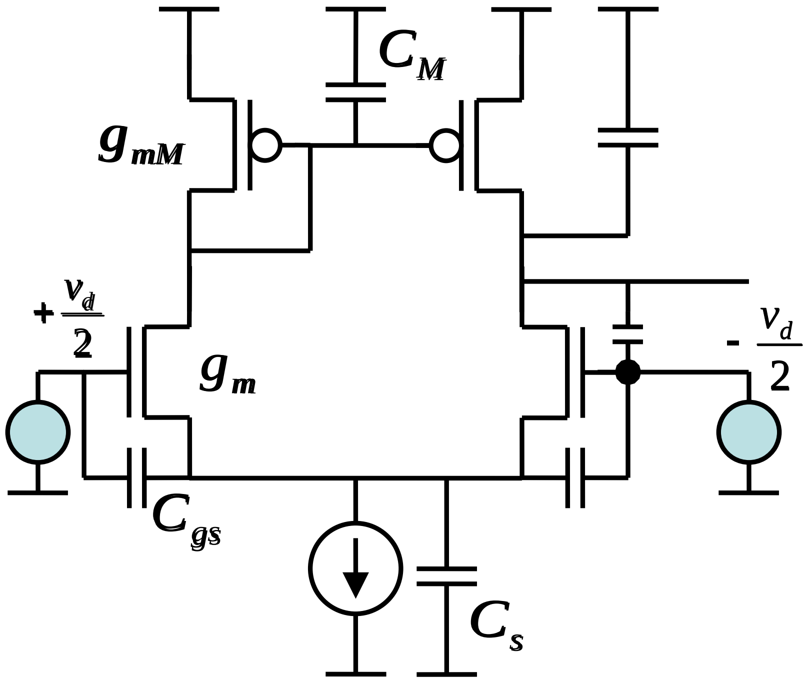
Cout = CL + Cjd_load + Cjd_2 ~ CL

Rout = rds_load || rds2

$$g_{mM} = g_m(T_{Load}, T_{Dio})$$

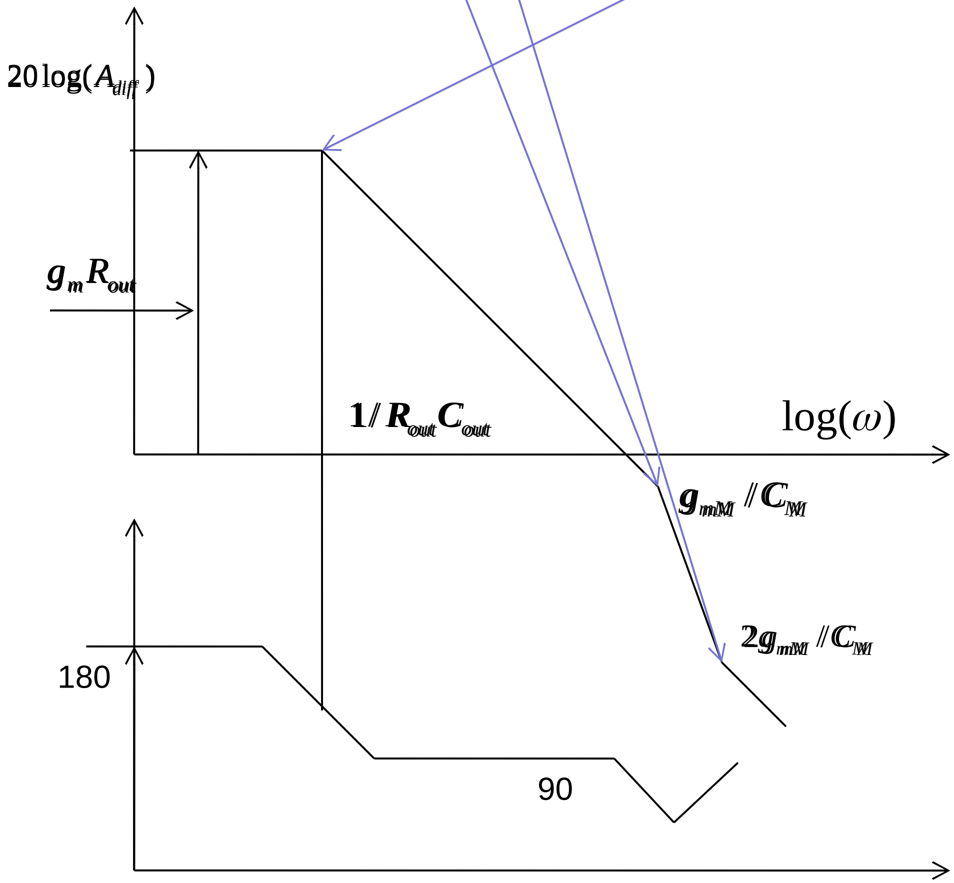
$$V_{out} = I_{out} Z_{out} = V_d g_m \left(\frac{(C_M / 2g_{mM})s + 1}{(C_M / g_{mM})s + 1} \right) \frac{R_{out}}{1 + sR_{out}C_{out}}$$

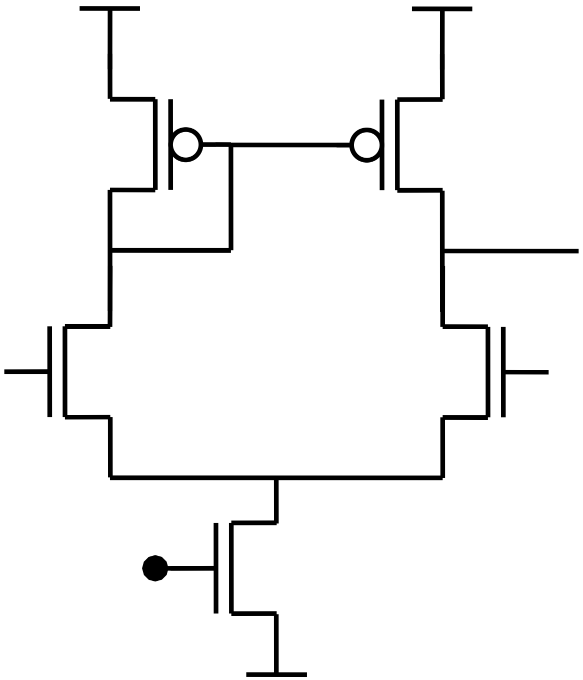
$$A_{diff} = g_m \left(\frac{(C_M / 2g_{mM})s + 1}{(C_M / g_{mM})s + 1} \right) \frac{R_{out}}{1 + sR_{out}C_{out}}$$

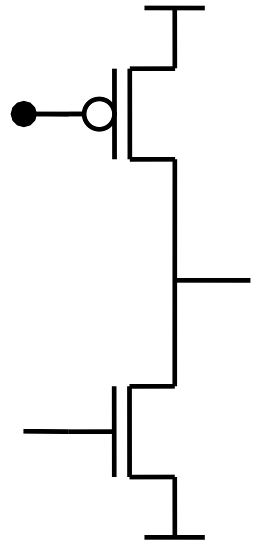


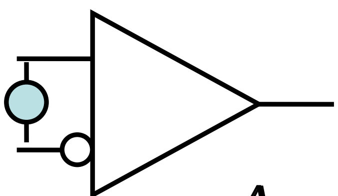
$$A_{diff} = g_m \left(\frac{(C_M / 2g_{mM})s + 1}{(C_M / g_{mM})s + 1} \right) \frac{R_{out}}{1 + sR_{out}C_{out}}$$

$$A_{diff} \sim g_m \frac{R_{out}}{1 + sR_{out}C_{out}}$$

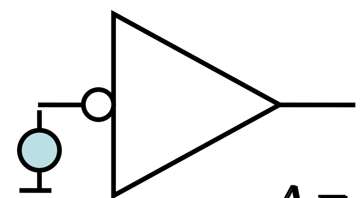








$$A_{diff} \sim g_m \frac{R_{out}}{1 + sR_{out}C_{out}}$$



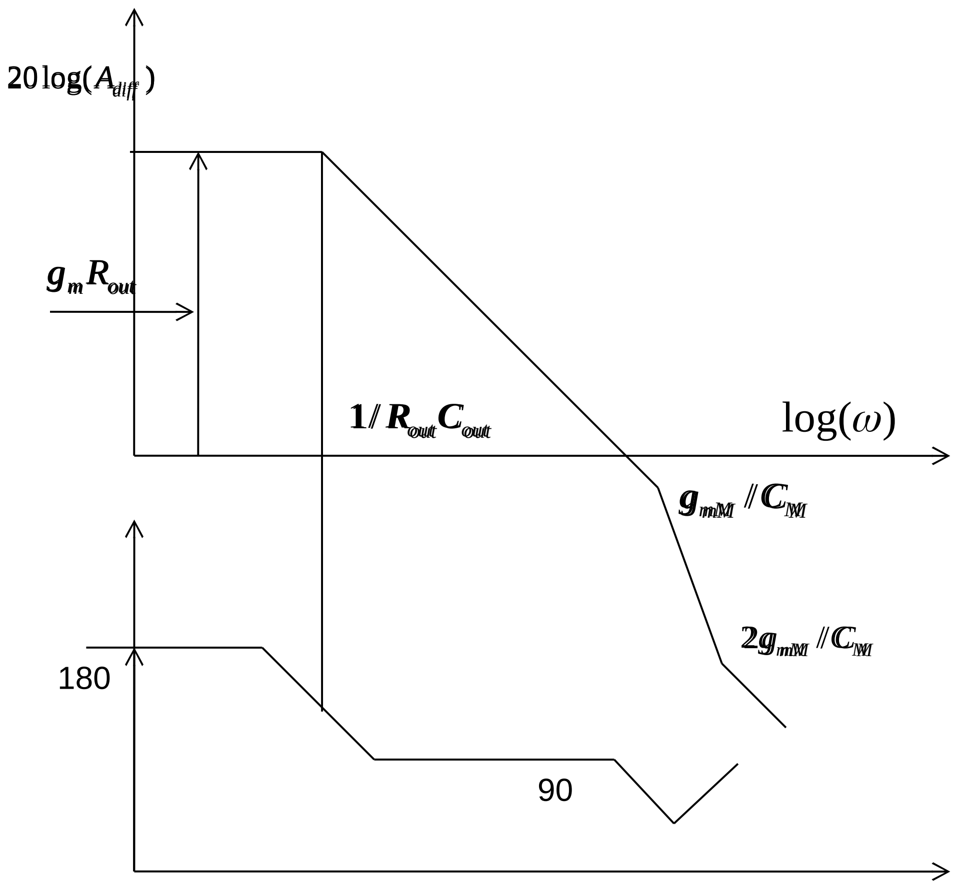
$$A = -g_m \frac{R_{out}}{1 + sR_{out}C_{out}}$$

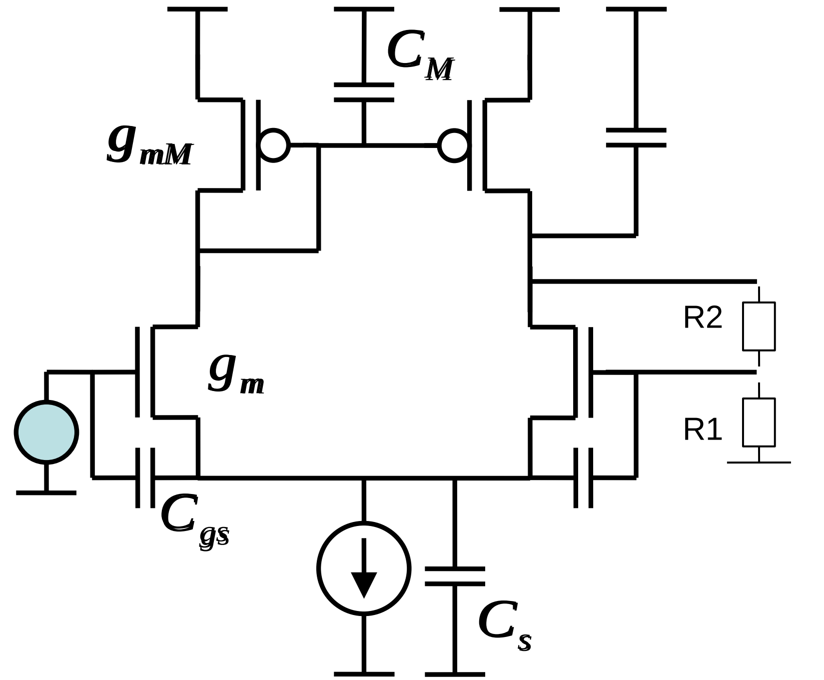
Operationsverstärker - Stabilität

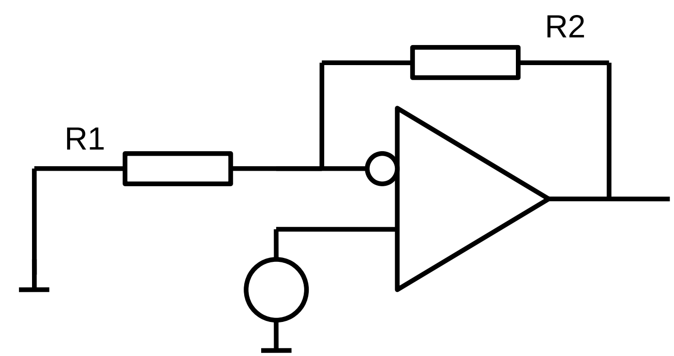
Stabilität

$$g_{mM} = g_m(T_{Load}, T_{Dio})$$

$$A_{diff} = A_{ol} = g_m \left(\frac{(C_M / 2g_{mM})s + 1}{(C_M / g_{mM})s + 1} \right) \frac{R_{out}}{1 + sR_{out}C_{out}}$$

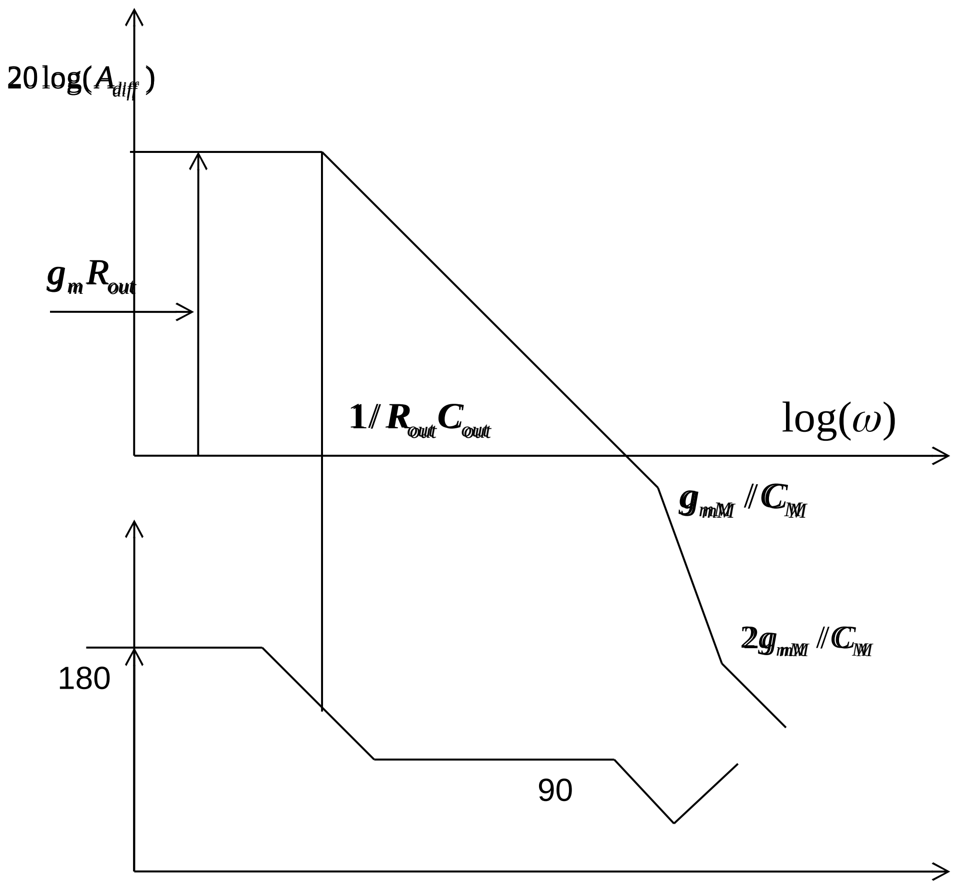


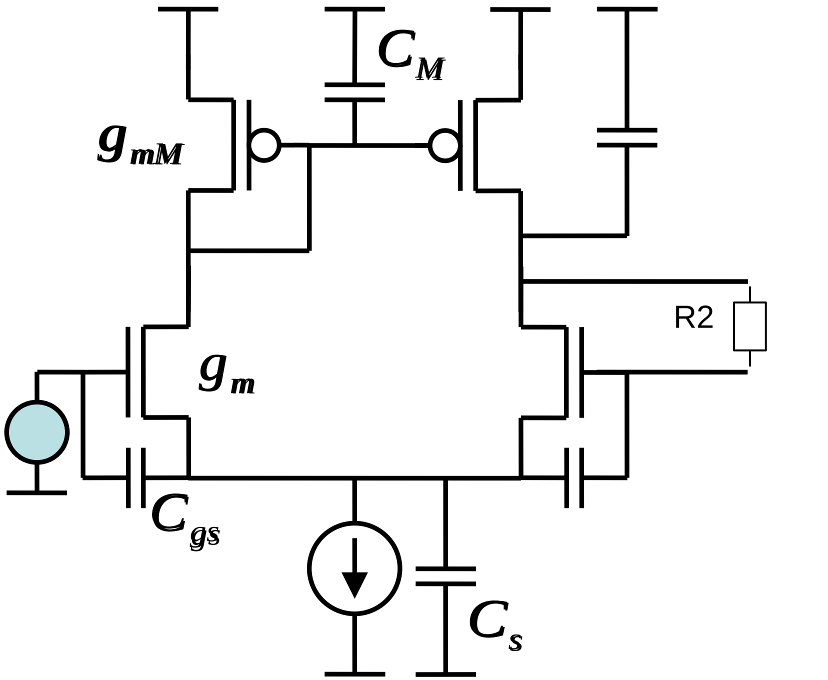


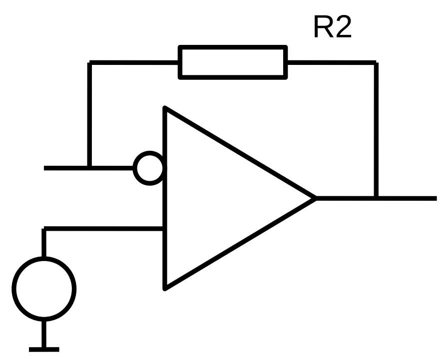


Stabilität

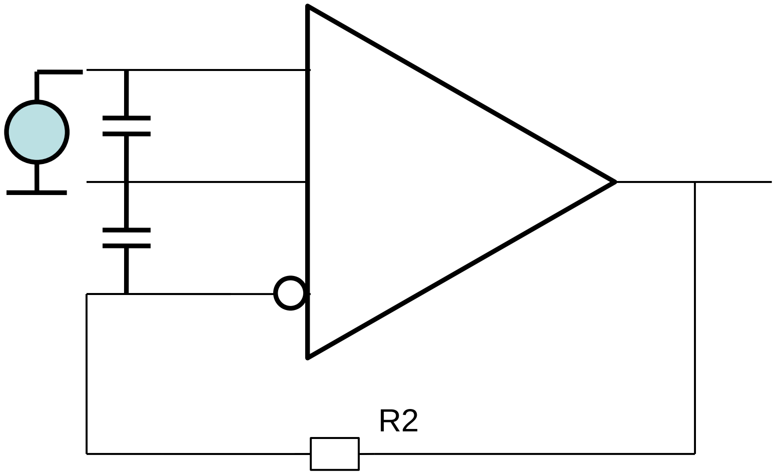
$$A_{diff} = A_{ol} = g_m \left(\frac{(C_M / 2g_{mM})s + 1}{(C_M / g_{mM})s + 1} \right) \frac{R_{out}}{1 + sR_{out}C_{out}}$$

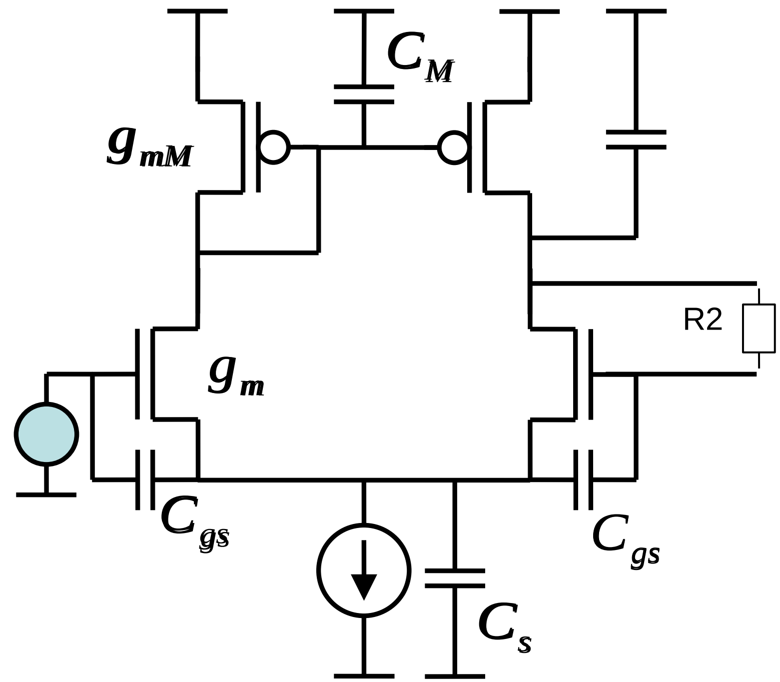


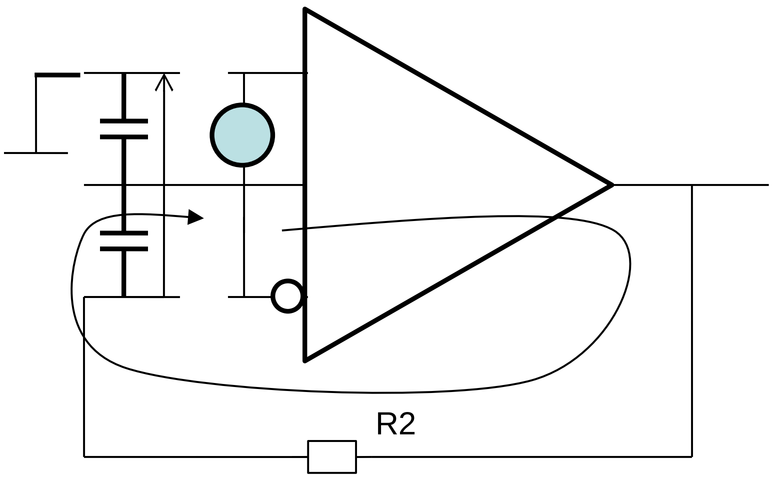


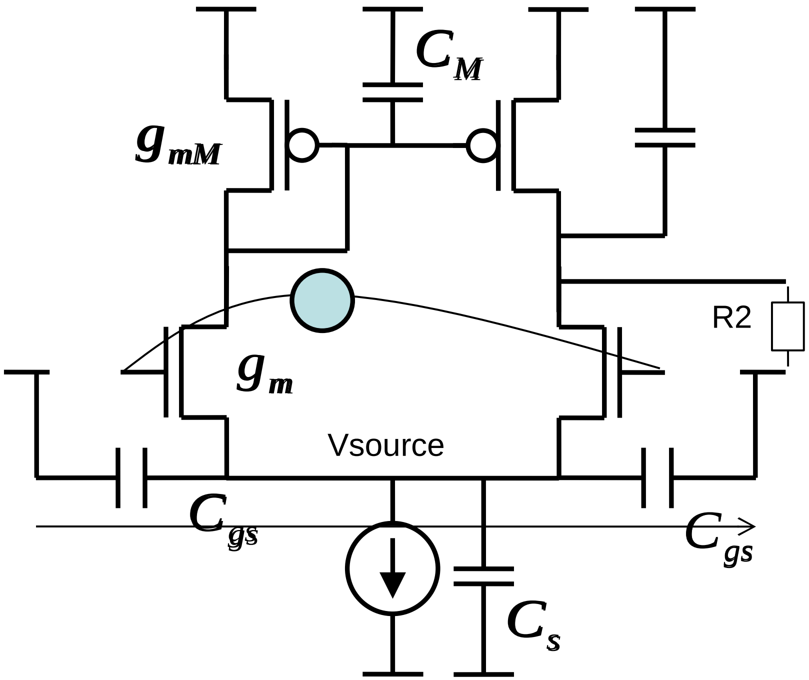


Stabilität

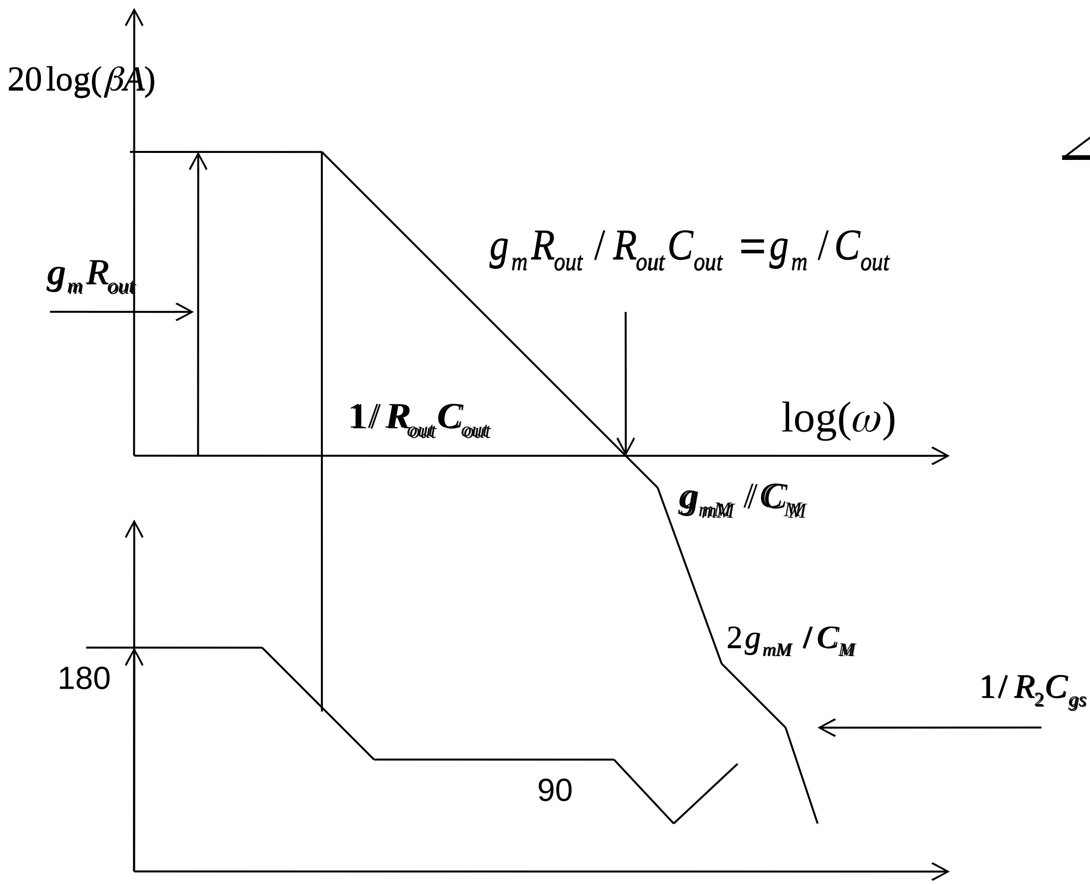


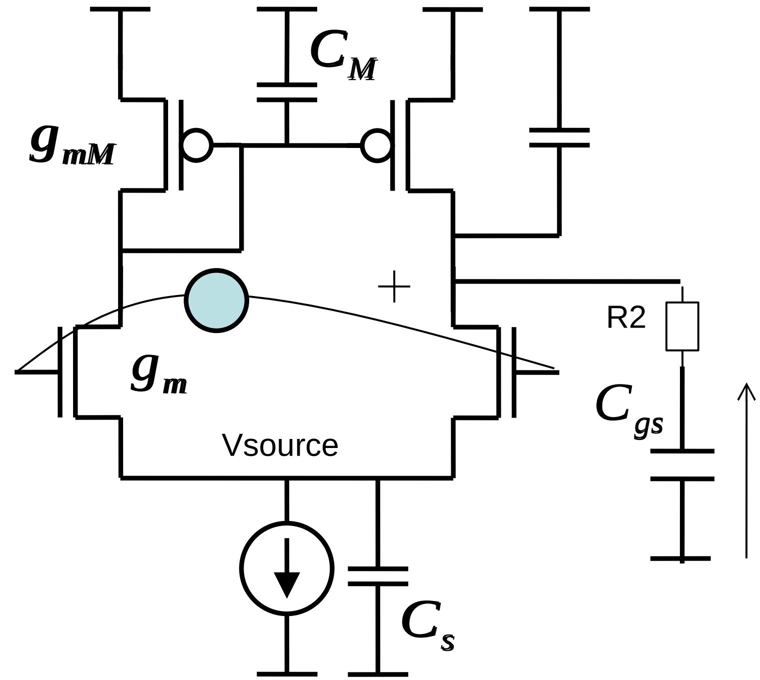


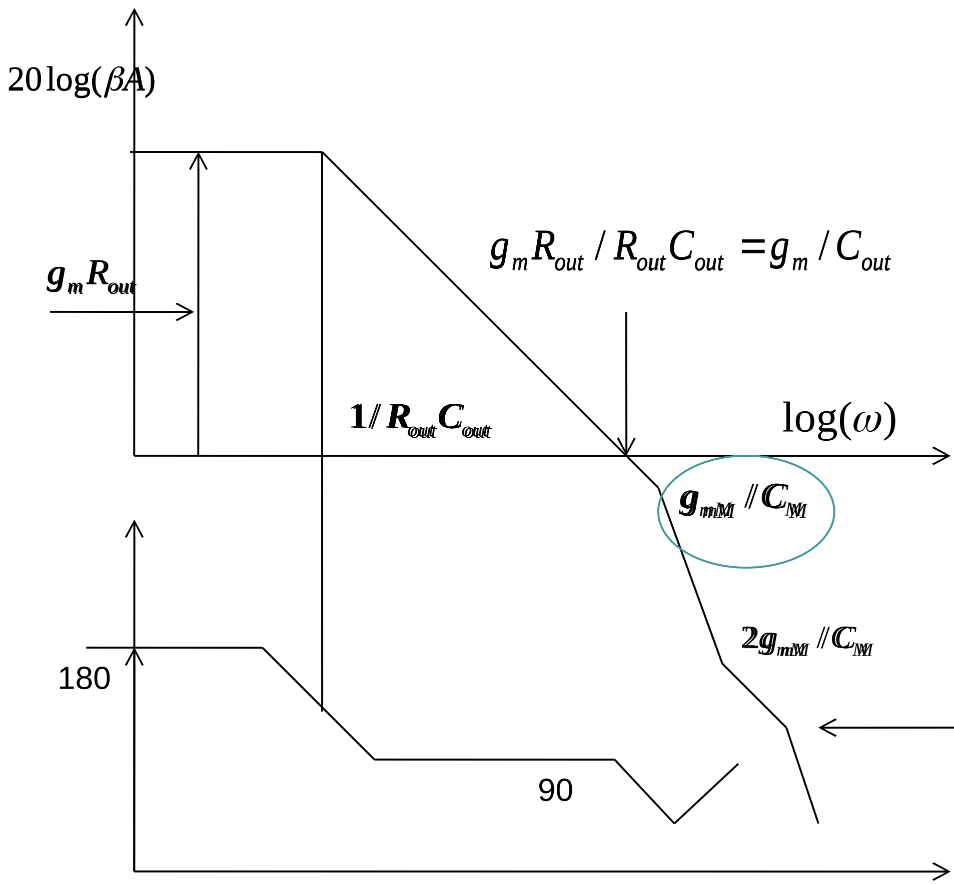

R2


C_M
g_{mM}
g_m
R2
Vsource
C_{gs}
C_{gs}
C_s

$$\beta A = -g_m \left(\frac{(C_M / 2g_{mM})s + 1}{(C_M / g_{mM})s + 1} \right) \frac{R_{out}}{1 + sR_{out}C_{out}}$$







Stabilitätskriterium

$$g_{mM} / C_M > g_m / C_{out}$$

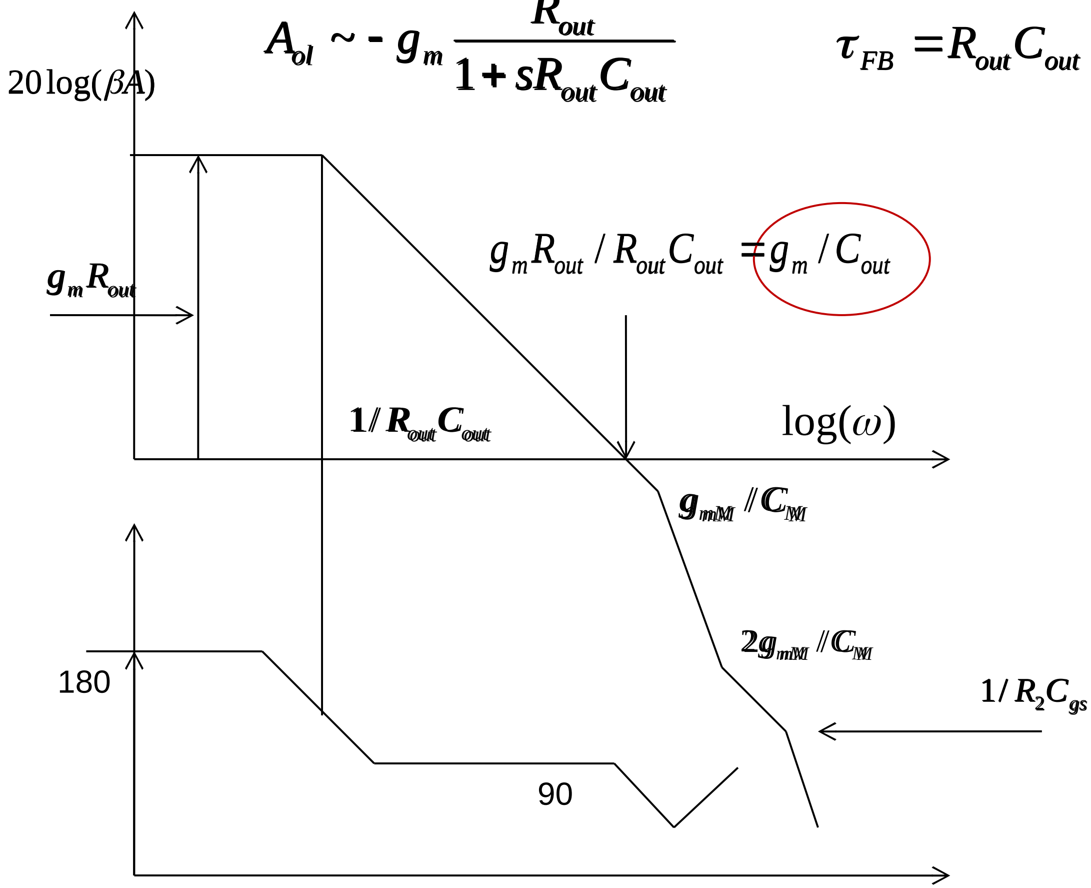
$$C_{out} > \frac{g_m}{g_{mM}} C_M$$

$$\beta A \sim -g_m \frac{R_{out}}{1 + sR_{out}C_{out}}$$

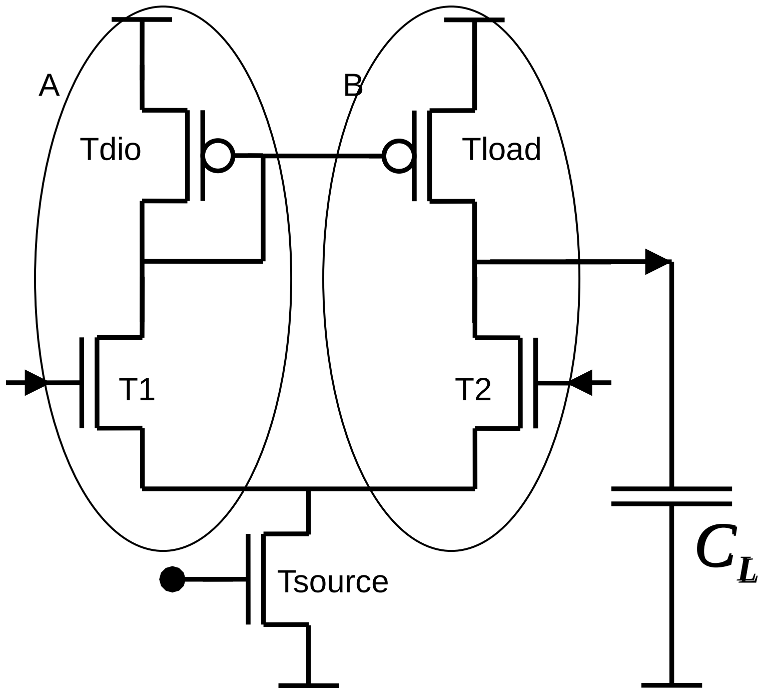
$$A_{ol} \sim -g_m \frac{R_{out}}{1 + sR_{out}C_{out}}$$

Zeitkonstante mit Gegenkopplung

$$\tau_{FB} = R_{out}C_{out} / g_m R_{out} = C_{out} / g_m$$



Verschiedene Operationsverstärker

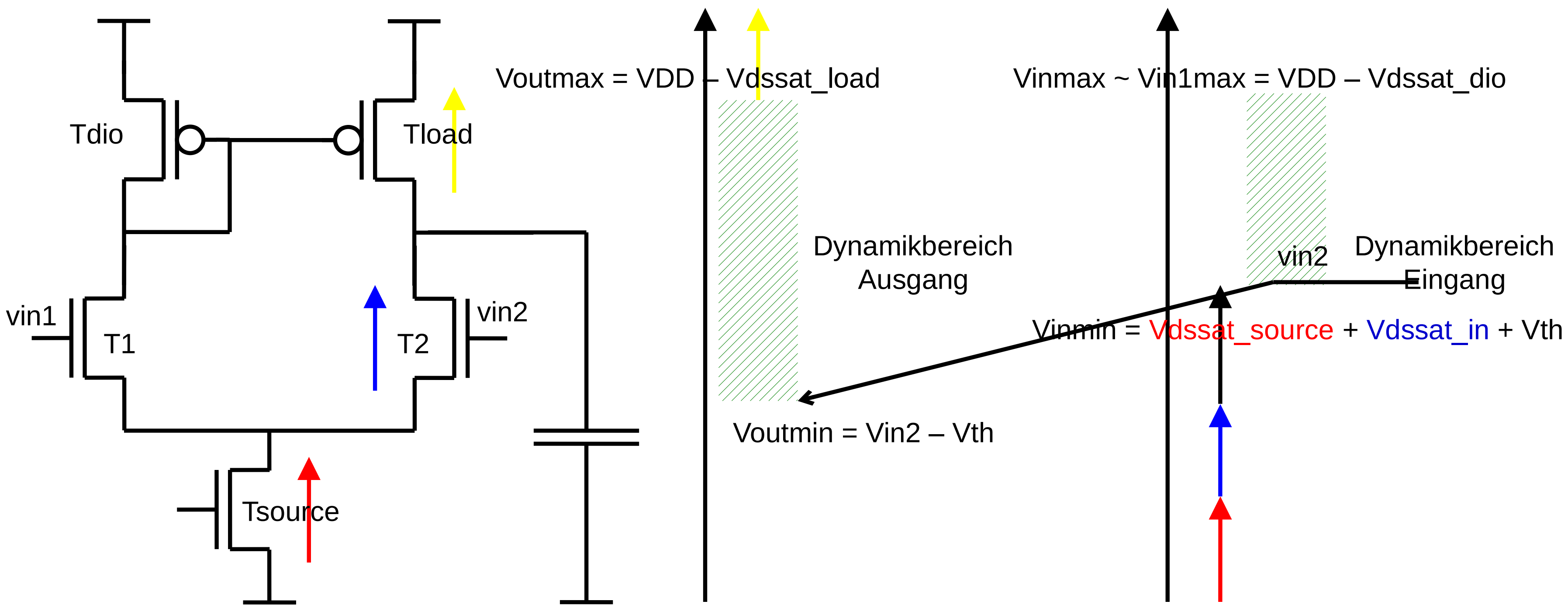


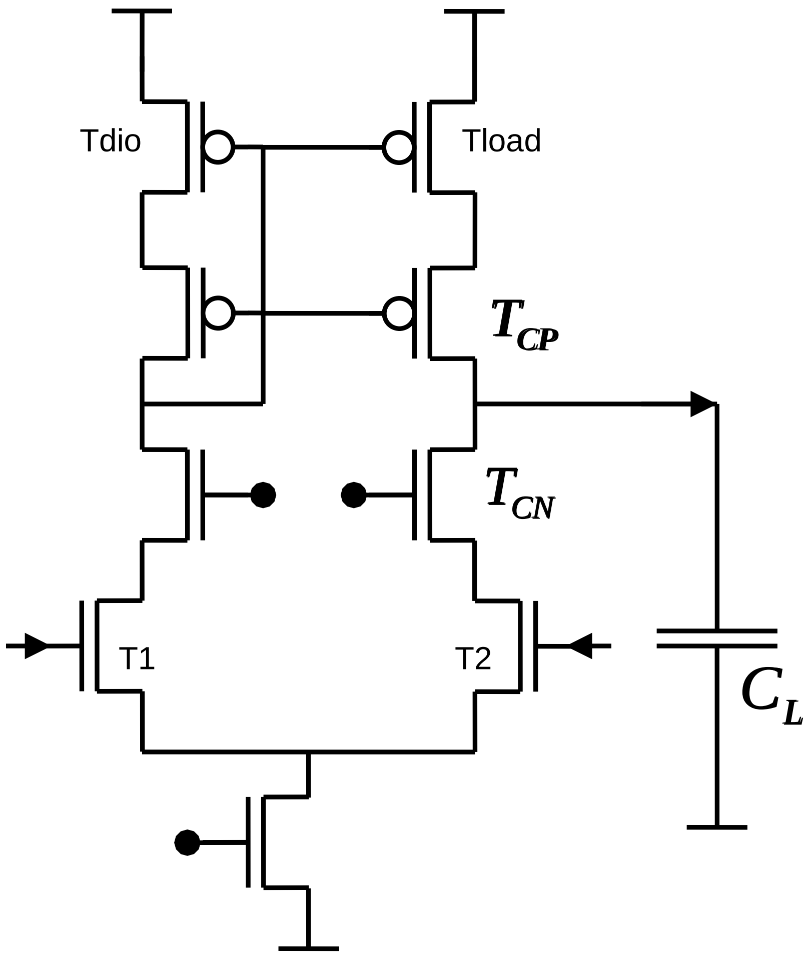
$$R_{out} = r_{ds2} \parallel r_{dsload} \qquad Z_{out} = R_{out} \parallel (1/sC_L)$$

$$A_{diff} = \frac{g_m R_{out}}{R_{out} C_L s + 1} \left(\frac{(C_M / 2g_{mM})s + 1}{(C_M / g_{mM})s + 1} \right)$$

$$A_{diff} \approx \frac{g_m R_{out}}{R_{out} C_L s + 1}$$

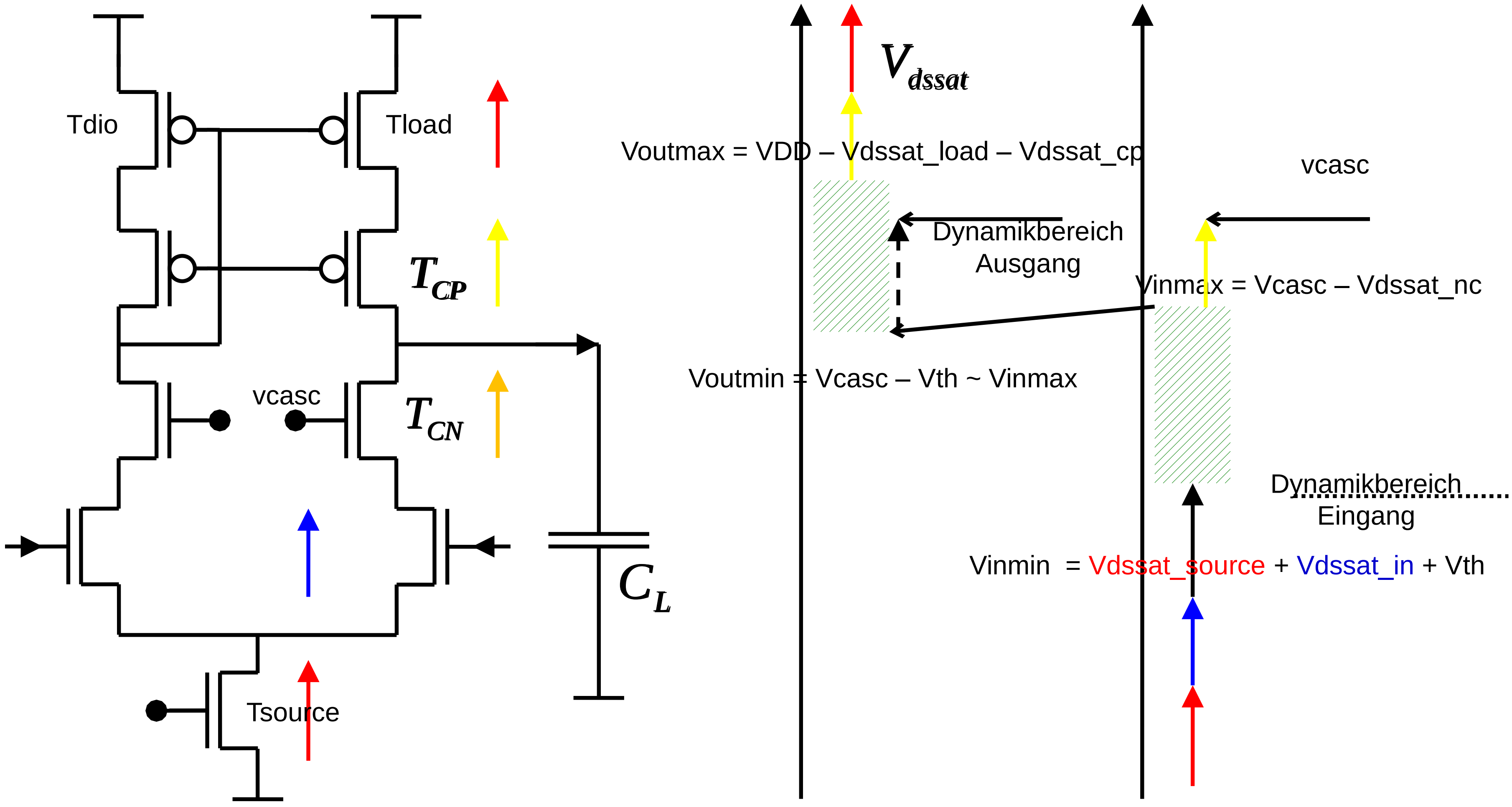
$$g_{mM} = g_m(T_{Load}, T_{Dio})$$


Tdio
Tload
vin1
T1
T2
vin2
Tsource
Voutmax = VDD – Vdssat_load
Dynamikbereich
Ausgang
Voutmin = Vin2 – Vth
Vinmax ~ Vin1max = VDD – Vdssat_dio
vin2
Dynamikbereich
Eingang
Vinmin = Vdssat_source + Vdssat_in + Vth

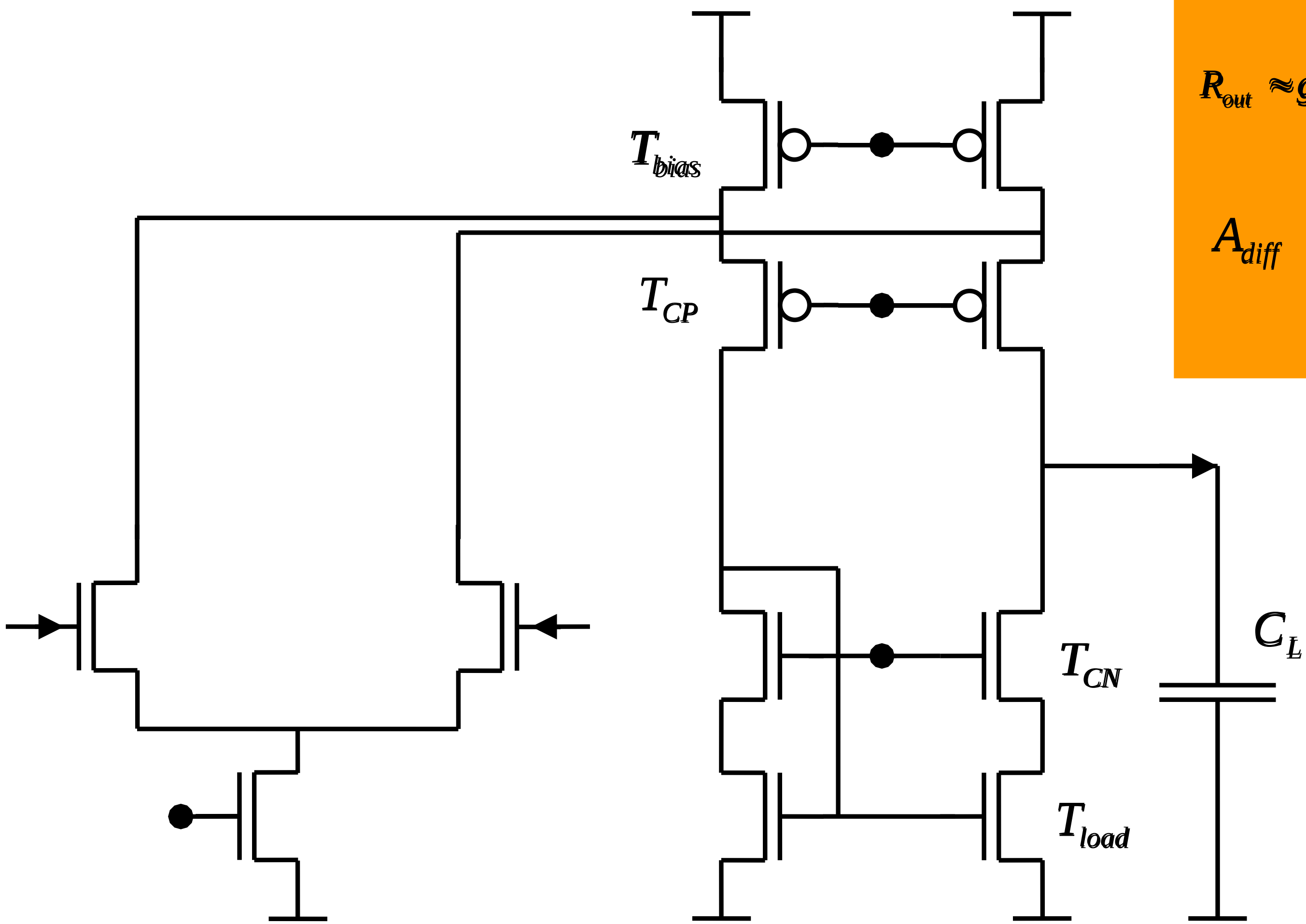


$$R_{out} \approx r_{ds2} g_{CN} r_{dsCN} \parallel r_{dsload} g_{CP} r_{dsCP}$$

$$A_{diff} \approx \frac{g_m R_{out}}{R_{out} C_L s + 1}$$


Tdio
Tload
T_{CP}
vcasc
T_{CN}
C_L
Tsource
V_{dssat}
Voutmax = VDD – Vdssat_load – Vdssat_cp
vcasc
Dynamikbereich
Ausgang
Vinmax = Vcasc – Vdssat_nc
Voutmin = Vcasc – Vth ~ Vinmax
Dynamikbereich
Eingang
Vinmin = Vdssat_source + Vdssat_in + Vth

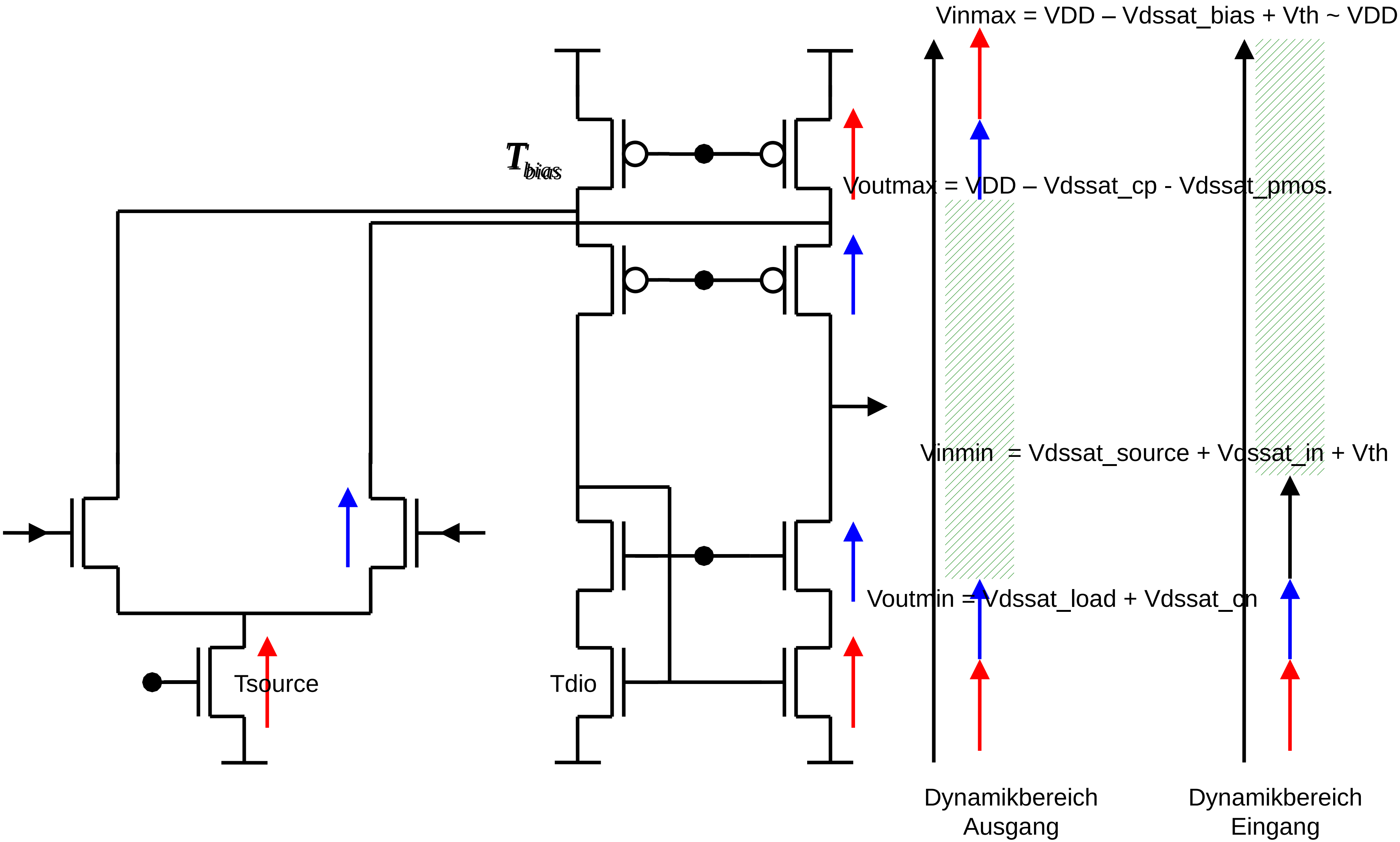
Gefaltete Kaskode: Verstärkung

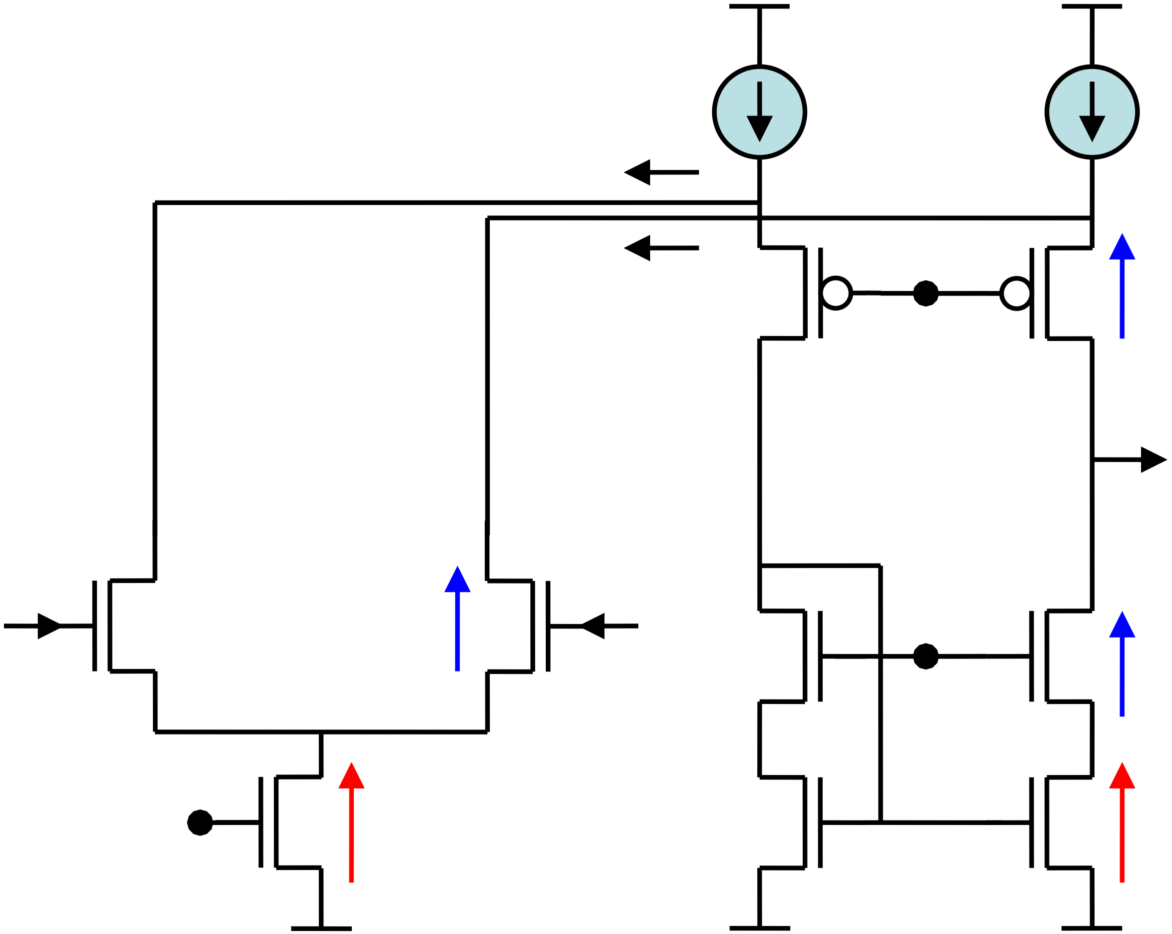


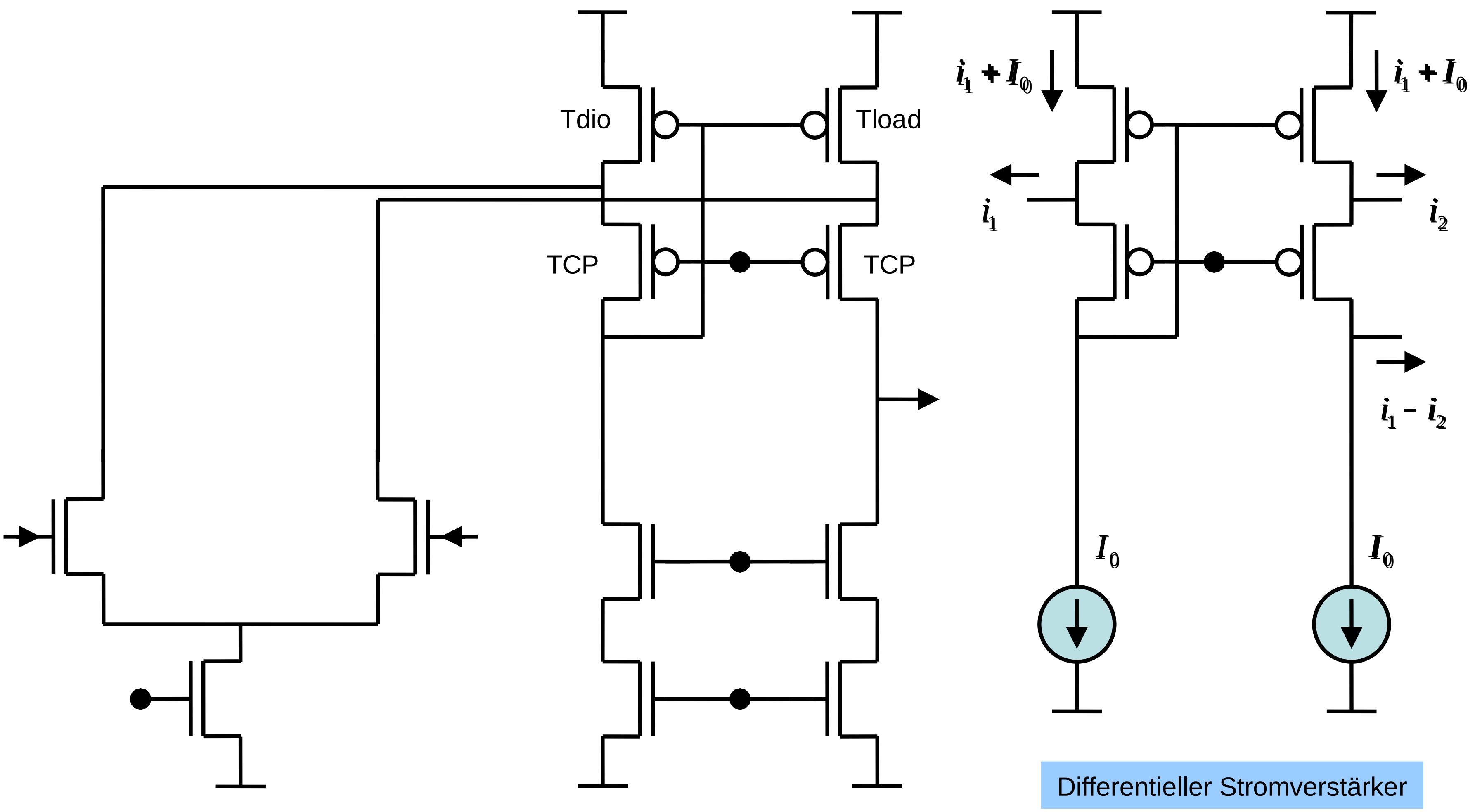
$$R_{out} \approx g_{CP} r_{dsCP} r_{dsbias} \parallel g_{CN} r_{dsCN} r_{dsload}$$

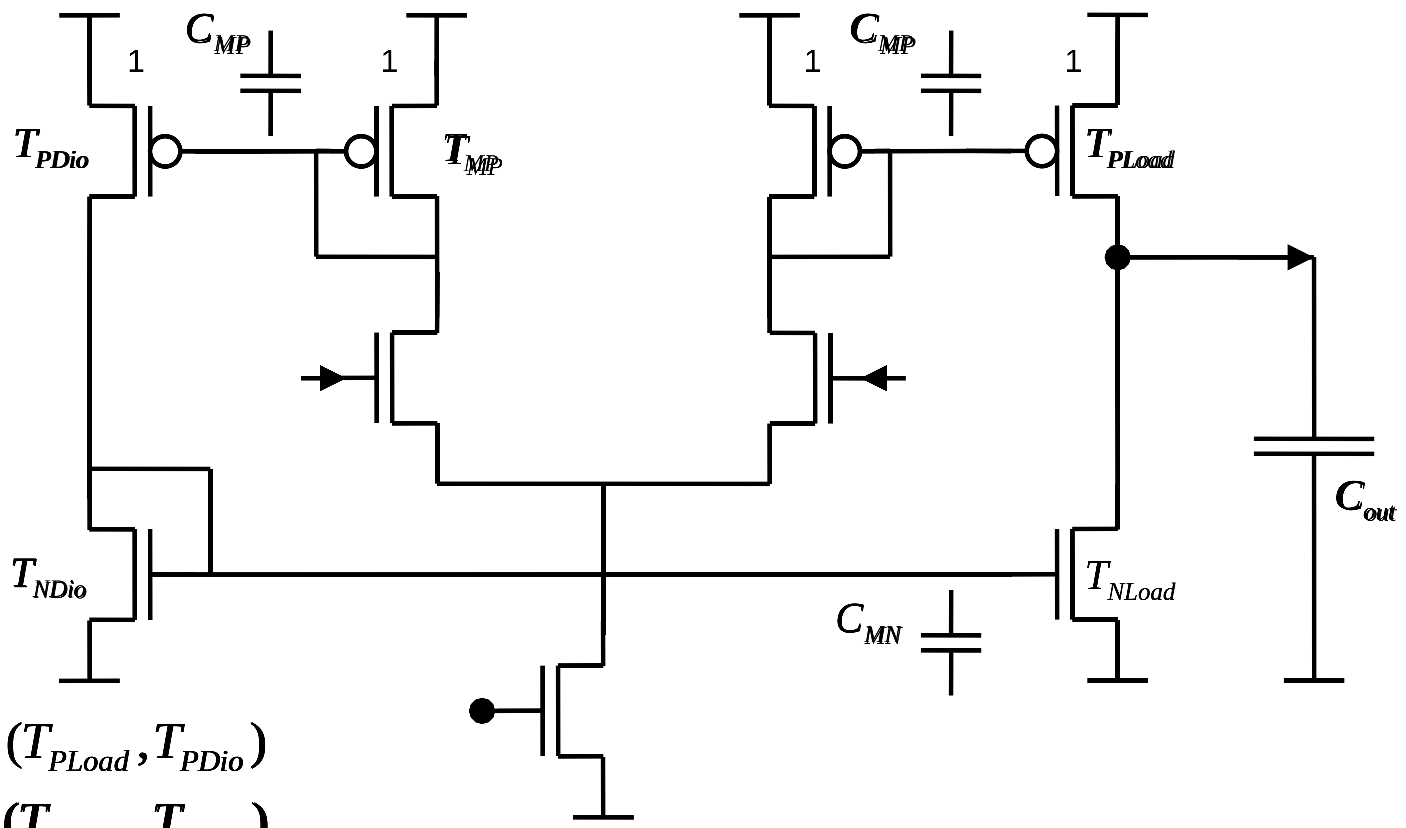
$$A_{diff} \approx \frac{g_m R_{out}}{R_{out} C_L D + 1}$$

Gefaltete Kaskode: Dynamikbereich






Tdio
Tload
TCP
TCP
$i_1 + I_0$
$i_1 + I_0$
i_1
i_2
$i_1 - i_2$
I_0
I_0
Differentieller Stromverstärker

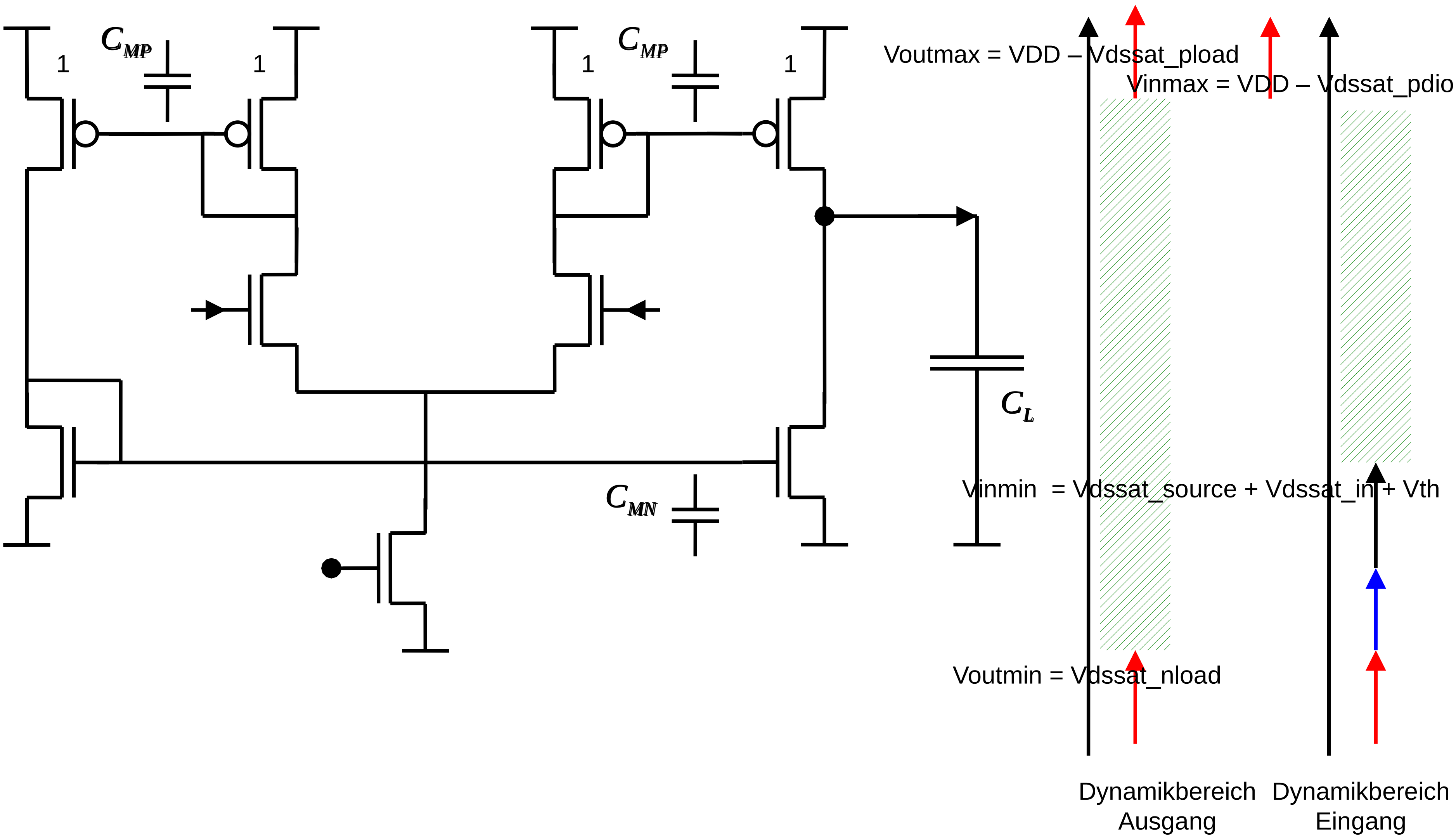


$$g_{mMP} = g_m(T_{PLoad}, T_{PDio})$$

$$g_{mMN} = g_m(T_{NLoad}, T_{NDio})$$

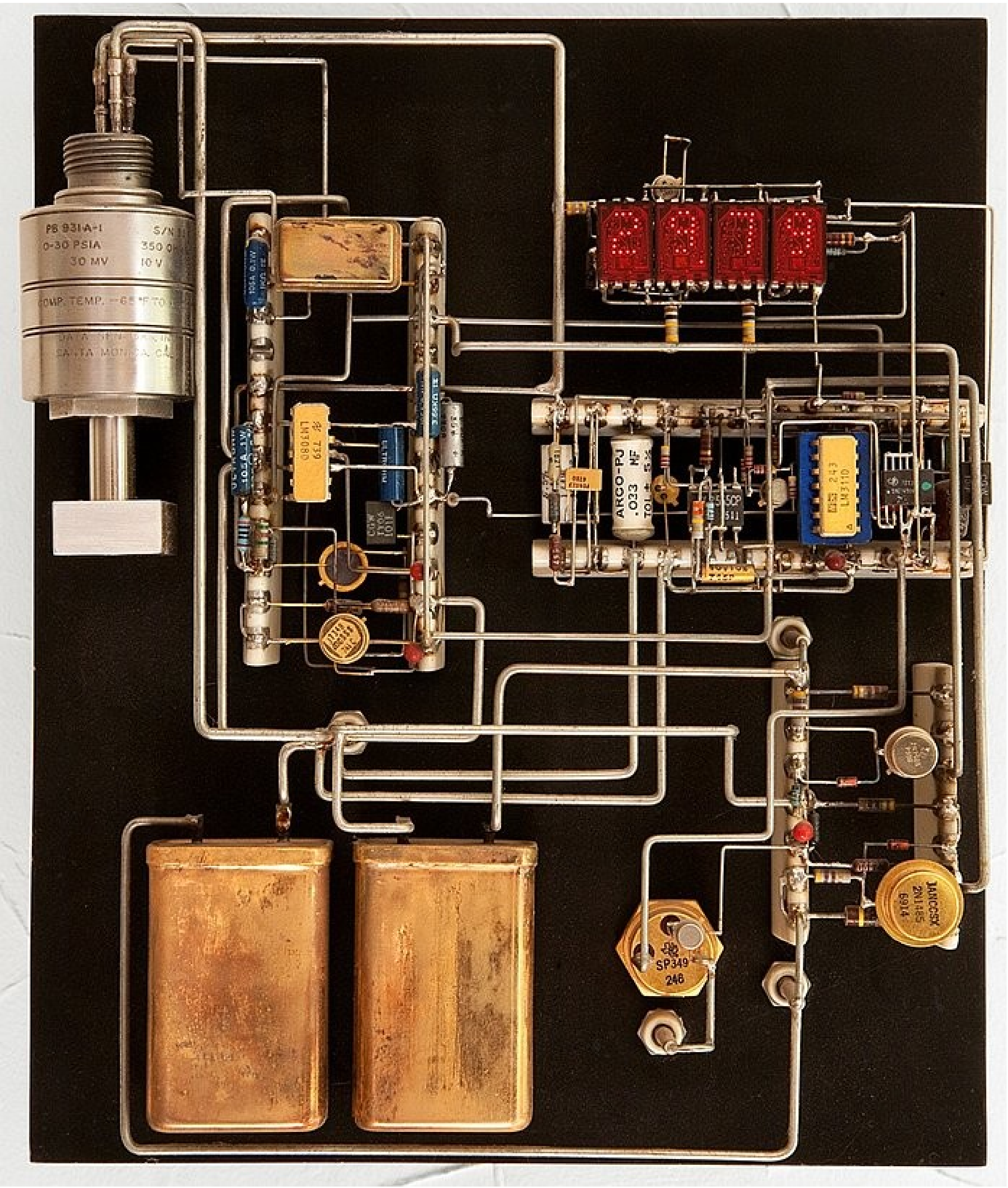
$$A(D) \approx g_{mIN} R_{out} \frac{1}{(R_{out} C_{out} s + 1)\left(\frac{C_{MP}}{g_{mMP}} s + 1\right)} \frac{\left(\frac{C_{MN}}{2 g_{mM}} s + 1\right)}{\left(\frac{C_{MN}}{g_{mMN}} s + 1\right)}$$

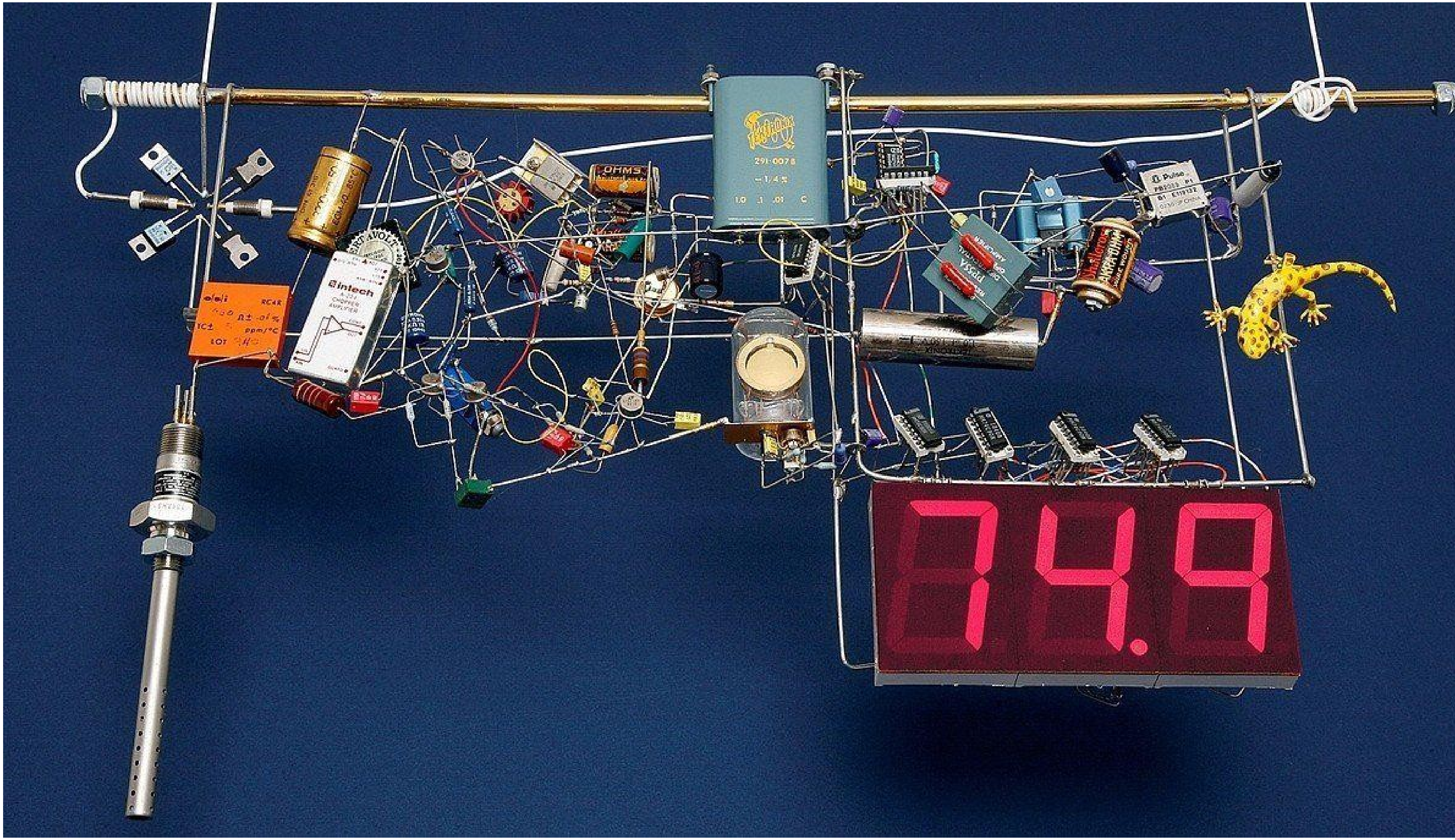
$$R_{out} = r_{dspload} \parallel r_{dsnload}$$

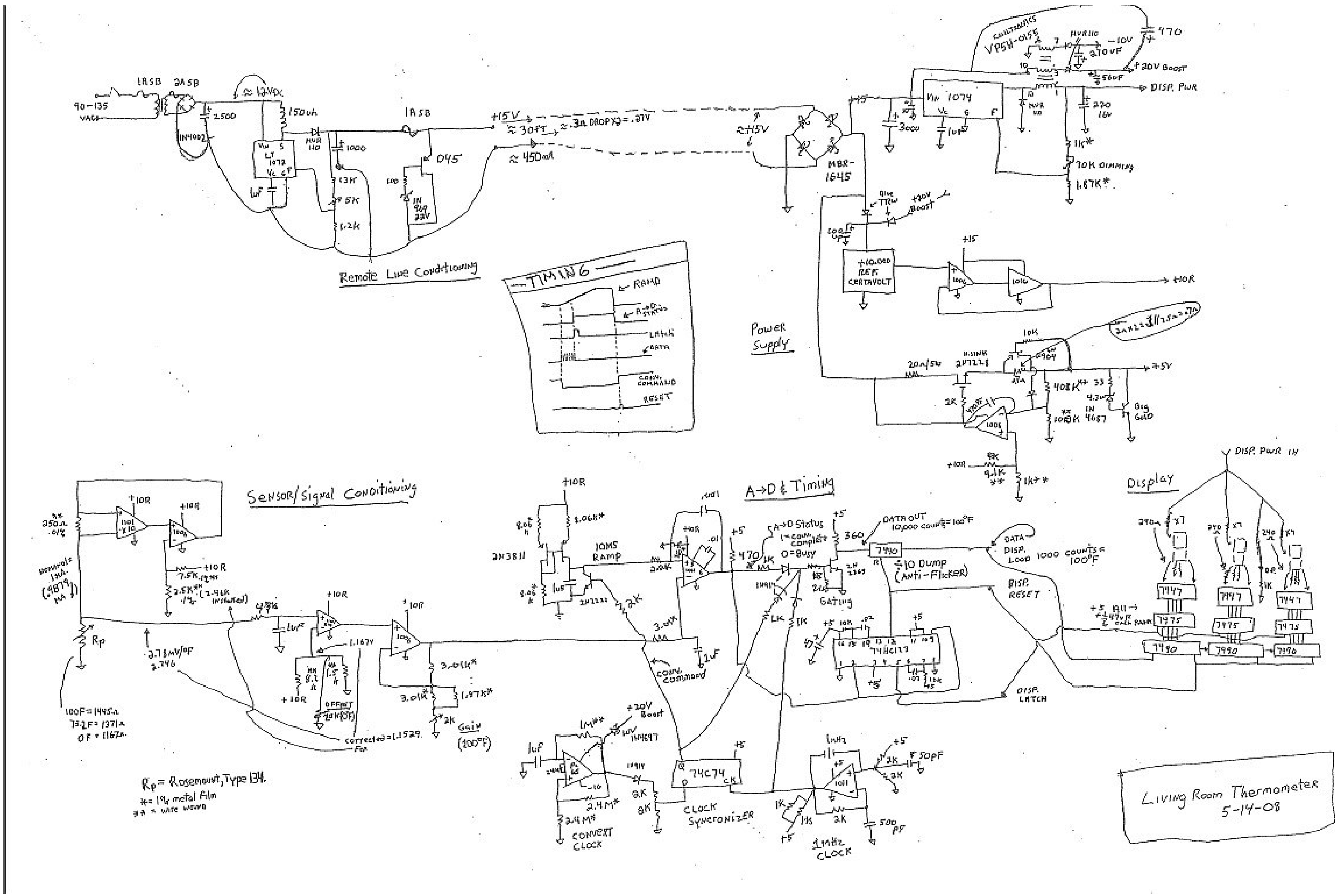


C_MP
1
1
C_MP
1
1
C_L
C_MN
Voutmax = VDD – Vdssat_pload
Vinmax = VDD – Vdssat_pdio
Vinmin = Vdssat_source + Vdssat_in + Vth
Voutmin = Vdssat_nload
Dynamikbereich
Ausgang
Dynamikbereich
Eingang

Anhang


PS 931-A-1
0-30 PSIA
30 MV
ARCO-PJ
.033
LM308
SP349
246
2N1485

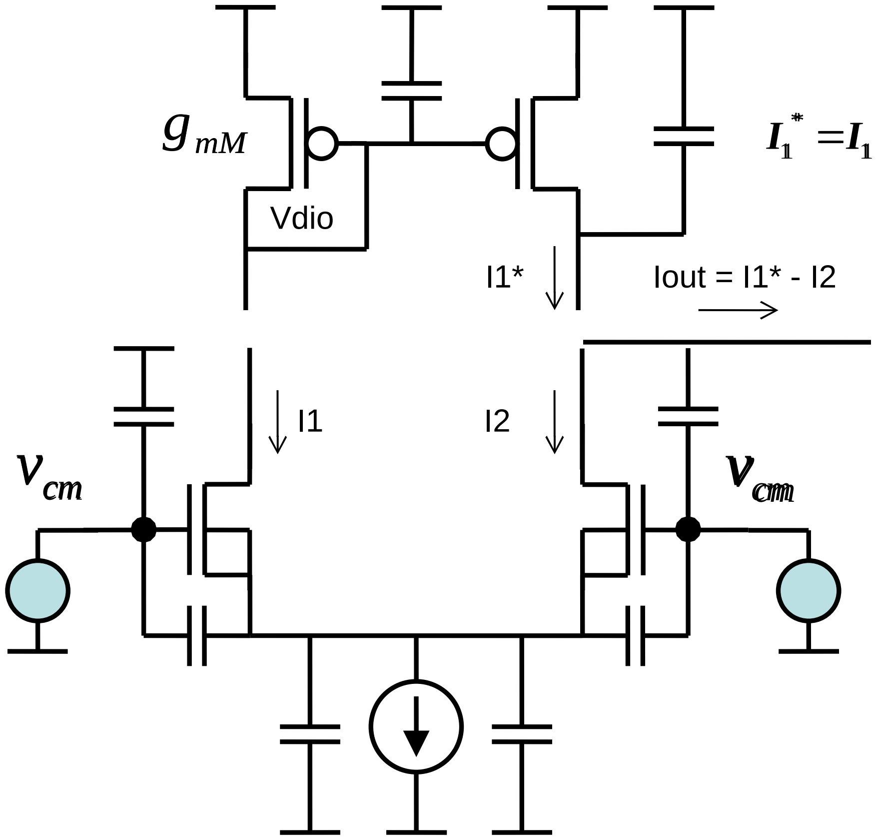

OHMS
291-0078
intech
74.9


Remote Line Conditioning
TIMING
Power Supply
Sensor/Signal Conditioning
A→D & Timing
Display
Rp = Rosemount, Type 134.
CONVERT CLOCK
CLOCK SYNCRONIZER
1MHz CLOCK
Living Room Thermometer
5-14-08

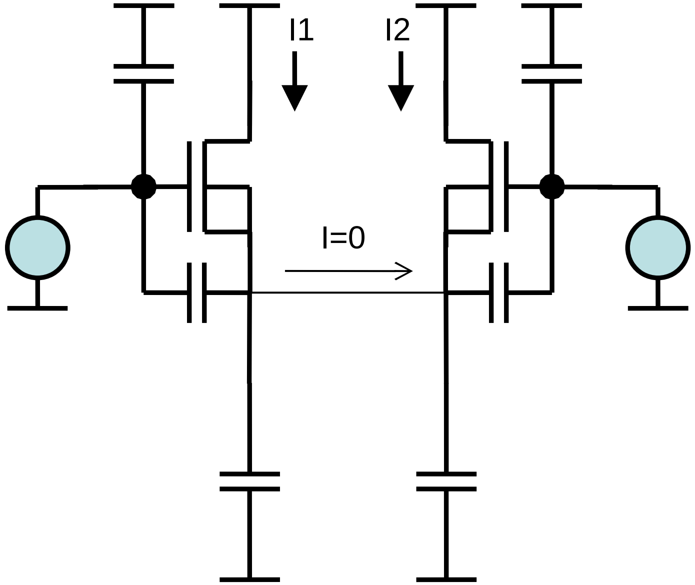
Jim Williams: Another thermometer design

Anhang

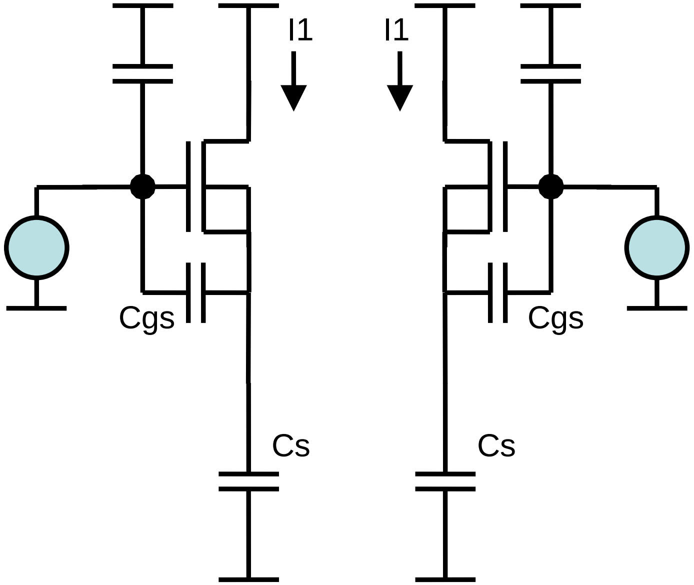
Gleichtaktverstärkung - Frequenzgang

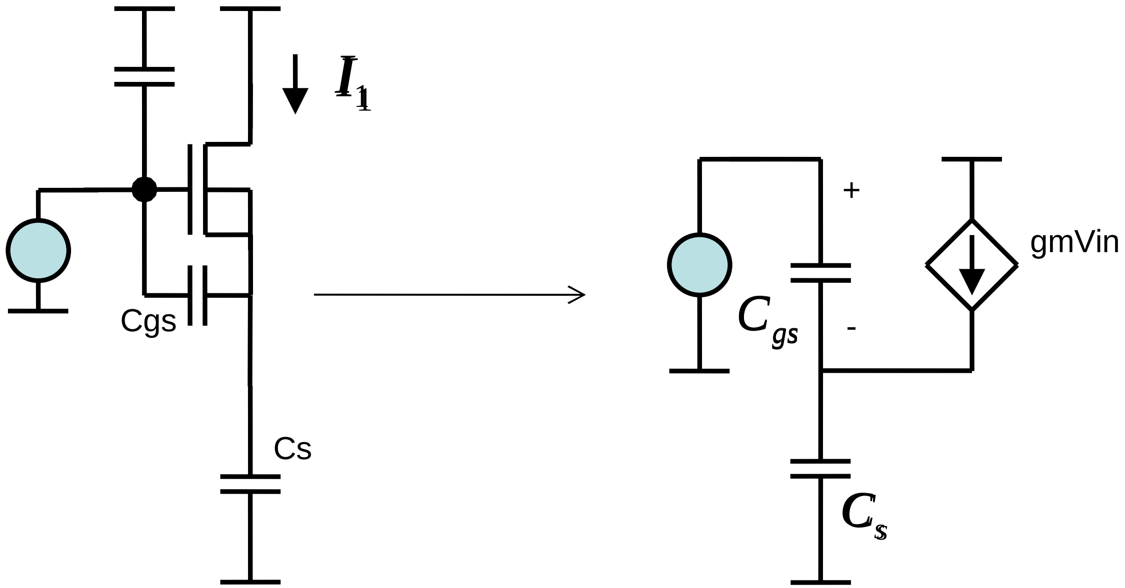


$$I_1^* = I_1 \frac{1}{(C_M / g_{mM})s + 1}$$



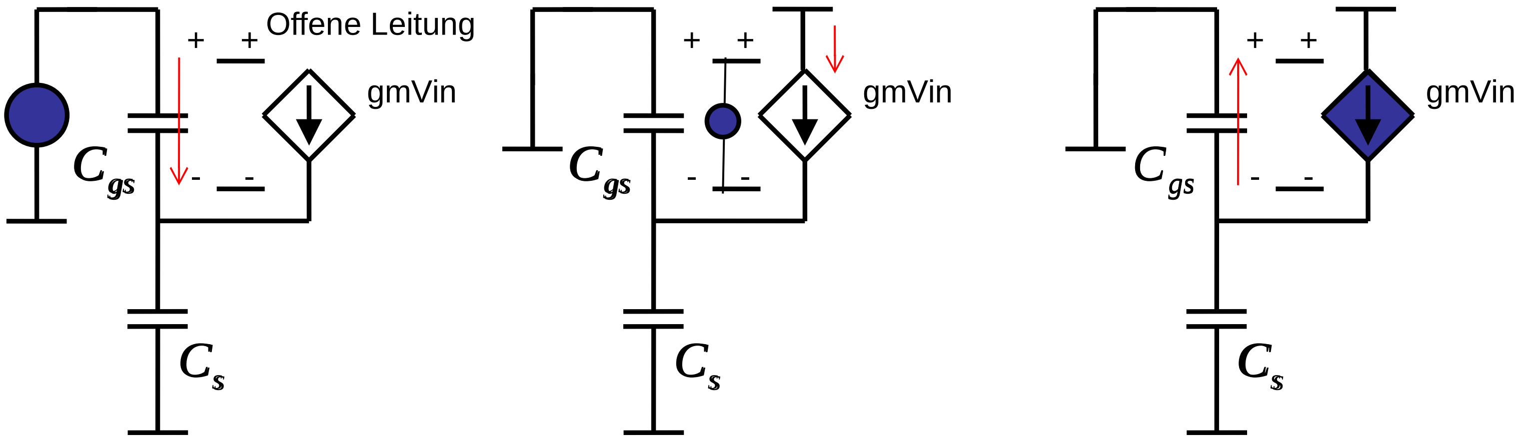
Gleichtaktverstärkung





I_1
Cgs
Cs
+
-
gmVin
C_{gs}
C_s

$$A_{in} = \frac{C_s}{C_s + C_{gs}} \qquad A_{ol} = g_m \qquad \beta A = -\frac{g_m}{s(C_s + C_{gs})} \qquad FF = 0$$



$$I_1 = \frac{A_{in} A_{ol}}{1 + \beta A} V_{cm} = \frac{sC_s}{1 + s(C_s + C_{gs})/g_m} V_{cm}$$

$$I_1 = I_2 = g_m \frac{(C_s / g_m)s}{s(C_s + C_{gs})/g_m + 1} V_{cm}$$

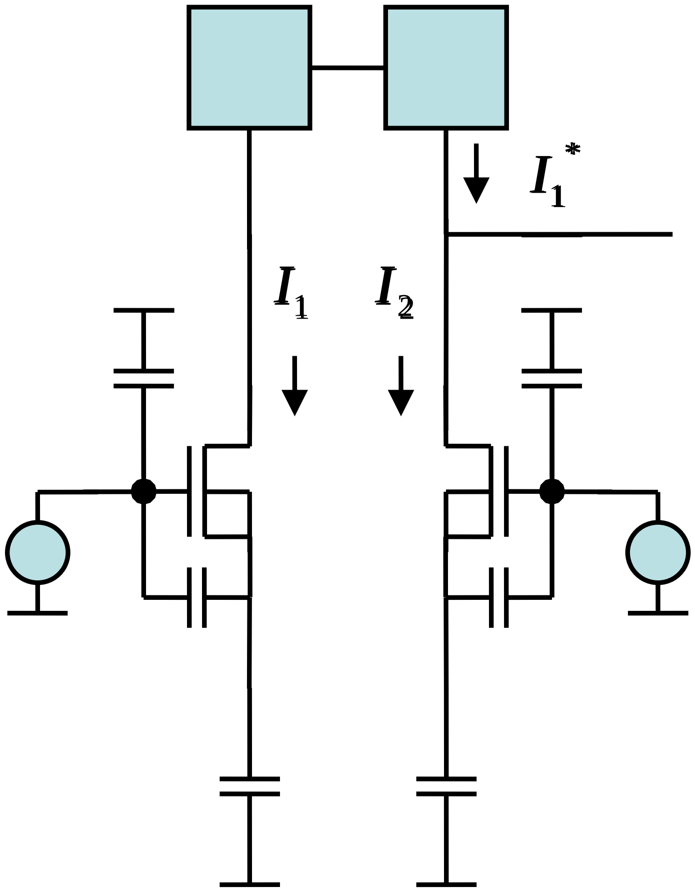
$$I_1^* = I_1 \frac{1}{(C_M / g_{mM})s + 1}$$

$$I_{out} = I_1^* - I_1$$

$$I_{out} = -V_{cm} g_m \left(\frac{(C_s / g_m)s}{s(C_s + C_{gs})/g_m + 1} \right) \left(\frac{(C_M / g_{mM})s}{(C_M / g_{mM})s + 1} \right)$$

$$I_{out}(0) = 0$$

$$I_{out}(\infty) = -V_{cm} g_m \frac{C_s}{(C_s + C_{gs})}$$



$$V_{out} = V_d g_m \left(\frac{(C_M / 2g_{mM})s + 1}{(C_M / g_{mM})s + 1} \right) Z_{out} \sim V_d g_m Z_{out}$$

$$V_{out} = -V_{cm} g_m \left(\frac{(C_s / g_m)s}{s(C_s + C_{gs})/g_m + 1} \right) \left(\frac{(C_M / g_{mM})s}{(C_M / g_{mM})s + 1} \right) Z_{out} \sim 0$$

$$Z_{out} = \frac{R_{out}}{(C_{out} R_{out})s + 1}$$