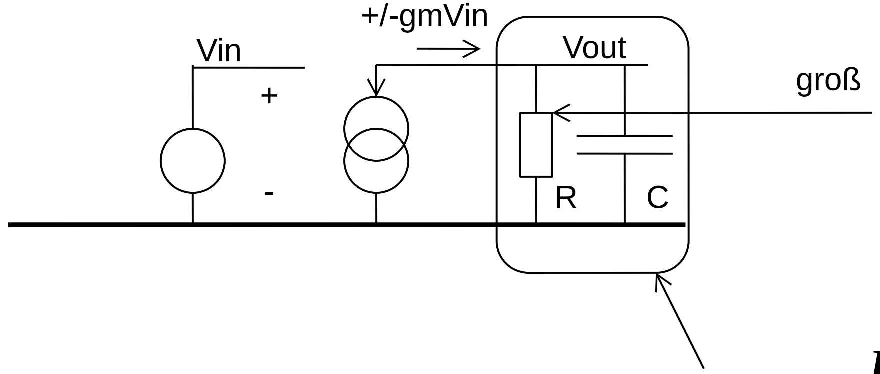
Verstärker mit zwei Stufen
Ausgangsstufen
Source-Follower, Common-Source

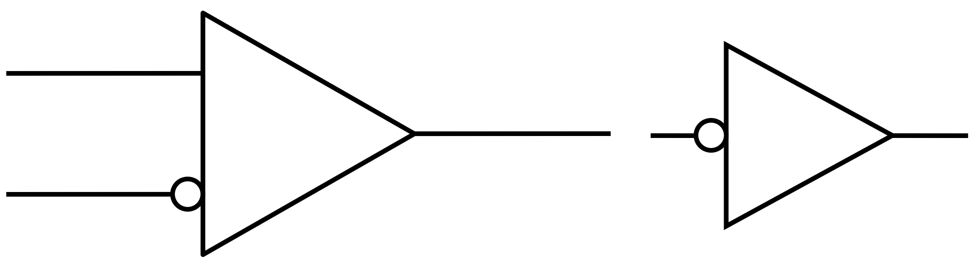
Einstufiger Verstärker

Einstufiger Verstärker

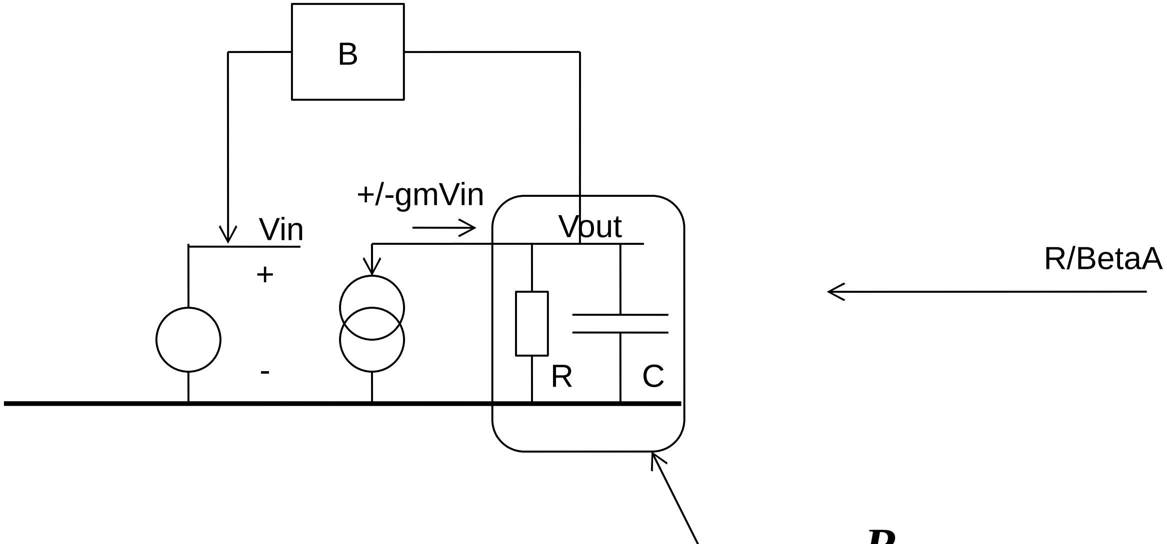
- Einstufige Verstärker
- U-I Konverter, Zout
- Nachteil Rout groß



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



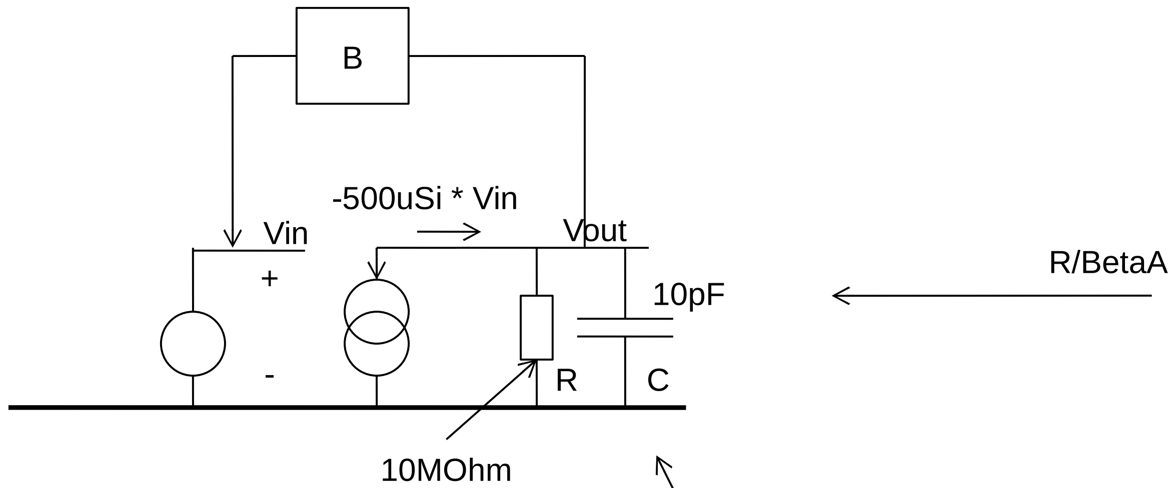
- Rout_fb < Rout



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

Einstufiger Verstärker

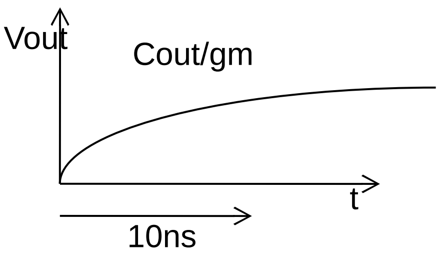
- Beispiel
- Afb = 100
- Aol = 5000

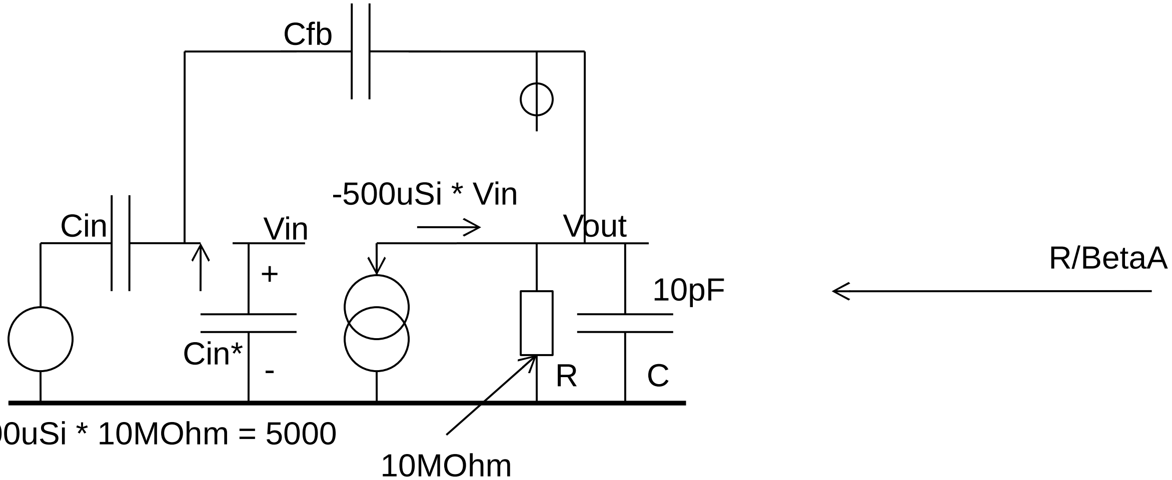


$$Z = \frac{R}{1 + sRC}$$

A = -500uSi * 10MOhm = 5000

- …





A = -500uSi * 10MOhm = 5000

Tfb = Cout Rout / Beta Aol = Cout Rout / Beta gm Rout = Cout / Beta gm

Beta = Cfb/(Cfb + Cin + Cin*)

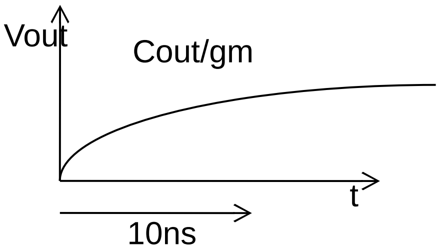
Afb = -Ain/Beta = - Cin/Cfb ~ - 1/Beta

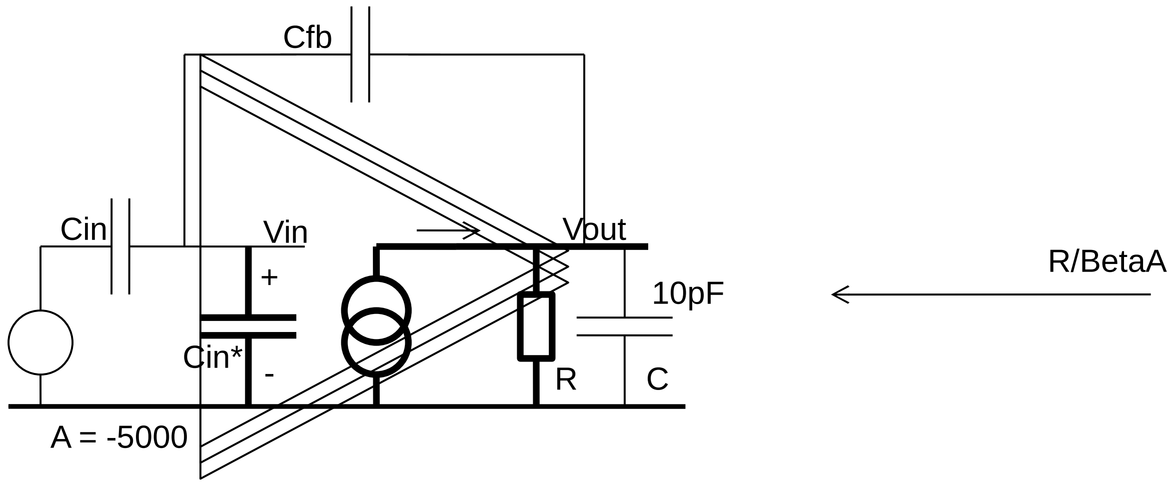
Beta ~ -1/Afb => Beta ~ 0.01 Falls Cin*,Cfb << Cin

Tfb ~ Cout / 0.01 gm ~ 100 * 10pF / 500uSi = 2000ns.

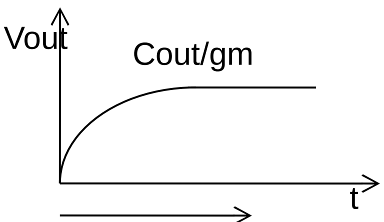
Einstufiger Verstärker

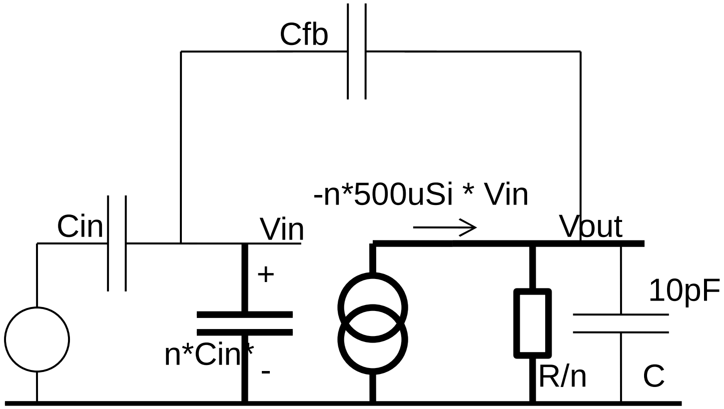
- …





- …



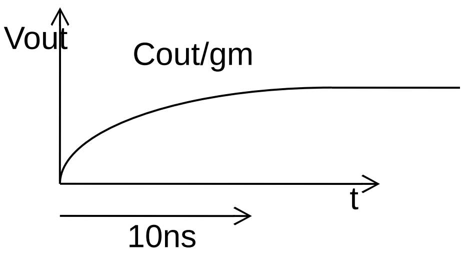


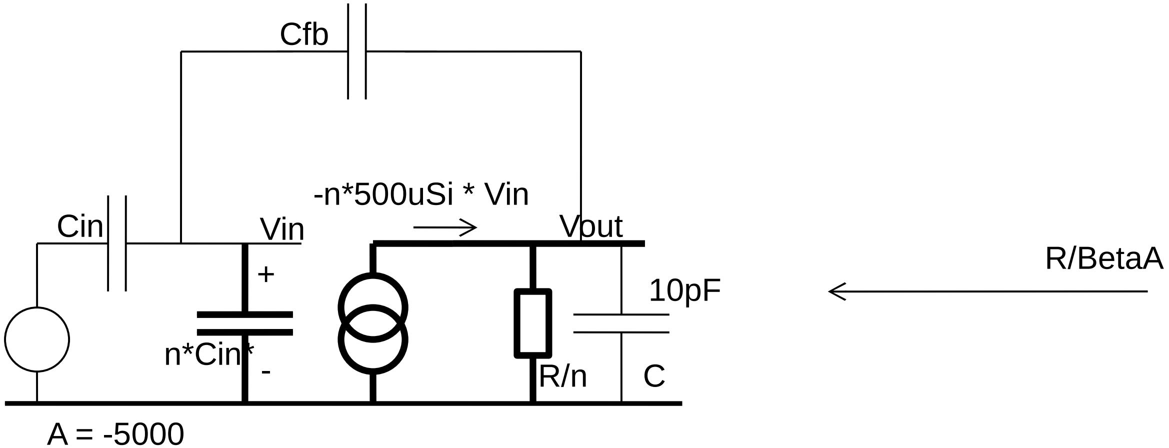
R/BetaA

Tfb = Cout Rout/n / Beta Aol* = Cout / Beta n*gm

N=200 -> Tfb = 10ns.

- …





Tfb = Cout Rout/n / Beta Aol* = Cout / Beta n*gm

N=200 -> Tfb = 10ns.

Cin* = 200 * 20f = 4pF.

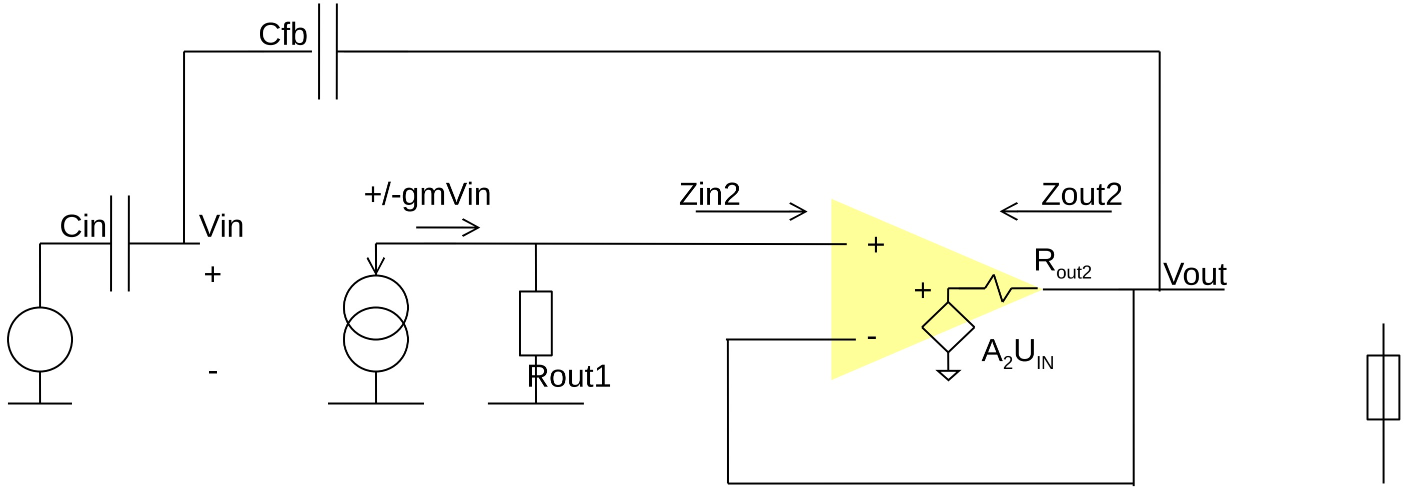
Falls Cin ~ Cin* Beta = Cfb/(Cfb + Cin + Cin*) << 1/Afb = 0.01

Tfb > 10ns.

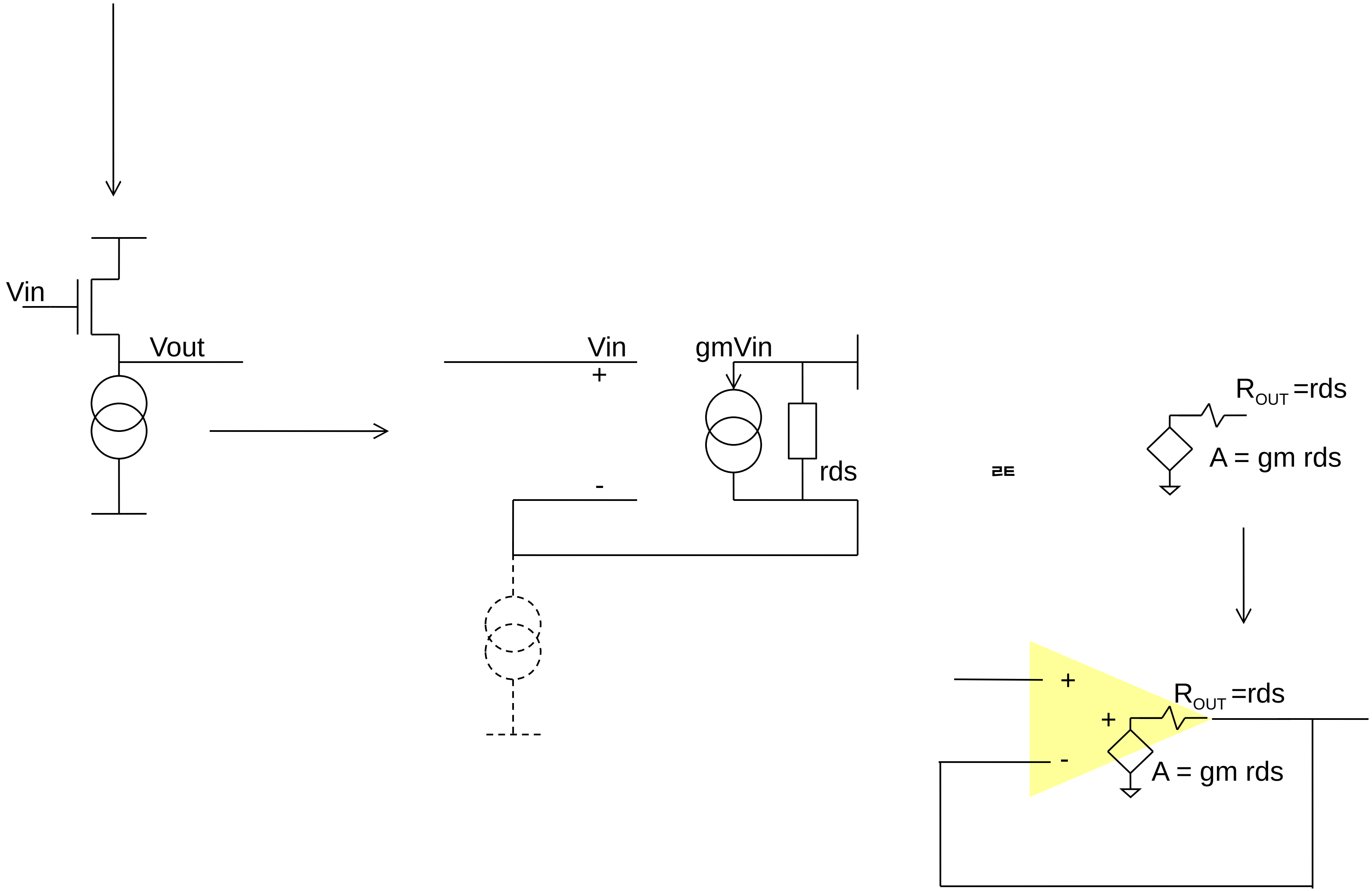
Verstärker mit zwei Stufen
Source-Follower als Ausgangsstufe

Verstärker mit Ausgangsstufe

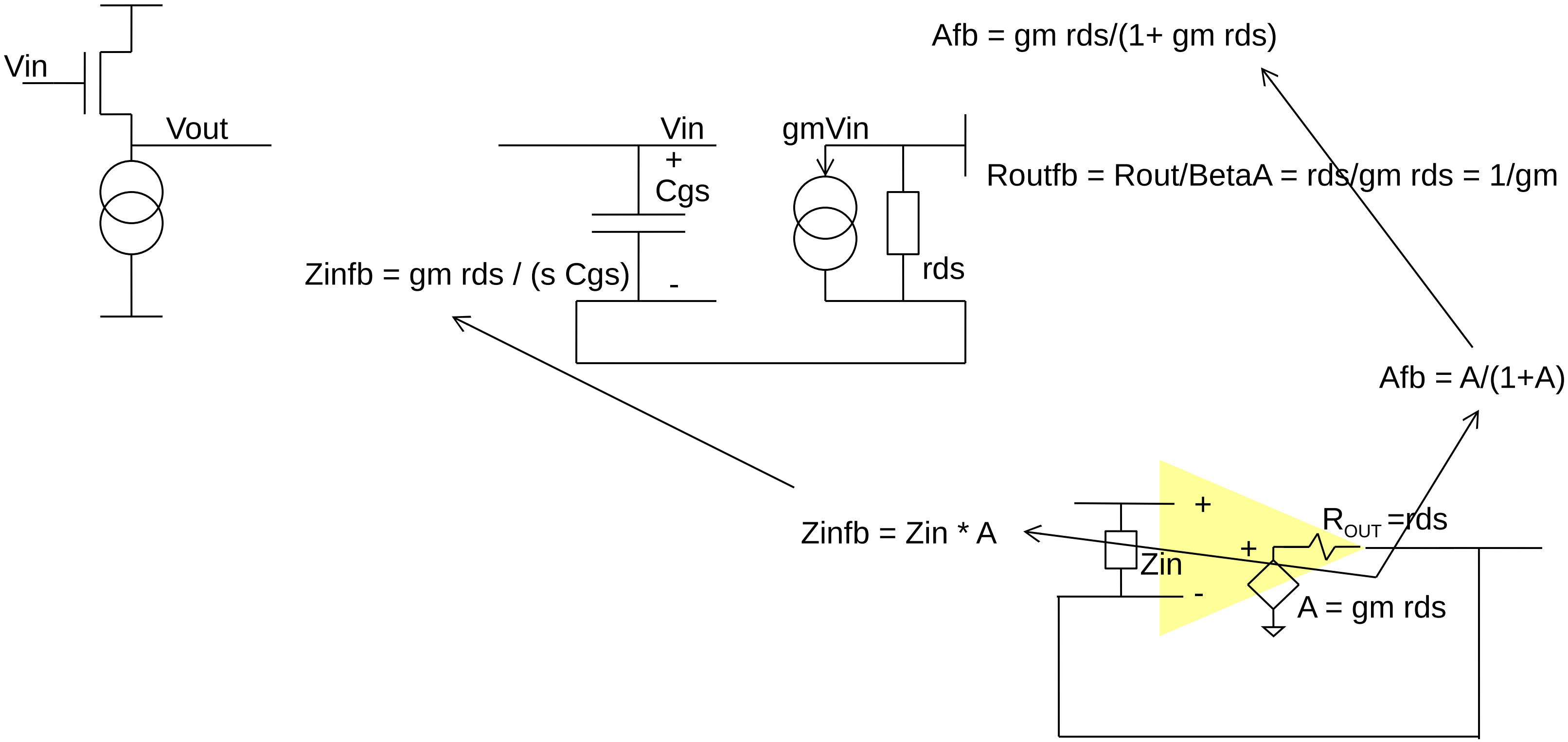
- Nichtinvertierender Verstärker (Buffer) als Ausgangsstufe
- Große Eingangsimpedanz Zin2 und kleine Ausgangsimpedanz Zout2
- Schneller, Rout klein



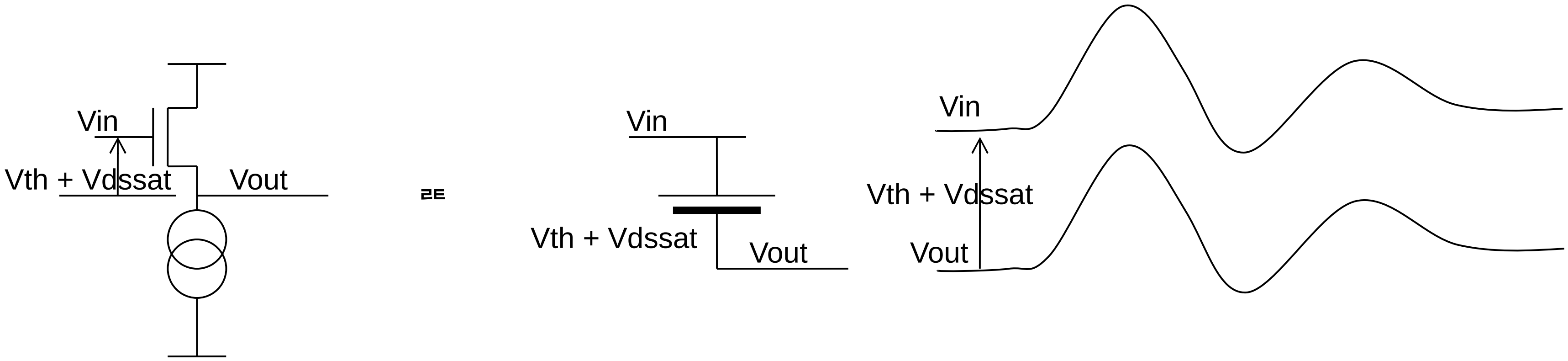
- Sourcefolger (Common Drain)



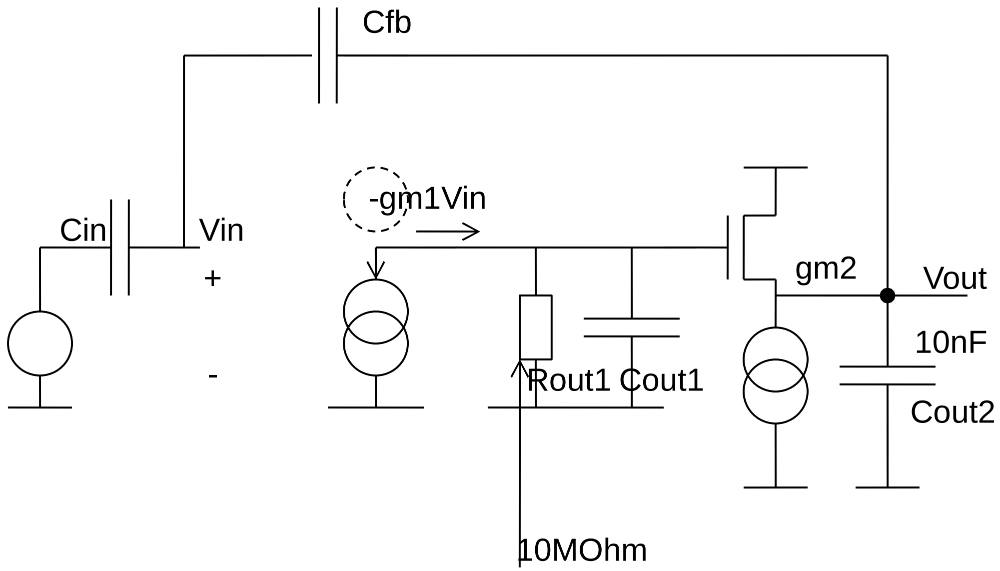
- Kleinsignalmodell



- Großsignalmodell

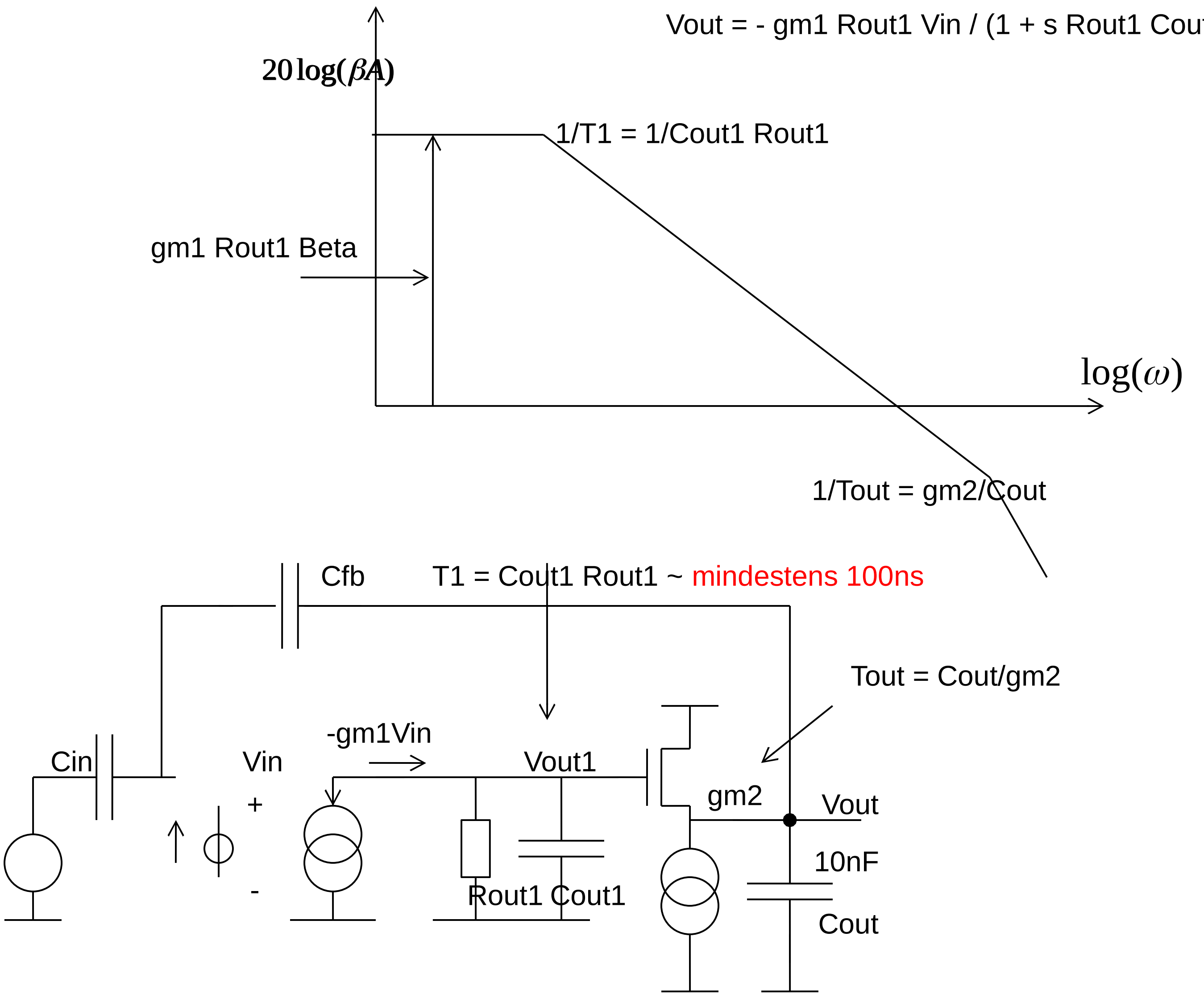


- Tfb = ?



- Schleifenverstärkung hat zwei Zeitkonstanten

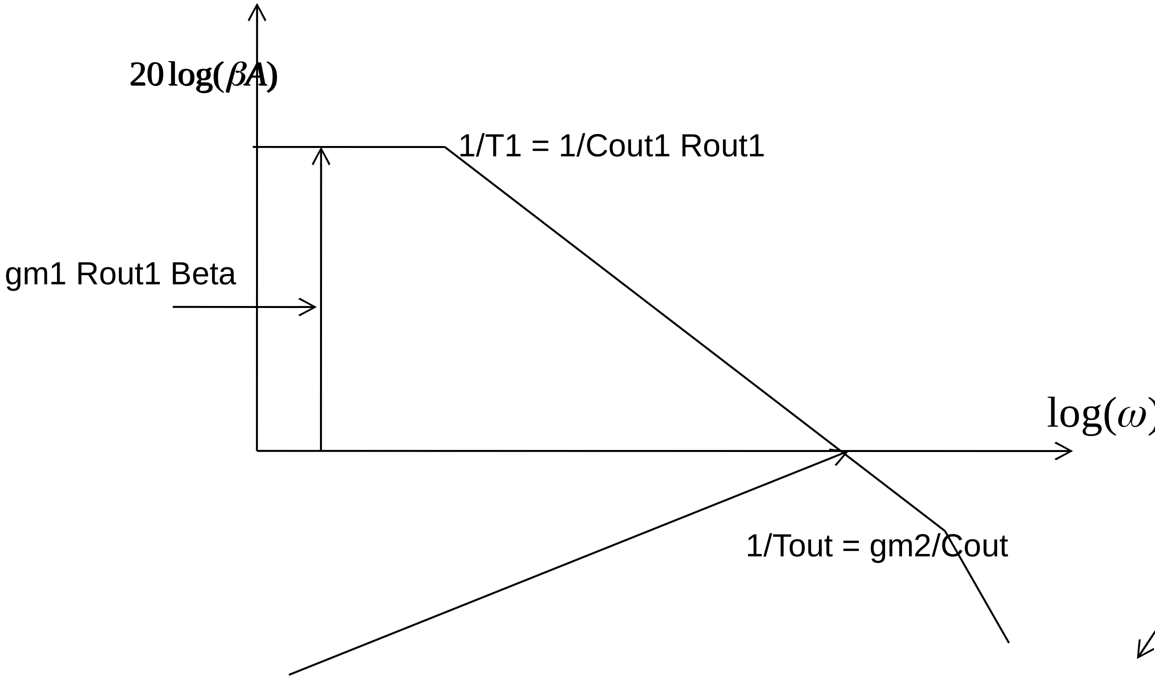
Vout = - gm1 Rout1 Vin / (1 + s Rout1 Cout1)(1 + s Cout/gm2)



T1 > 10fF * 10MOhm = 100ns.

Tout < T1.

- Stabilität



T1 > 10fF * 10MOhm = 100ns.

Tout < T1.

Stabilität

Tout * beta A < T1

Tfb = T1/betaA = Rout1 Cout1 / (Rout1 gm1 Beta) = Cout1 / (gm1 Beta) > Tout = Cout/gm2

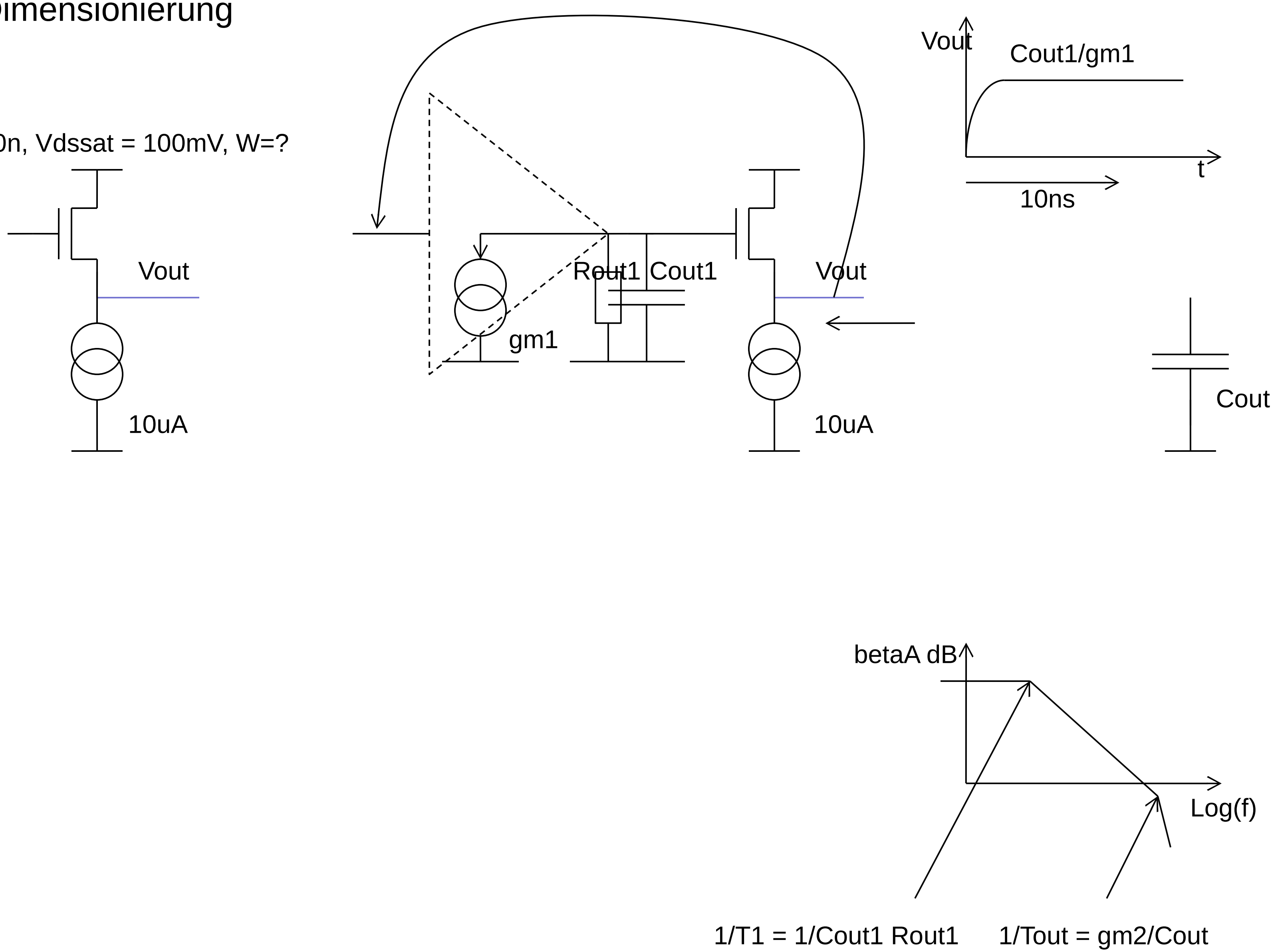
Tfb = 10ns -> Cout/gm2 < 10ns, oder gm2 > 10pF/10ns = 1mSi

Tfb = Cout1/gm1 Beta != f(Cout)

Stabilität: Tout = Cout/gm2 < Tfb

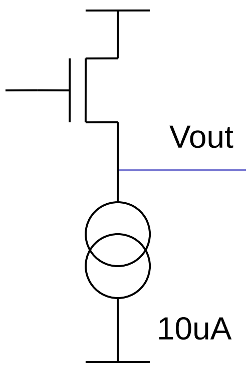
- Dimensionierung

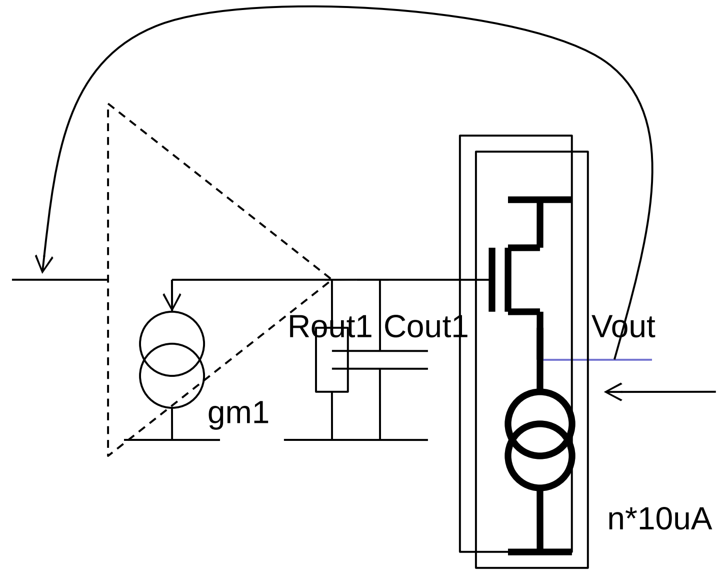
L = 200n, Vdssat = 100mV, W=?

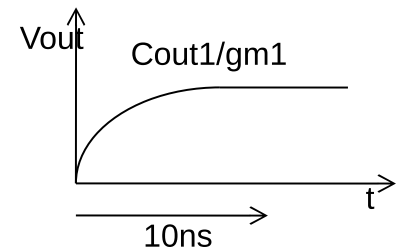


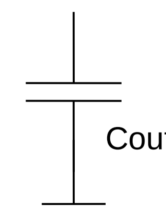
- Dimensionierung

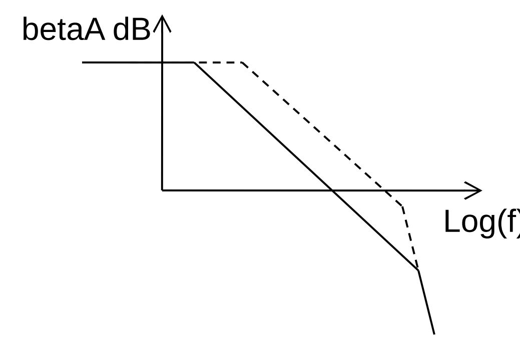
L = 200n, Vdssat = 100mV, W=?





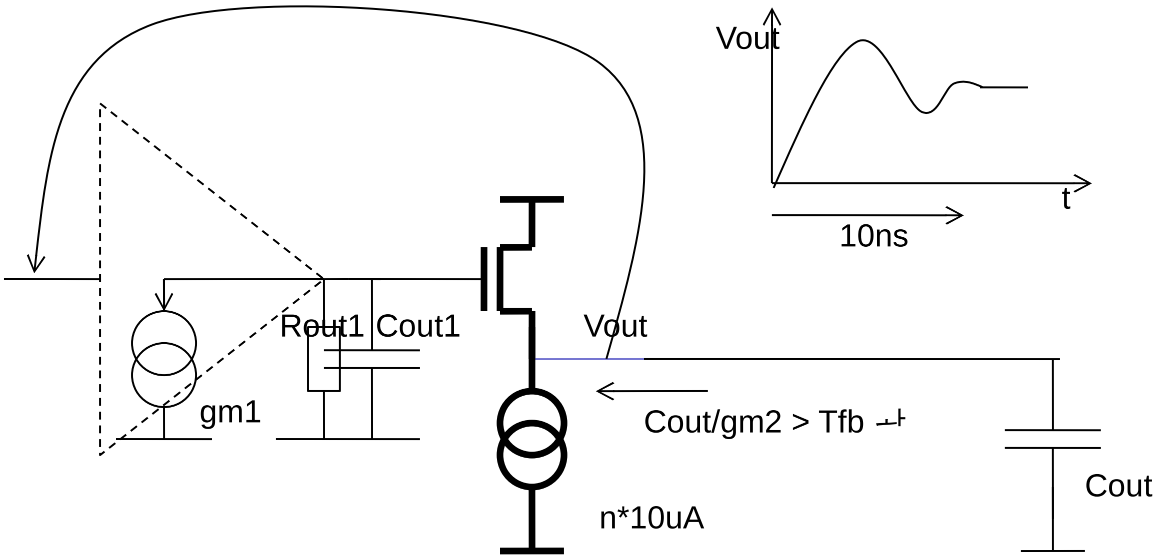


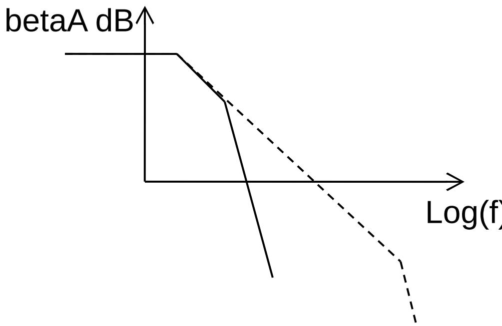




1/T1 = 1/Cout1 Rout1 1/Tout = gm2/Cout

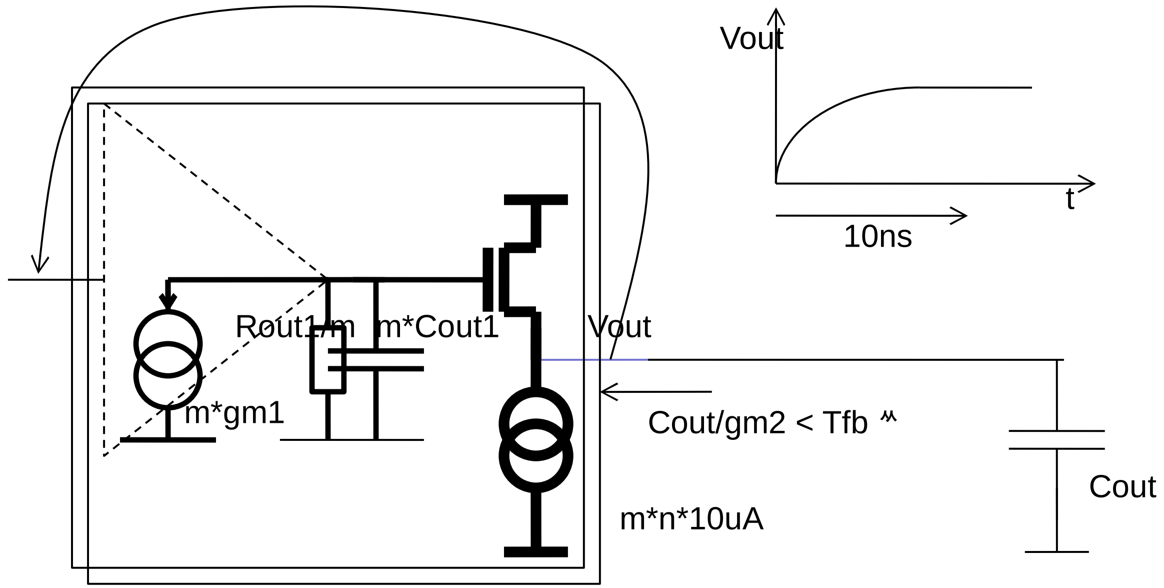
- Dimensionierung

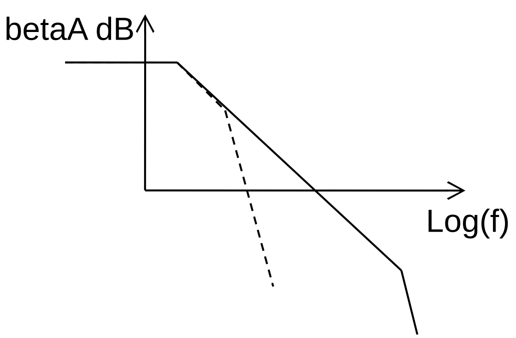




1/T1 = 1/Cout1 Rout1 1/Tout = gm2/Cout

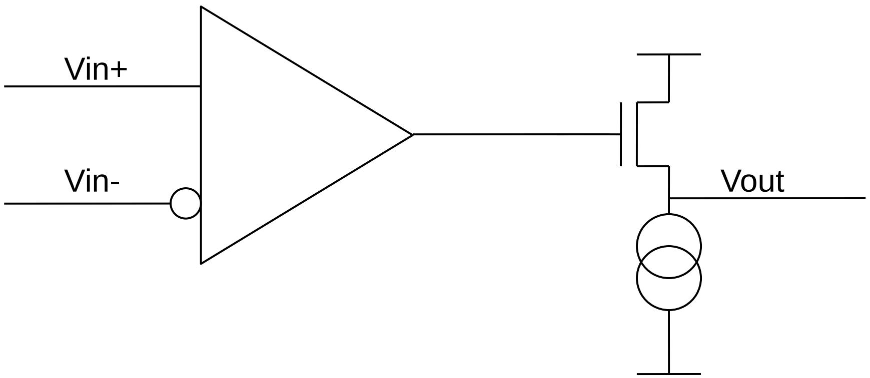
- Dimensionierung

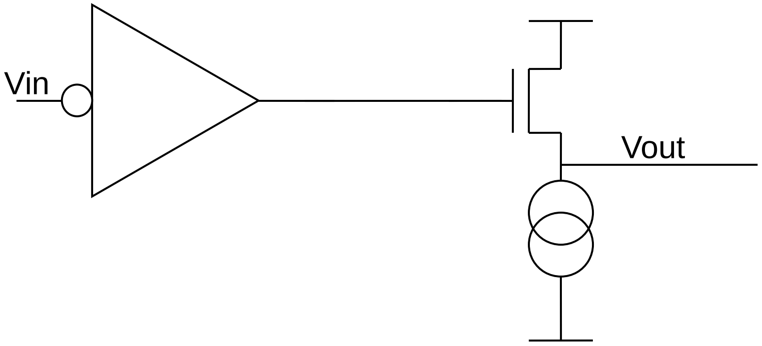




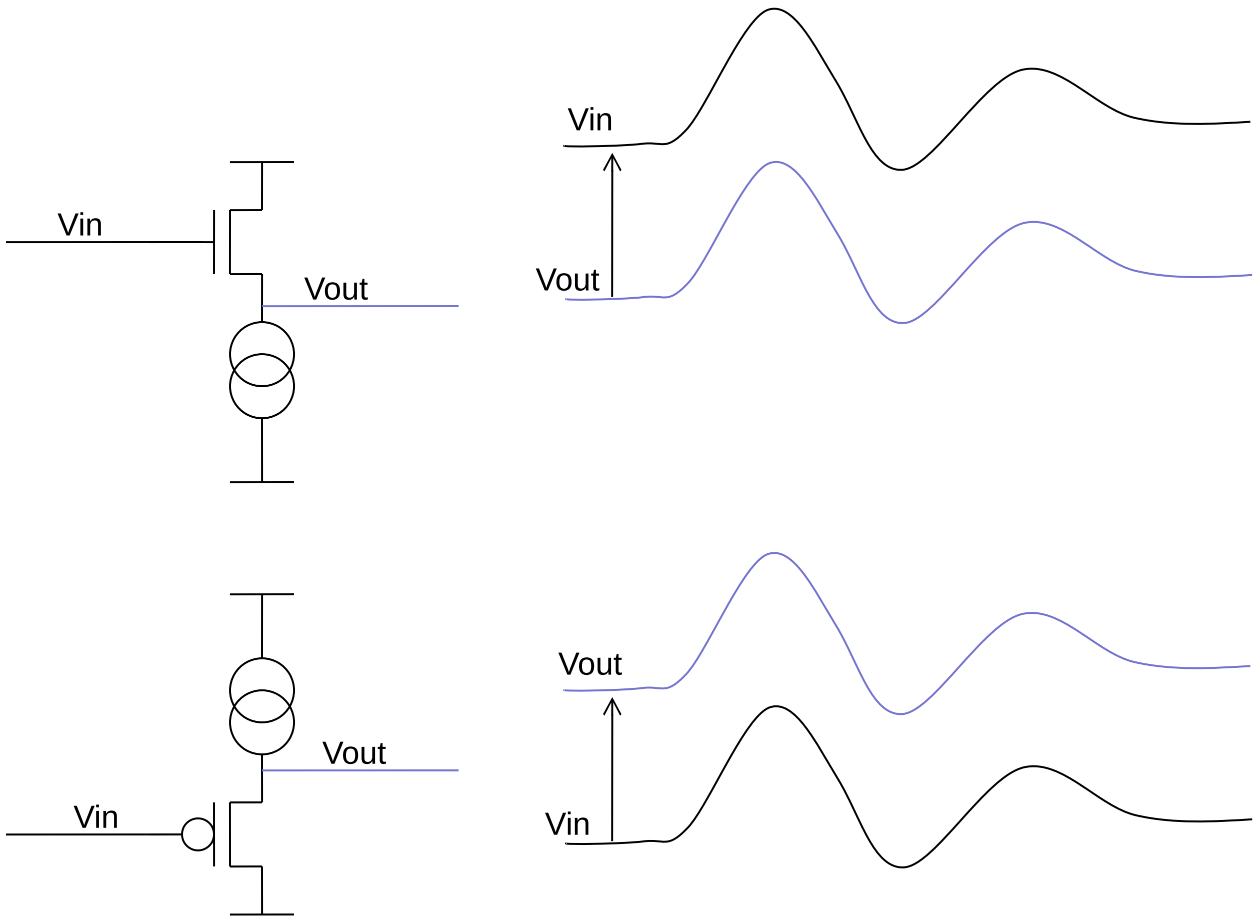
1/T1 = 1/Cout1 Rout1 1/Tout = gm2/Cout

- Varianten



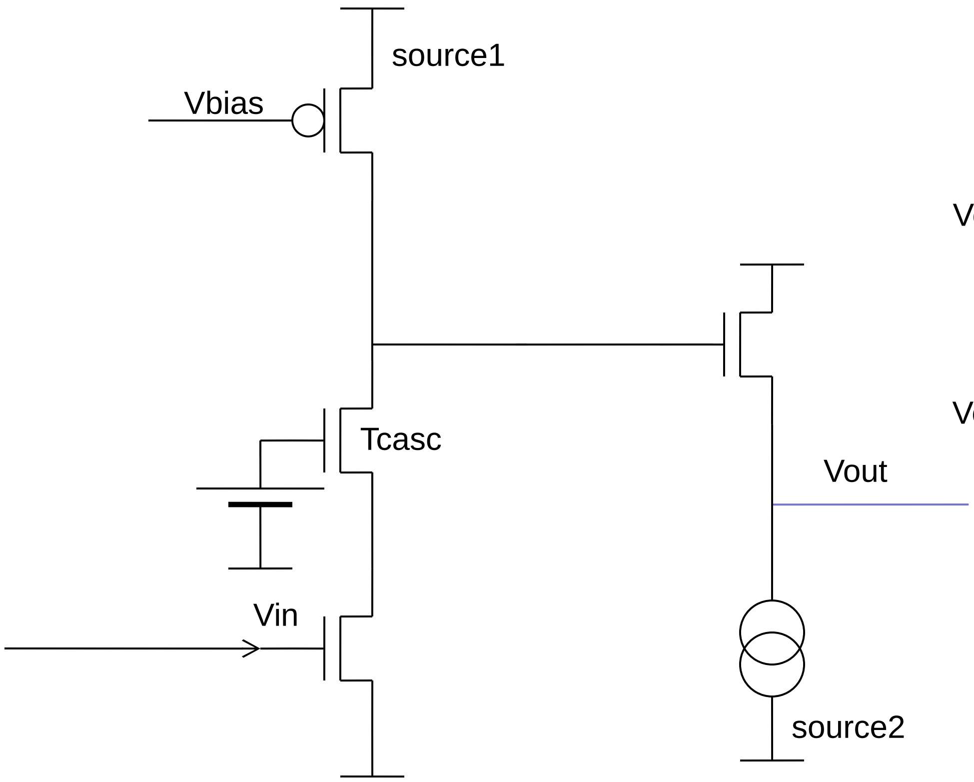


- Varianten



Verstärker mit Sourcefolger

- Nachteile
- Keine Spannungsverstärkung in der zweiten Stufe, Rauschen
- Eingeschränkter Signalbereich



Voutmax = VDD – Vdssat_source1 – Vth2 – Vdssat2

Voutmin = Vdssat_source2

65nm Technologie

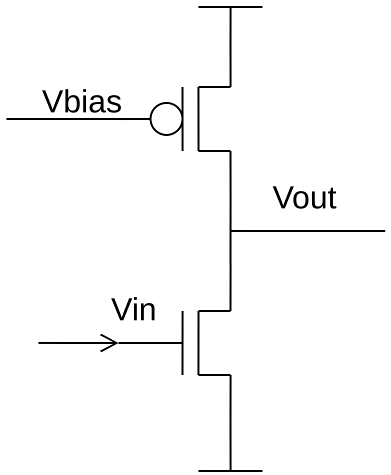
Voutmin = 100mV

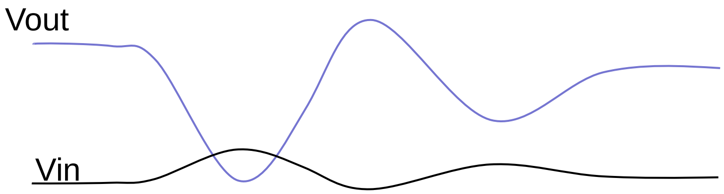
Voutmax = 600mV

Verstärker mit zwei Stufen
Common-Source als Ausgangsstufe

Verstärker mit CS-Ausgangsstufe

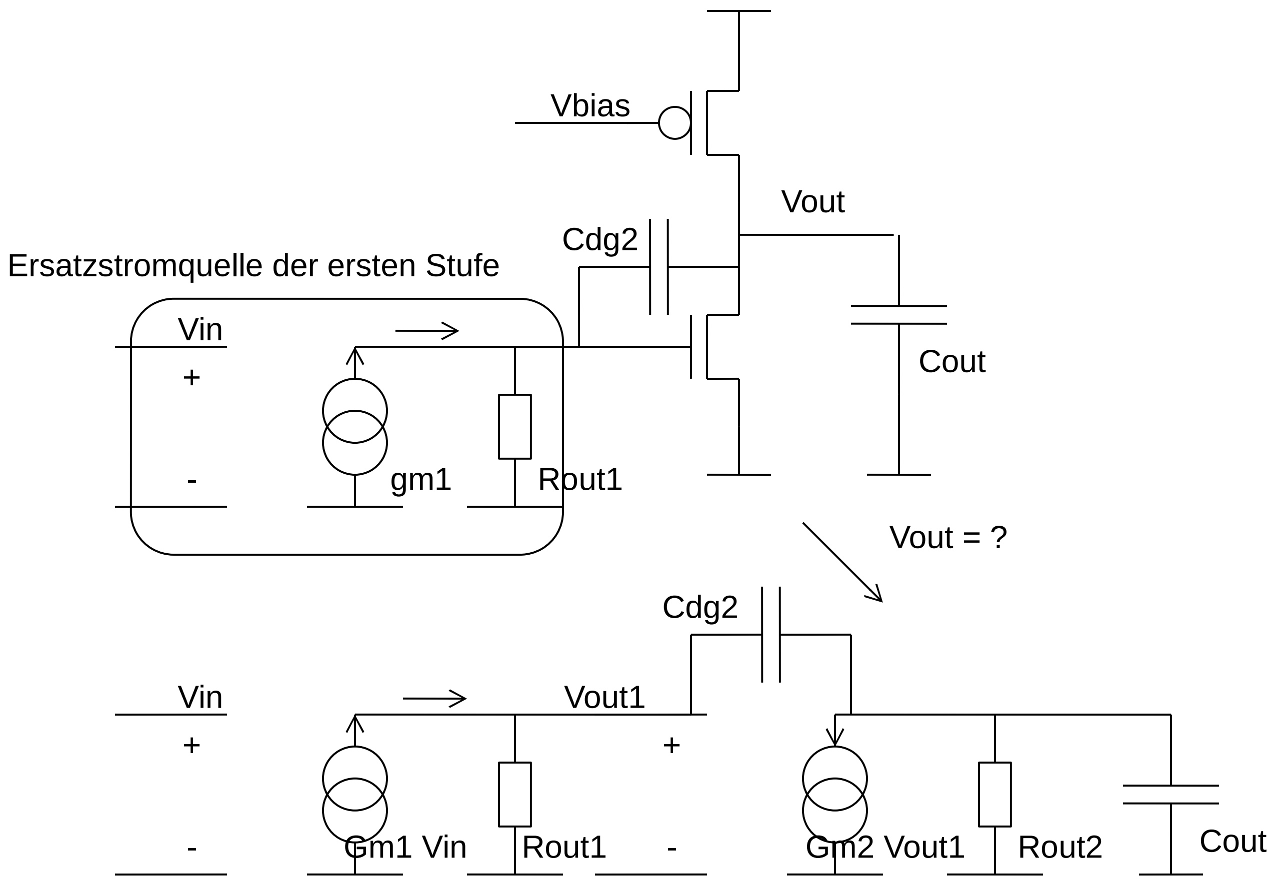
- Common Source Verstärker





A = - gm Rout

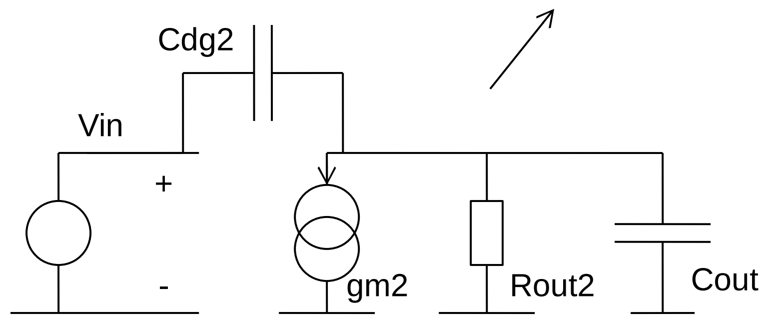
- Zweistufiger Verstärker



- Zweistufiger Verstärker

Vout = - gm2 Rout2 (1 – s Cdg2/gm2) Vin /(1 + s Rout2 Cout)

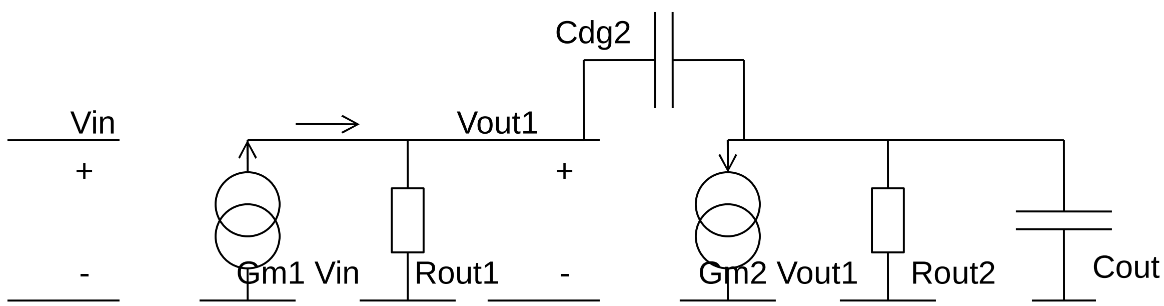
Vorlesung 9



!=

Vout = ?

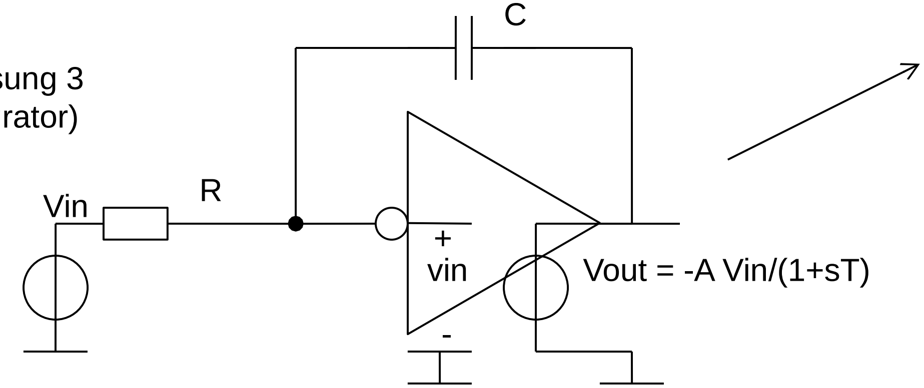
Vorlesung 10



Verstärker mit CS-Ausgangsstufe

- Zweistufiger Verstärker

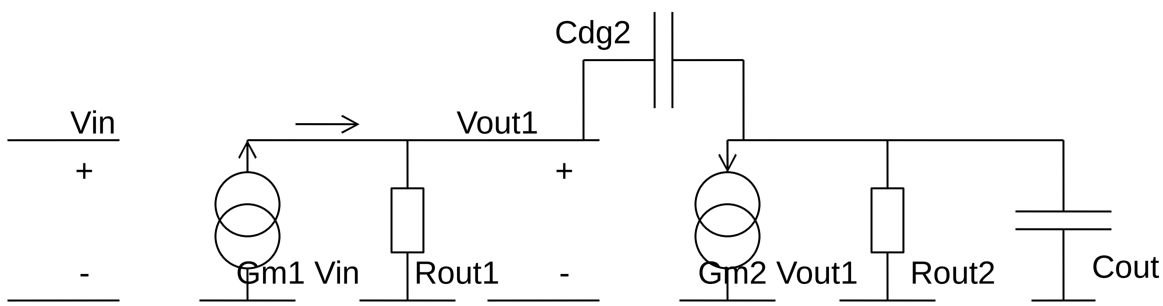
Vorlesung 3
(Integrator)



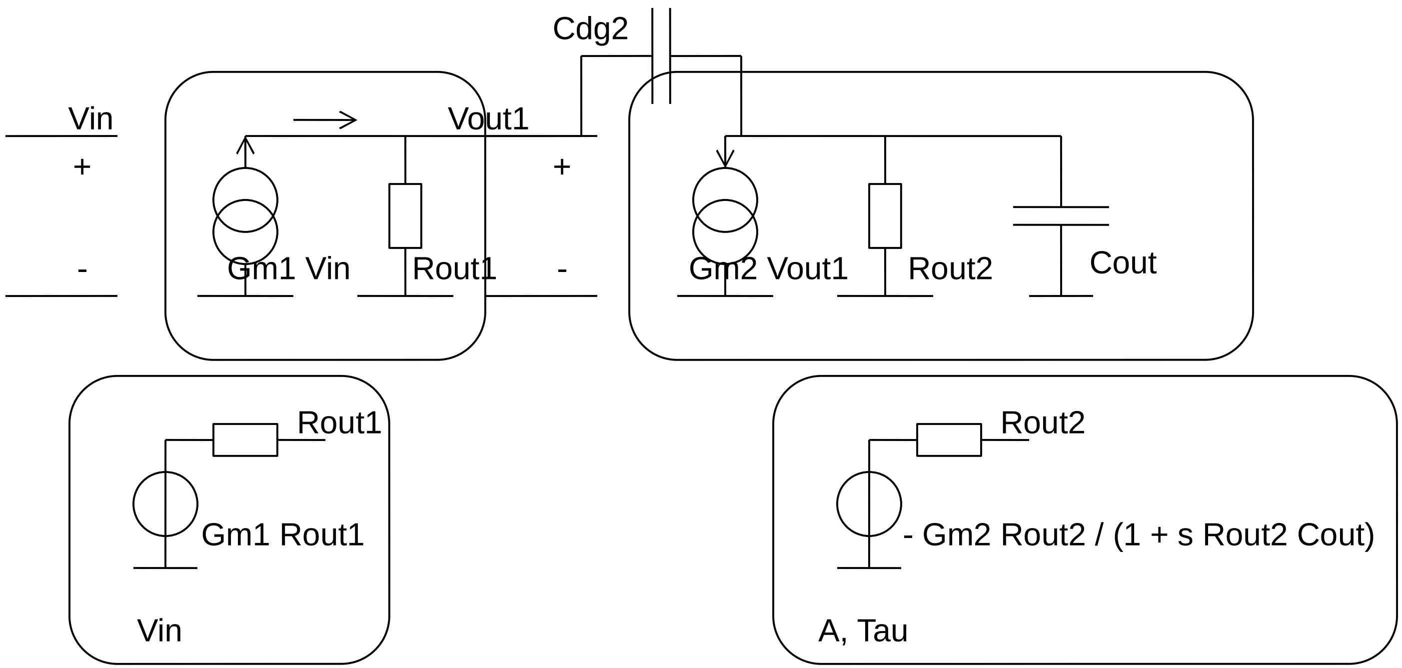
Vout = -A/(1 + s ARC)(1 + sT/A) Vin

Vout = ?

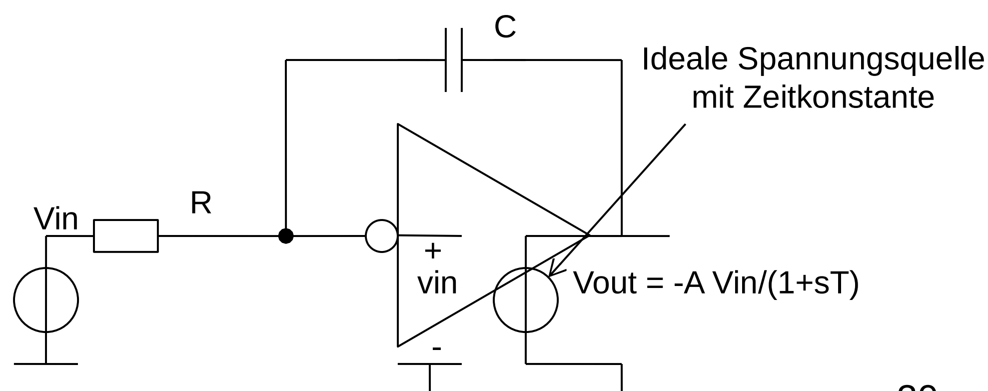
Vorlesung 10



- Zweistufiger Verstärker

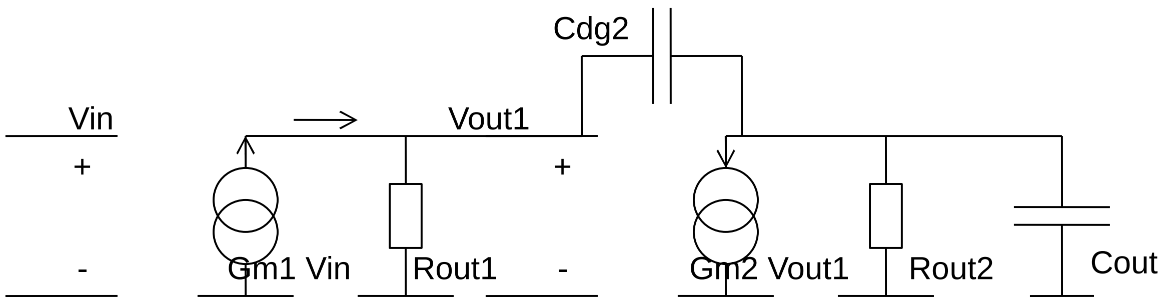


R = Rout1	A = gm2 Rout2
Vin = gm1 Rout1	T = Rout2 Cout
C = Cdg2	



Verstärker mit CS-Ausgangsstufe

- Zweistufiger Verstärker



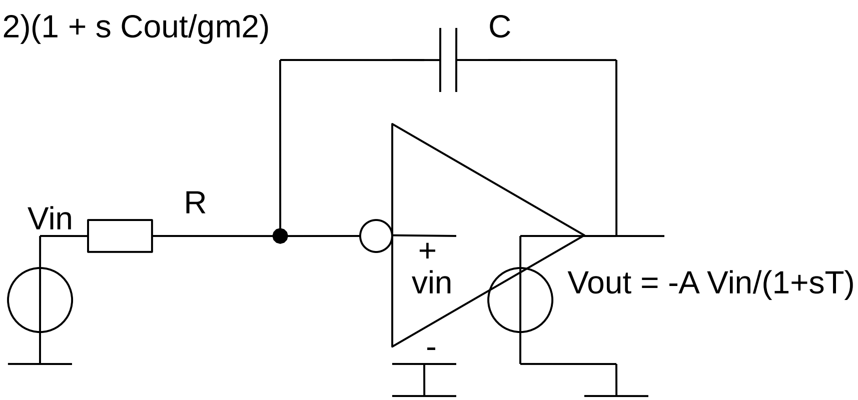
R = Rout1 A = gm2 Rout2

Vin = gm1 Rout1 T = Rout2 Cout

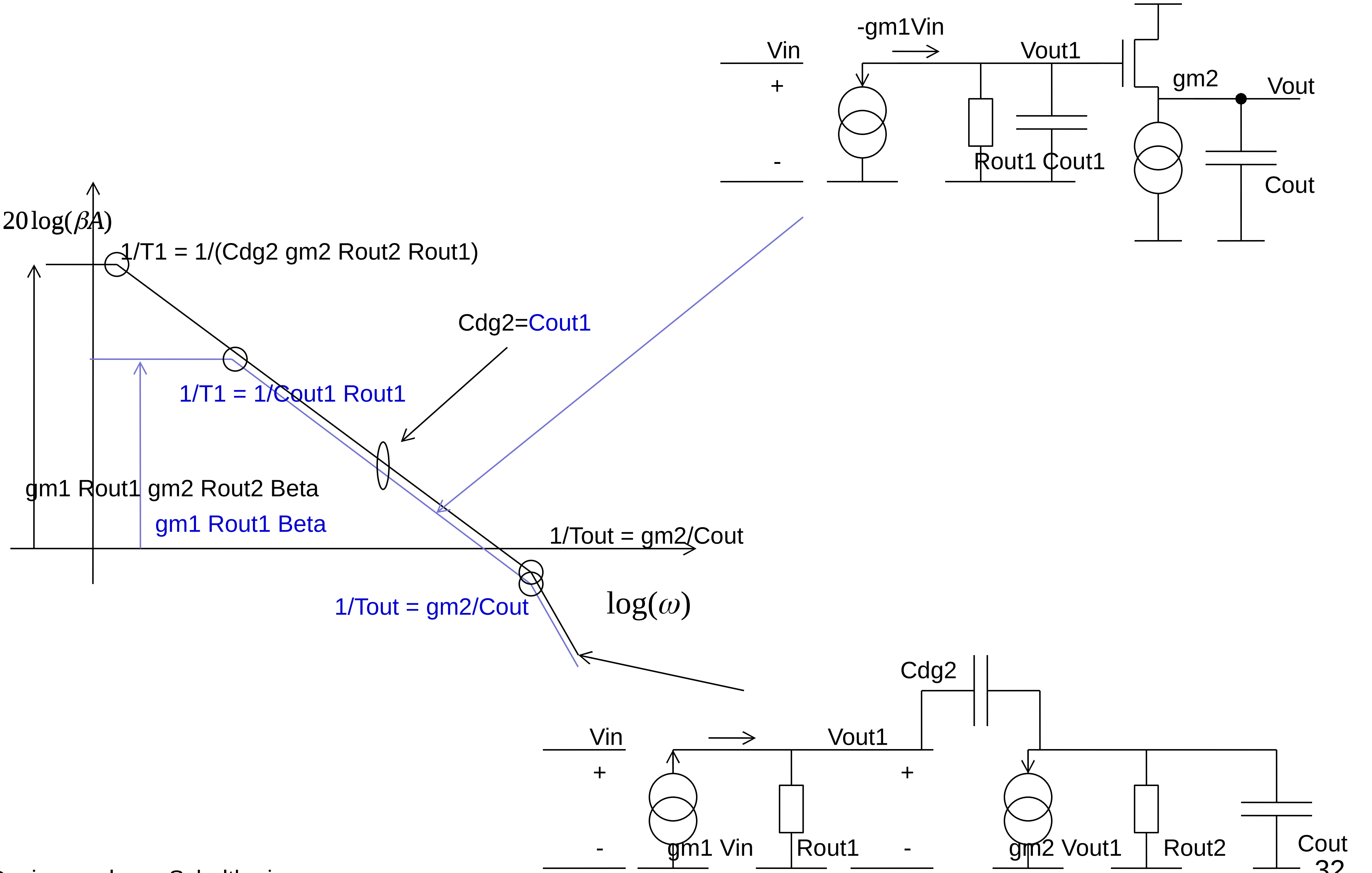
C = Cdg2

Vout = -A/(1 + s ARC)(1 + sT/A) Vin

Vout = - gm1 Rout1 gm2 Rout2/(1 + s Rout1 gm2 Rout2 Cdg2)(1 + s Cout/gm2)

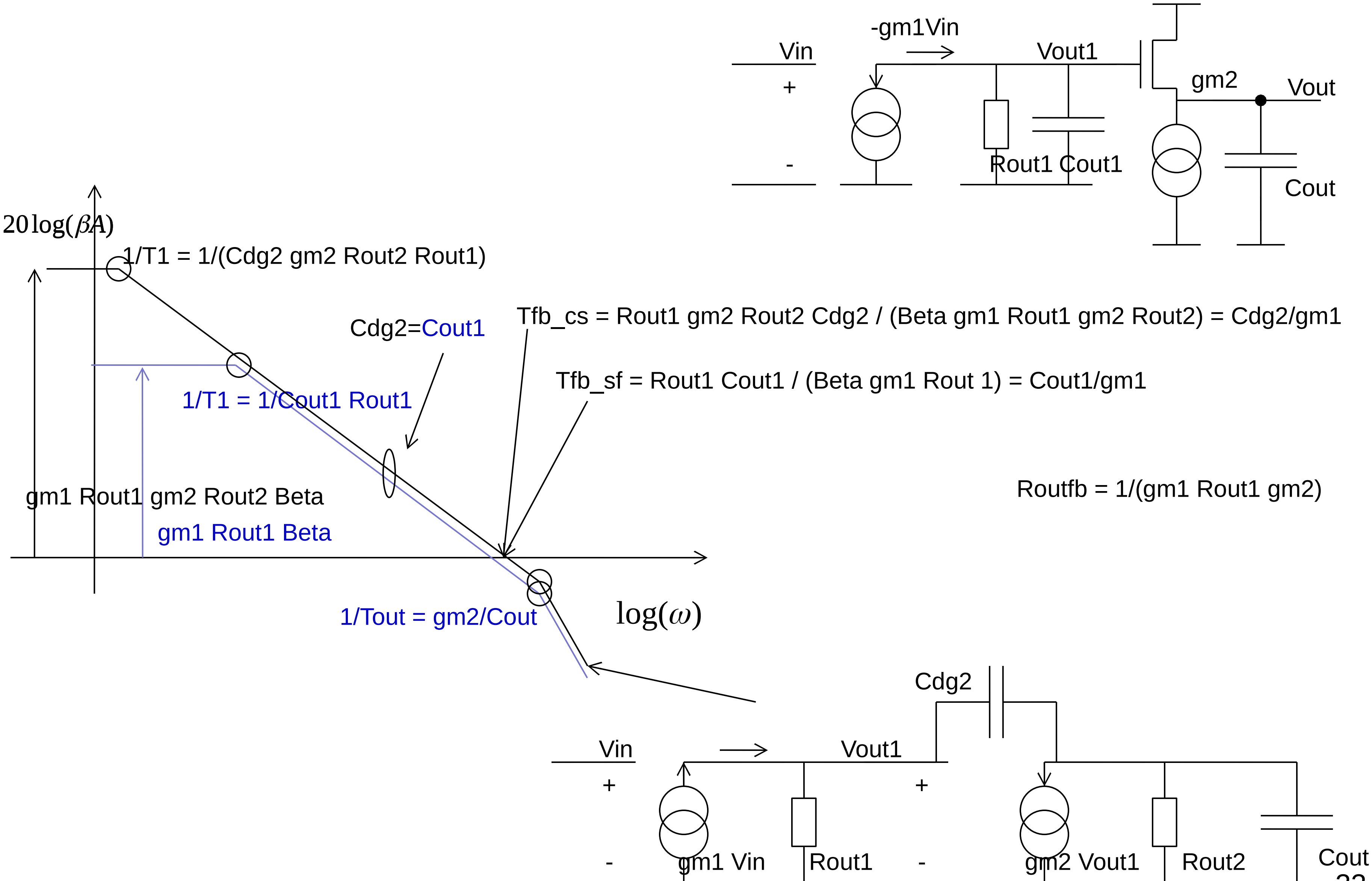


- Vergleich: Sourcefolger, Common-Source

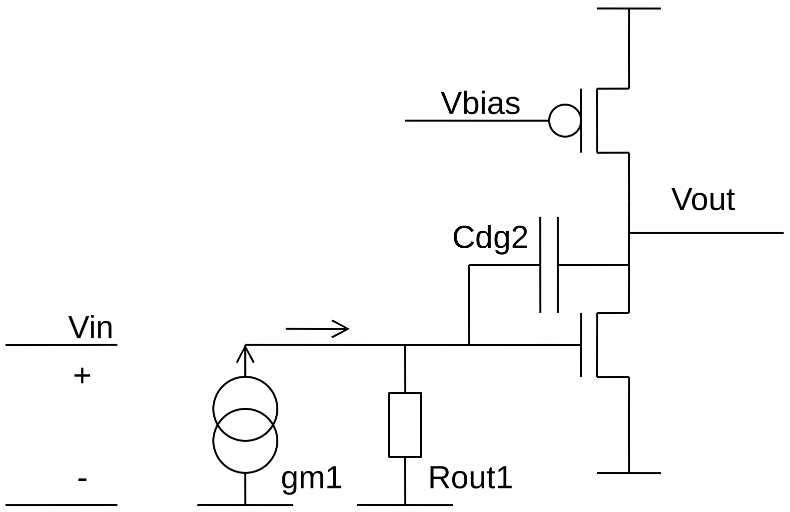


Vergleich: Sourcefolger, Common-Source

- …



- Beide Schaltungen sind stabil und gleich schnell.
- Beide Verstärker haben sehr niedrigen Ausgangswiderstand ~ 1 Ohm.
- Der Verstärker mit der Common-Source Ausgangsstufe hat um Faktor gm2 Rout2 höhere DC Verstärkung. Das ist wichtig wenn wir eine hohe Afb-Verstärkung (Verstärkung mit Gegenkopplung) realisieren wollen – die Linearität ist besser.
- Der Signalbereich am Ausgang ist ebenfalls besser.



Voutmin = Vdssat_2

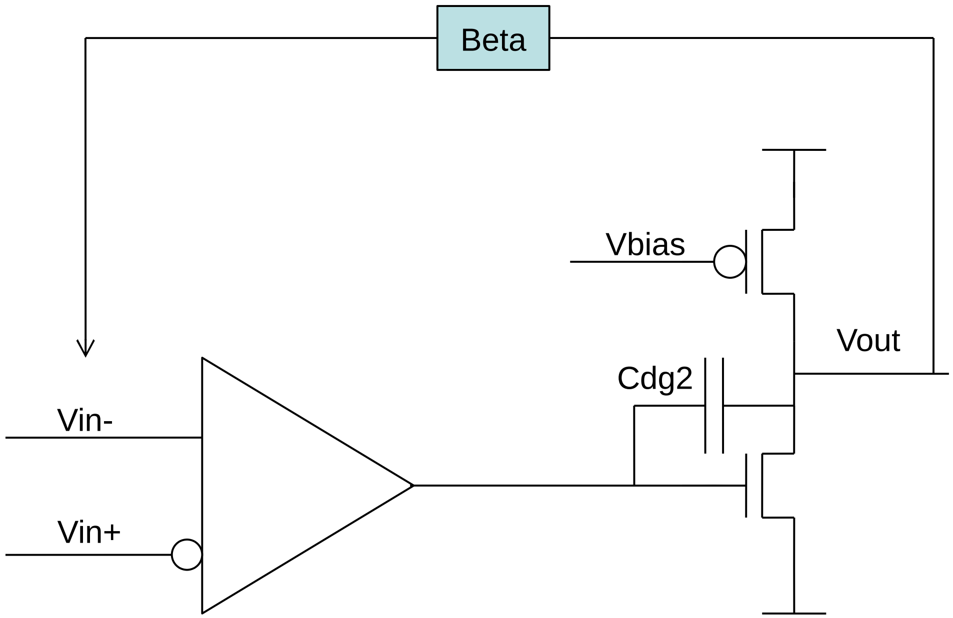
Voutmax = VDD – Vdssat_source2

65nm Technologie

Voutmin = 100mV

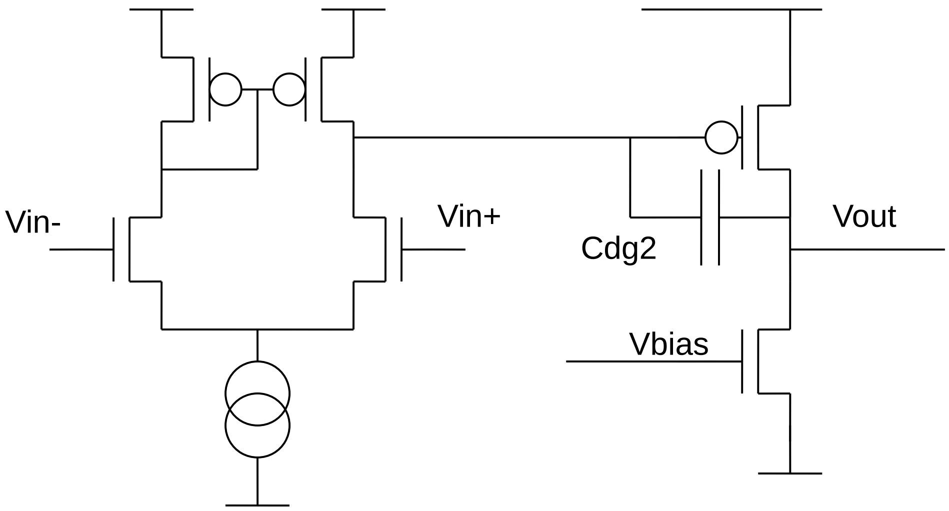
Voutmax = 1.2 – 100mV = 1.1V

- Nachteil:
- Um eine Gegenkopplung zu realisieren muss entweder die erste Stufe eine positive Verstärkung haben, oder das Netzwerk für Rückkopplung eine negative Verstärkung

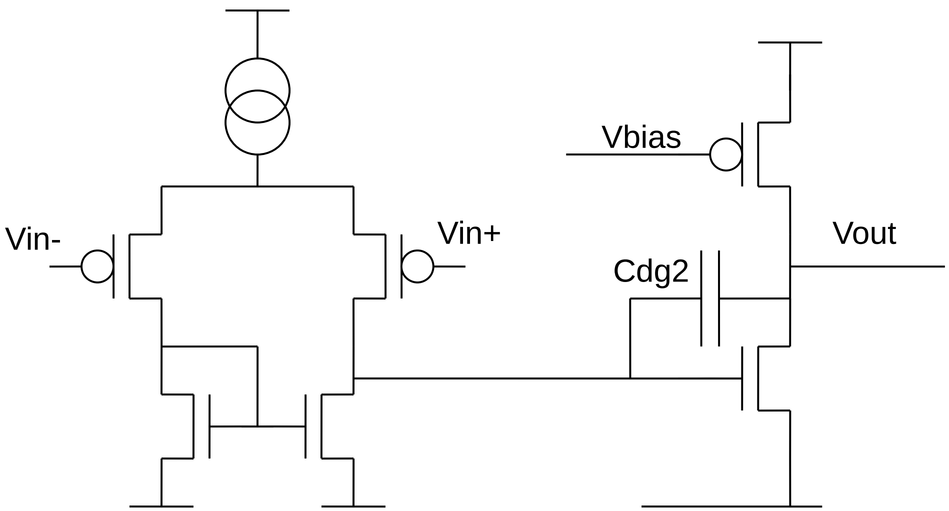


Verstärker mit CS-Ausgangsstufe

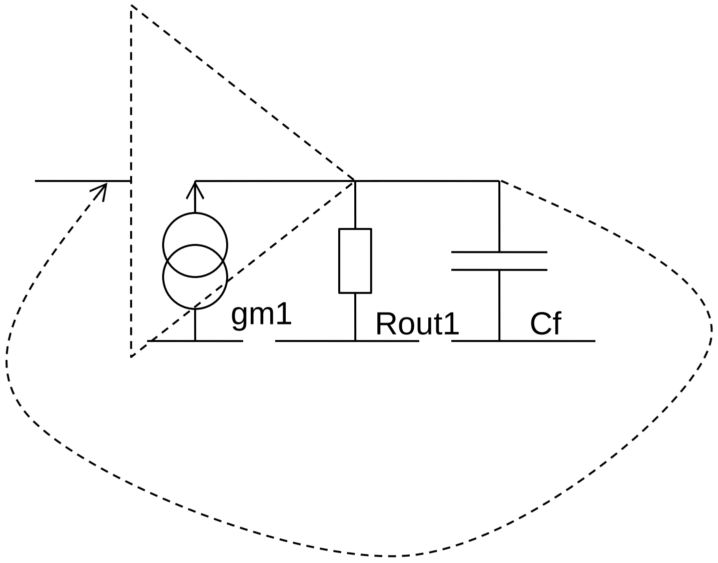
- Realisierung mit einem Differenzverstärker als 1. Stufe
- NMOS Variante

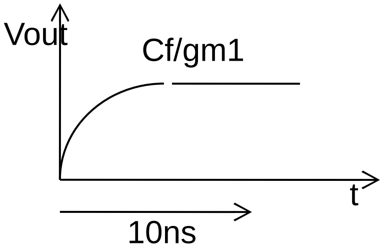


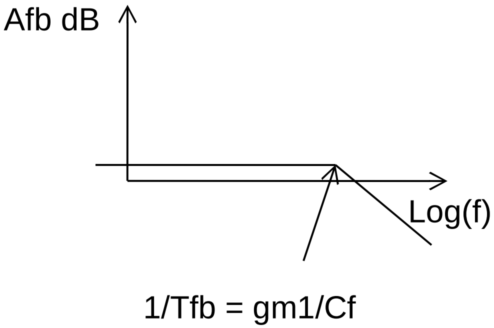
- Realisierung mit einem Differenzverstärker als 1. Stufe
- PMOS Variante



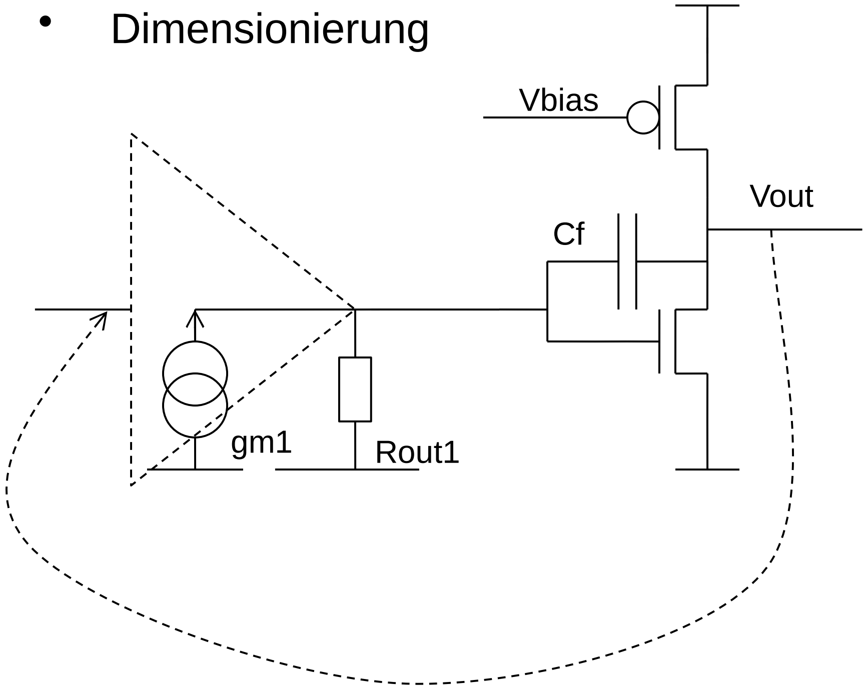
- Dimensionierung

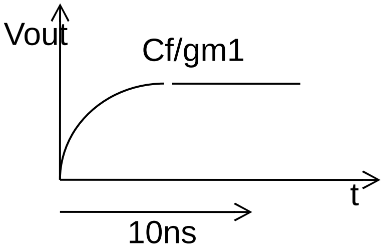


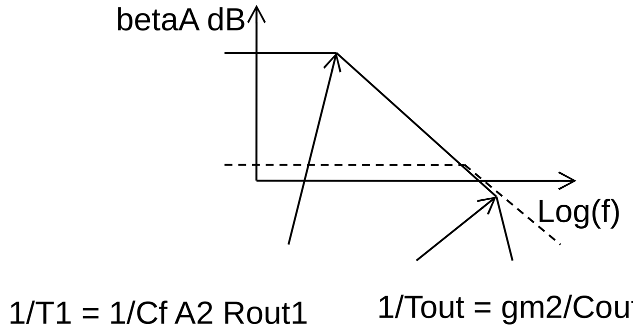




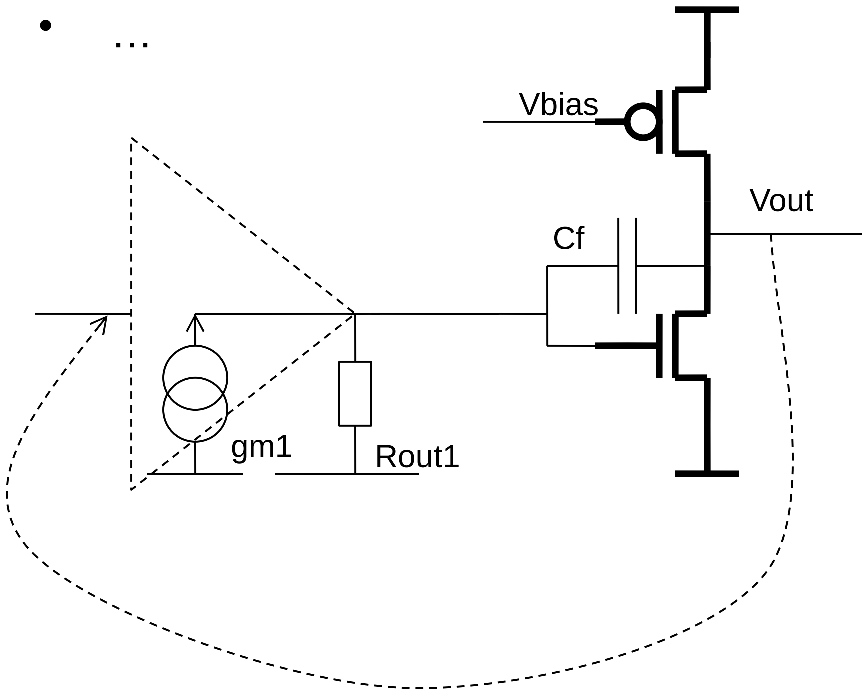
- Dimensionierung

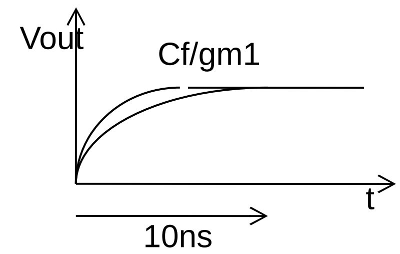


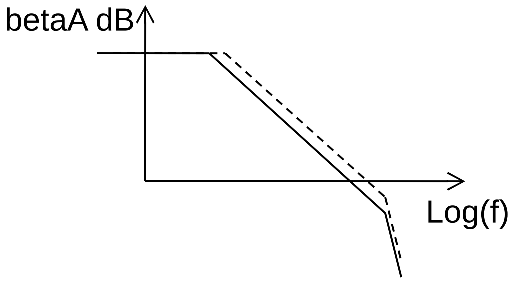




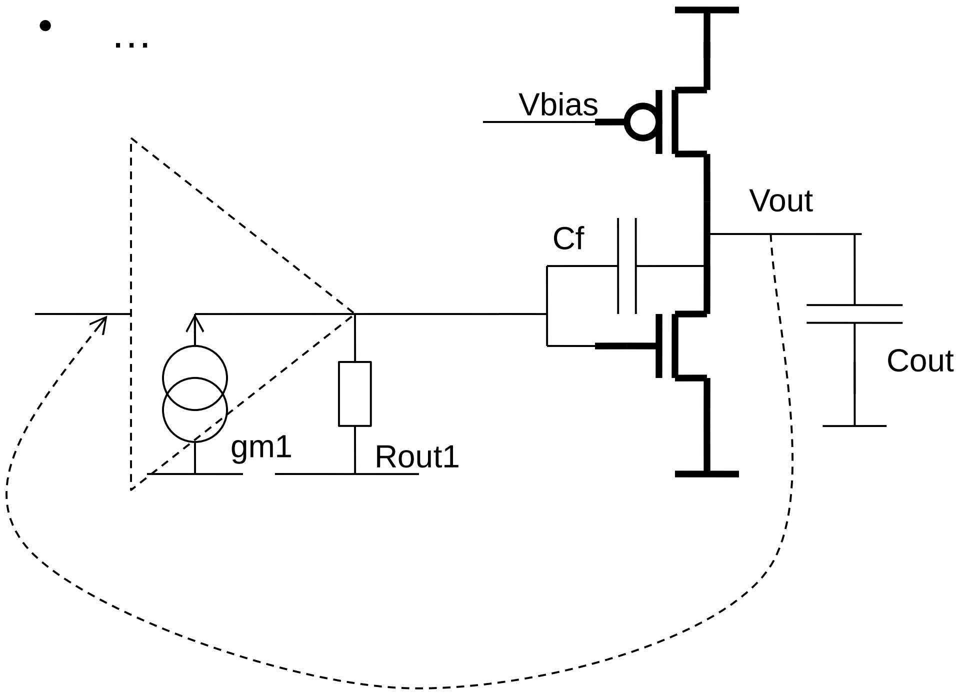
- …

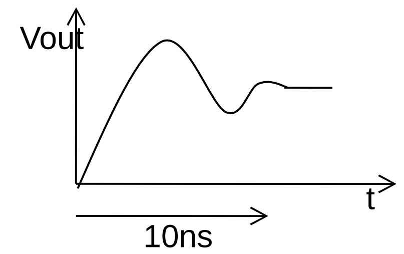

Vbias
Vout
Cf
gm1
Rout1

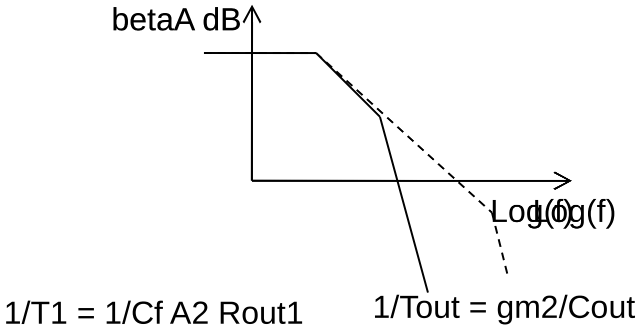

Vout
Cf/gm1
t
10ns


betaA dB
Log(f)
1/T1 = 1/Cf A2 Rout1
1/Tout = gm2/Cout

- …


Vbias
Vout
Cf
Cout
gm1
Rout1


Vout
t
10ns


betaA dB
Log(f)
1/T1 = 1/Cf A2 Rout1
1/Tout = gm2/Cout

Verstärker mit CS-Ausgangsstufe

- …