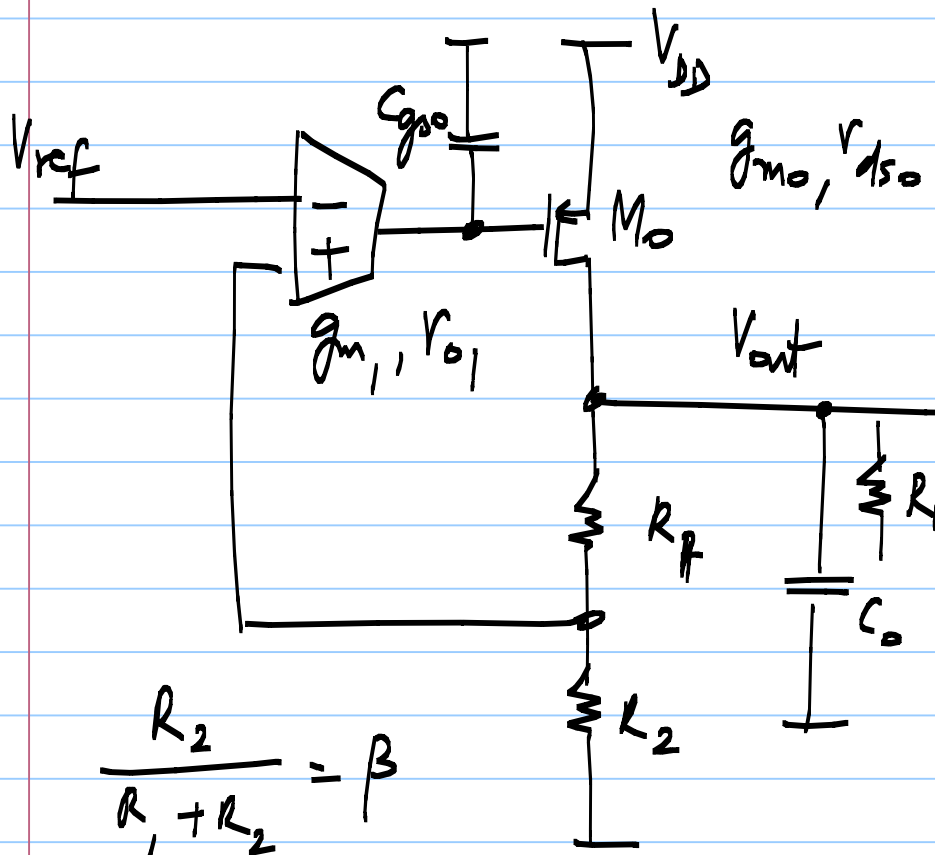
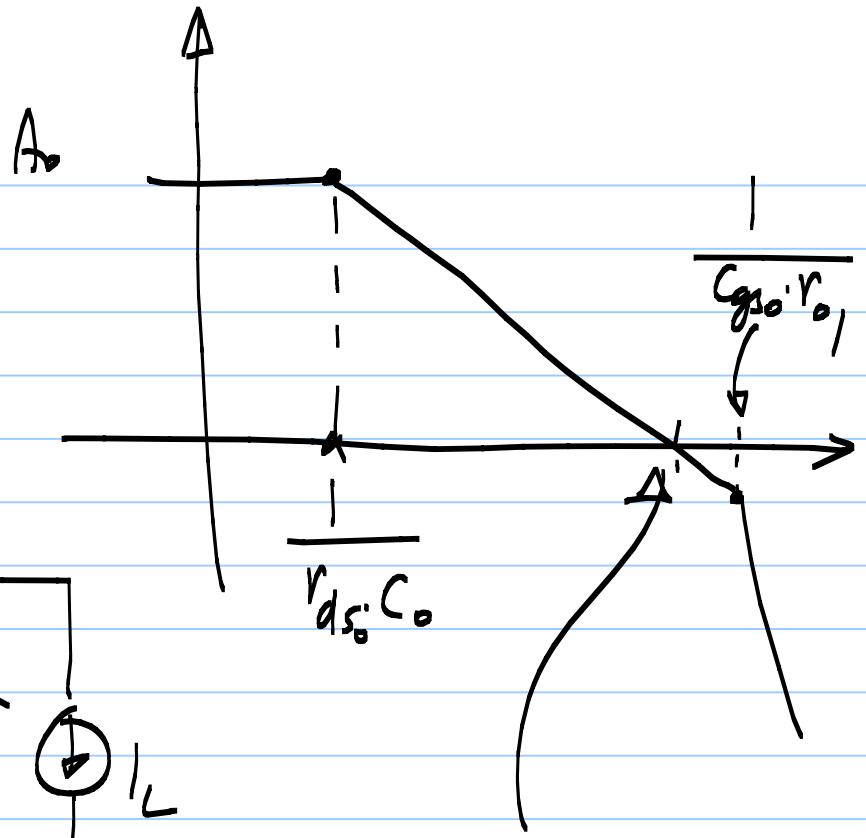
Voltage regulators:



$$\frac{R_2}{R_1 + R_2} = \beta$$



$$\omega_{u,loop} = g_{m1} r_{o1} \cdot g_{m0} r_{ds0} \cdot \beta = \frac{1}{r_{ds0} \cdot C_0}$$

For good phase margin

$$p_2 > \omega_{u,loop}$$

$$\frac{1}{C_{gs0} r_{o1}} > g_{m1} r_{o1} \cdot \frac{g_{m0}}{C_0} \cdot \beta$$

Worst case is @ $I_{L,max}$

$$r_{o1} < \sqrt{\frac{C_0}{C_{gs0}} \cdot \frac{1}{g_{m1} \cdot g_{m0} \cdot \beta}}$$

g_{m0}, r_{ds0} vary widely because of variations in I_L

$$g_{m0} = \sqrt{\frac{2 I_L}{\mu C_{ox} W/L}}$$

$$r_{ds0} = \frac{1}{\lambda I_L}$$

$$A_0 = g_{m1} \cdot r_{o1} \cdot g_{m0} \cdot r_{ds0} \cdot \beta = \rightsquigarrow$$

limited because of the constraint on r_{o1}

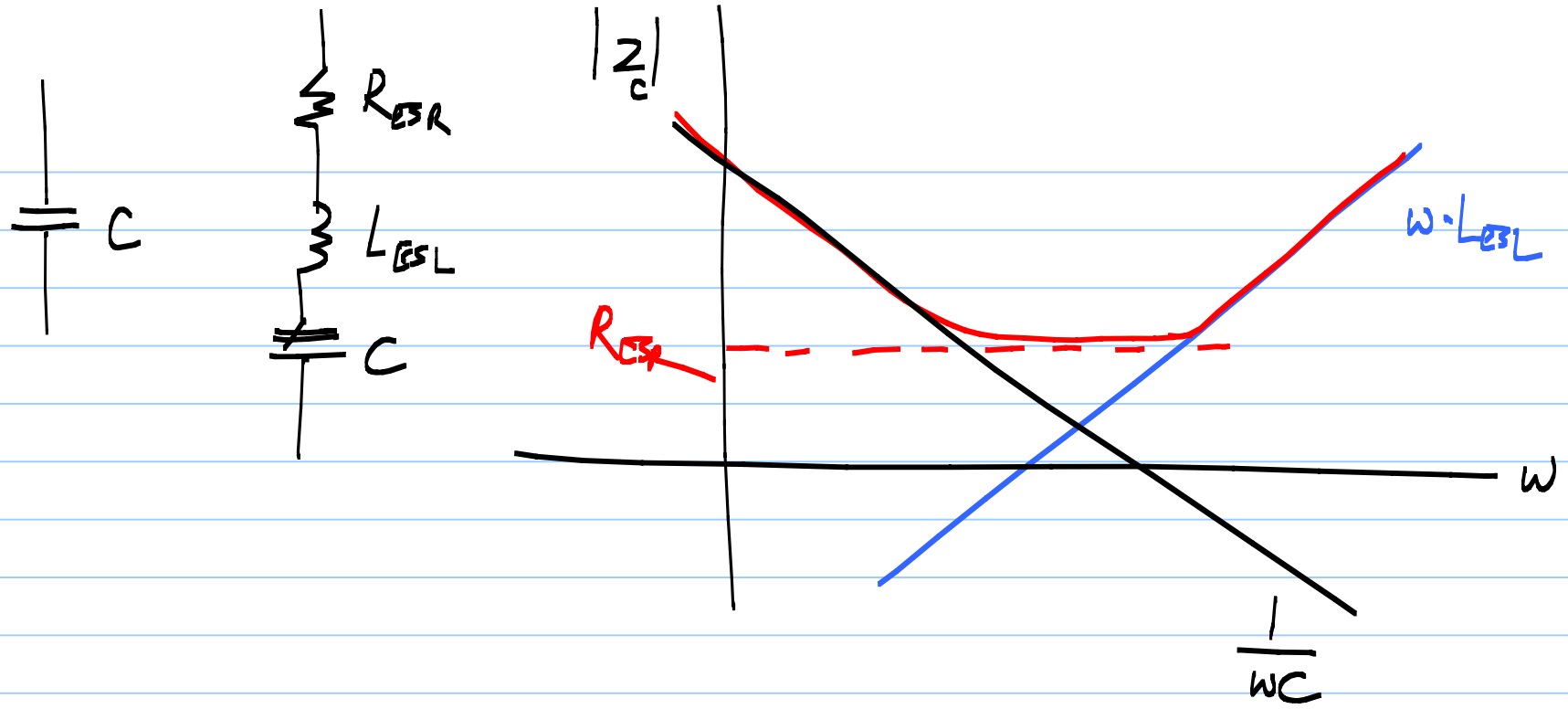
$$A_0 = g_{m_1} r_{o_1} \cdot g_{m_0} \cdot r_{ds_0} \cdot \beta$$

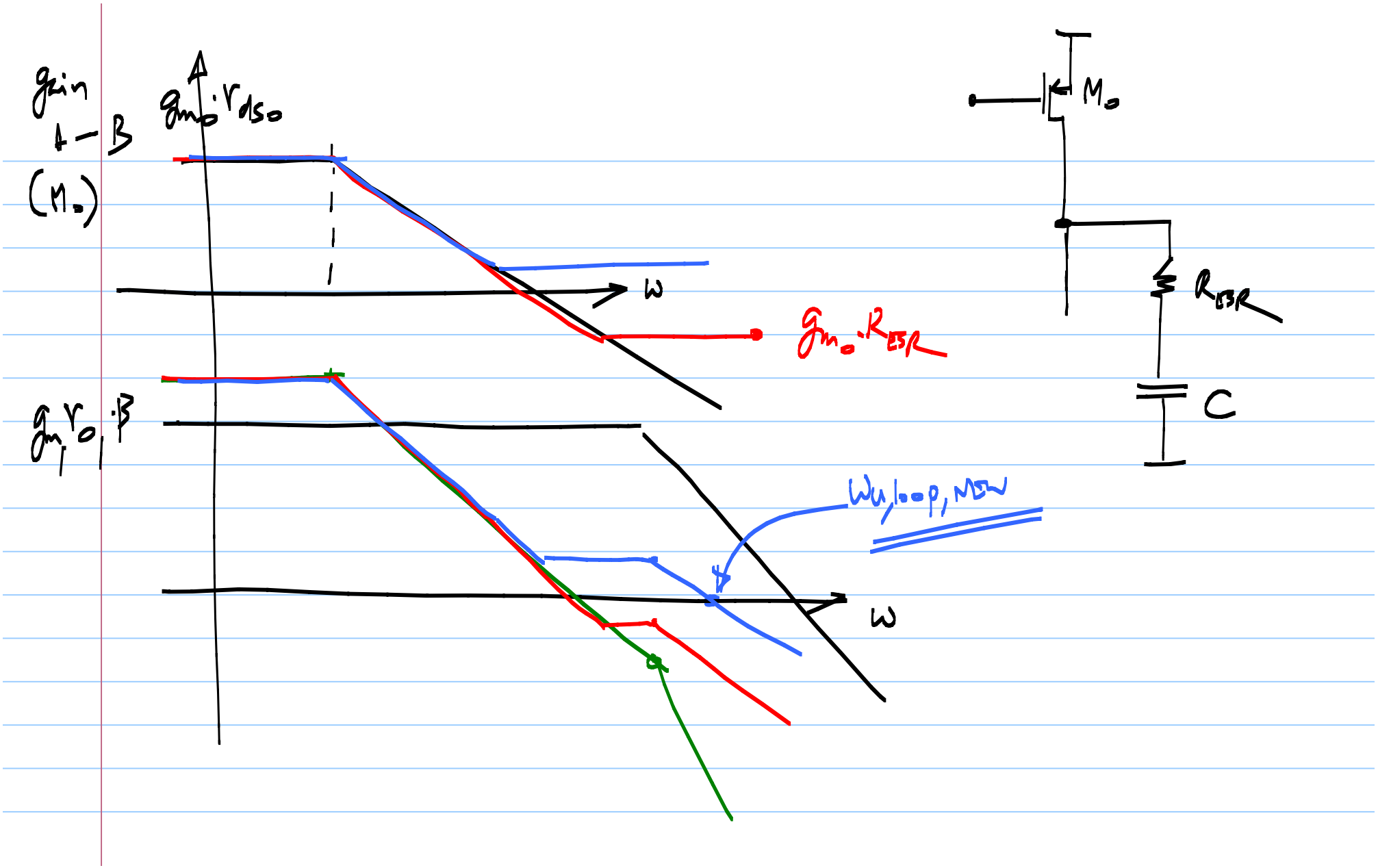
$$= g_{m_1} \sqrt{\frac{C_0}{C_{gs_0}} \frac{1}{g_{m_1} g_{m_0} \beta}} \cdot g_{m_0} \cdot r_{ds_0} \cdot \beta$$

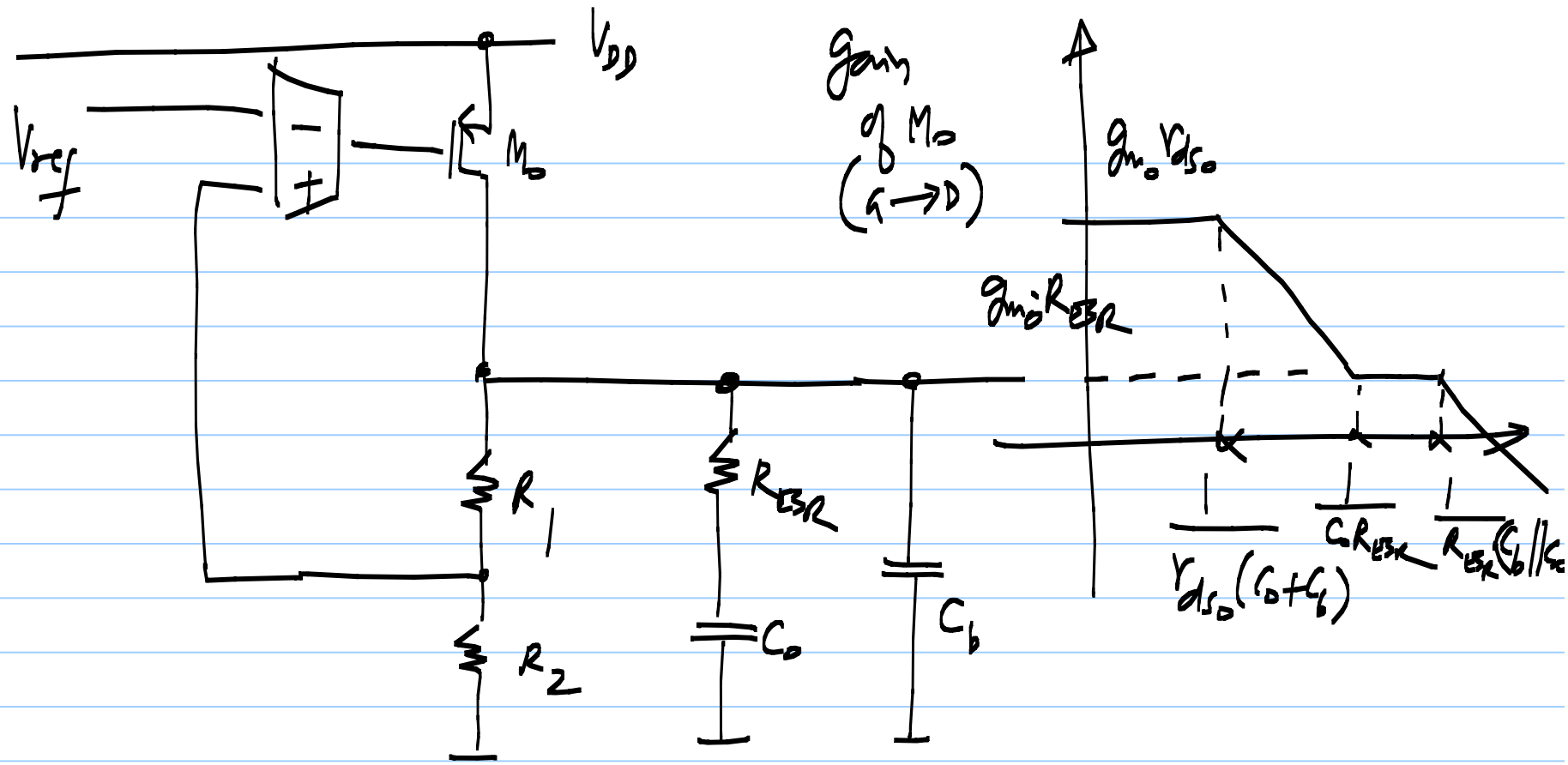
$$= \sqrt{\frac{C_0}{C_{gs_0}}} \cdot \sqrt{g_{m_1} g_{m_0} \beta} \cdot r_{ds_0}$$

* Upper limit on A_0 due to upper limit on r_{o_1} (stability constraint

$\Rightarrow$ $R_{out} = \frac{r_{ds_0}}{1 + A_0}$ cannot be reduced indefinitely.

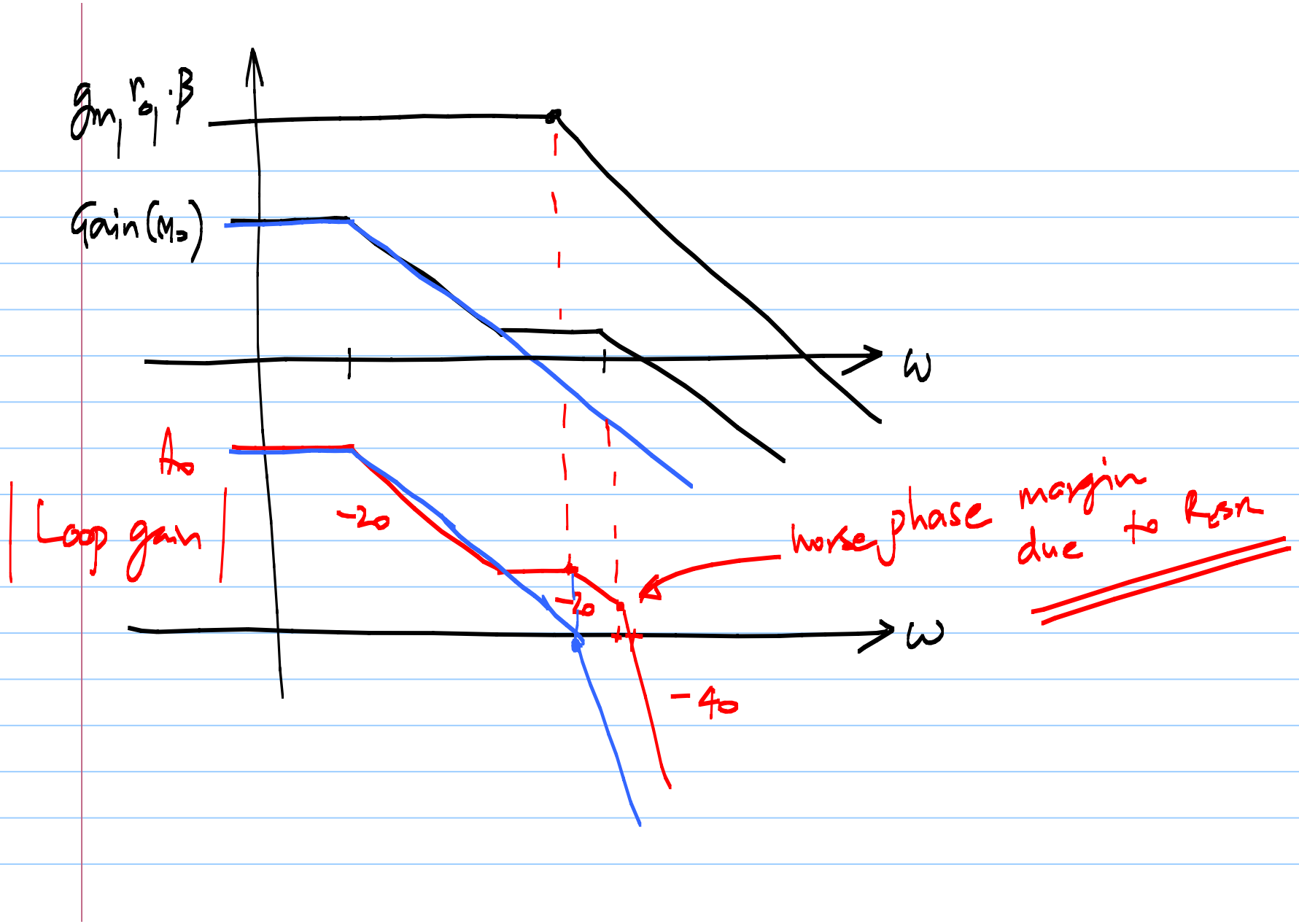

C
R_{ESR}
L_{ESL}
C
$|Z_C|$
R_{ESR}
$\omega \cdot L_{ESL}$
ω
$\frac{1}{\omega C}$

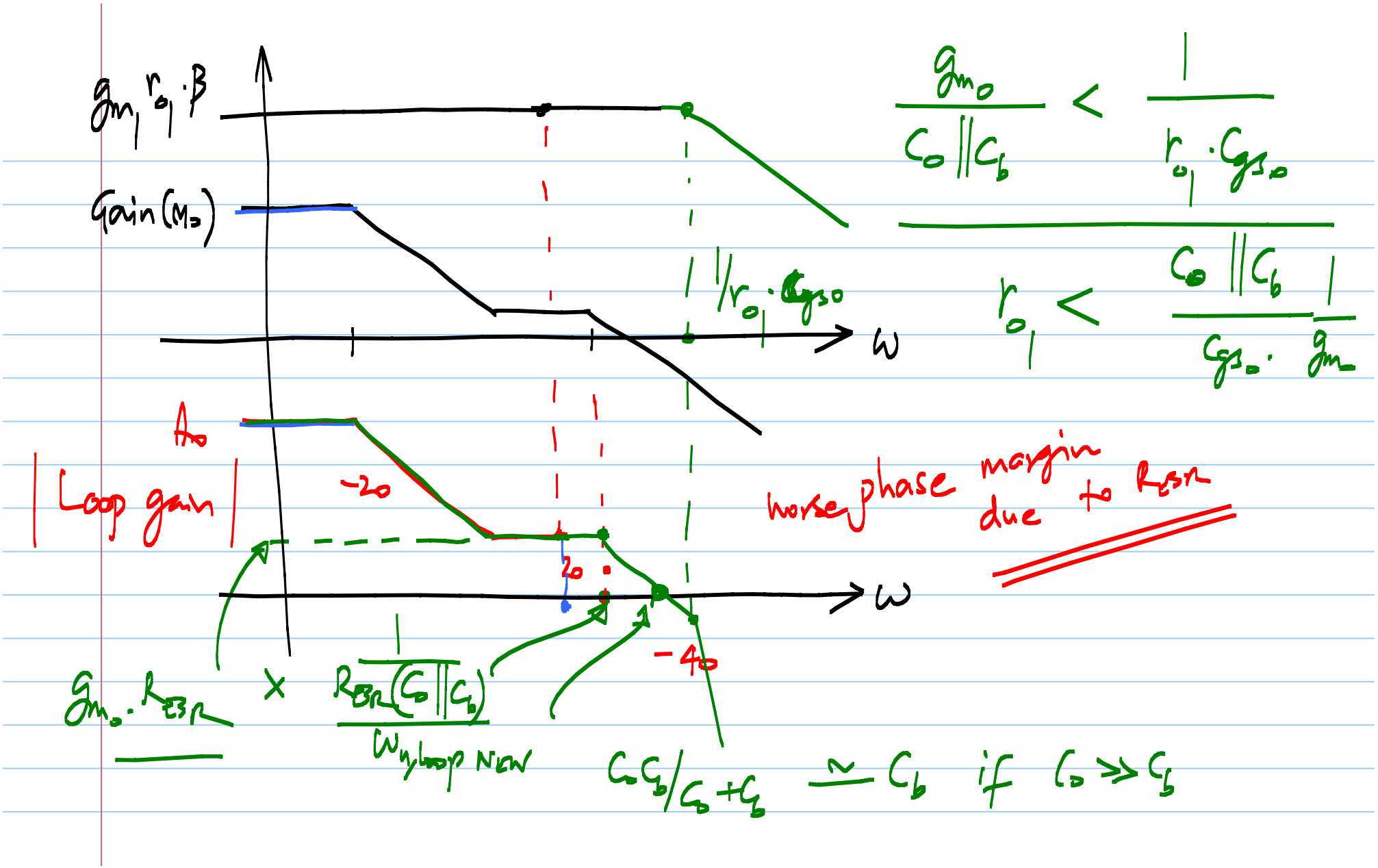

g_{in}
A − B
(M_o)
$g_{mb} \cdot r_{dso}$
ω
$g_{mo} \cdot R_{ESR}$
$g_m r_o \beta$
$\omega_{u,loop,MSW}$
ω
M_o
R_{ESR}
C

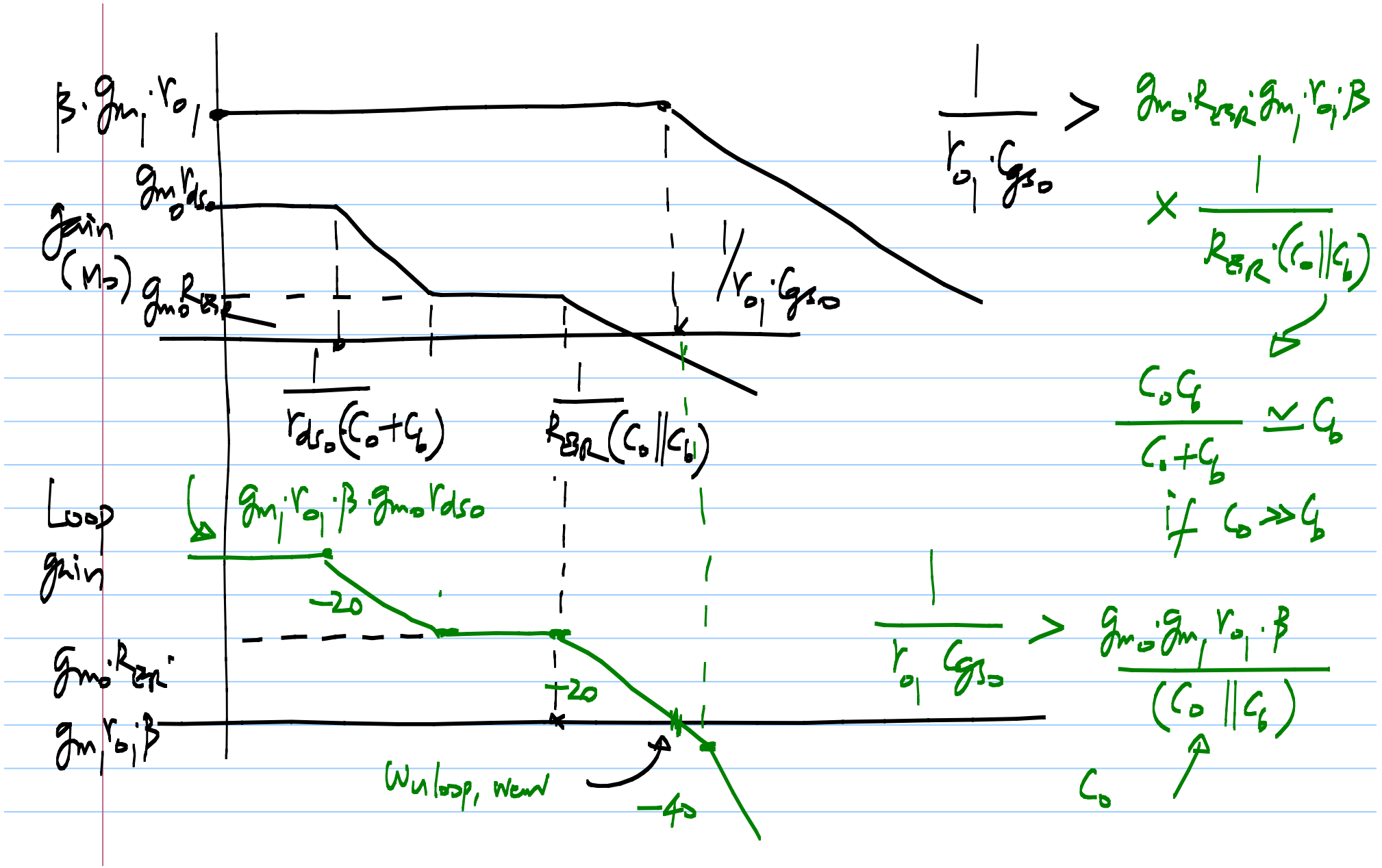


C_b : smaller than C_0

→ physically smaller — smaller ESR


$g_{m_1} r_{o_1} \cdot \beta$
Gain (M_2)
ω
A_0
| Loop gain |
-20
-40
ω
worse phase margin
due to R_{SR}


$g_{m_1} r_{o_1} \cdot \beta$
Gain (M_2)
ω
$\| r_{o_1} \cdot C_{gs_2}$
A_0
-20
Loop gain
ω
20°
-40
$g_{m_2} \cdot R_{ESR}$
$\times$
$\frac{R_{ESR}(C_b \| C_b)}{\omega_{yloop\ NEW}}$
worse phase margin due to R_{ESR}
$C_b C_b / C_b + C_b \simeq C_b$ if $C_b \gg C_b$
$\frac{g_{m_2}}{C_b \| C_b} < \frac{1}{r_{o_1} \cdot C_{gs_2}}$
$r_{o_1} < \frac{C_b \| C_b}{C_{gs_2} \cdot g_{m_2}}$


$\beta \cdot g_{m_1} \cdot r_{o_1}$
$g_{m_0} r_{ds_0}$
gain (M3)
$g_{m_0} R_{EQR}$
$r_{ds_0}(C_0 + C_b)$
$R_{EQR}(C_0 \| C_b)$
$1/r_{o_1} \cdot C_{gs_0}$
Loop gain
$g_{m_1} \cdot r_{o_1} \cdot \beta \cdot g_{m_0} r_{ds_0}$
-20
$g_{m_0} \cdot R_{EQR} \cdot g_{m_1} r_{o_1} \beta$
+20
$\omega_{u\,loop,\,new}$
-40
$\frac{1}{r_{o_1} \cdot C_{gs_0}} > \frac{g_{m_0} \cdot R_{EQR} \cdot g_{m_1} \cdot r_{o_1} \cdot \beta}{R_{EQR} \cdot (C_0 \| C_b)}$
$\frac{C_0 C_b}{C_0 + C_b} \simeq C_b$ if $C_0 \gg C_b$
$\frac{1}{r_{o_1} C_{gs_0}} > \frac{g_{m_0} \cdot g_{m_1} r_{o_1} \cdot \beta}{(C_0 \| C_b)}$
C_0

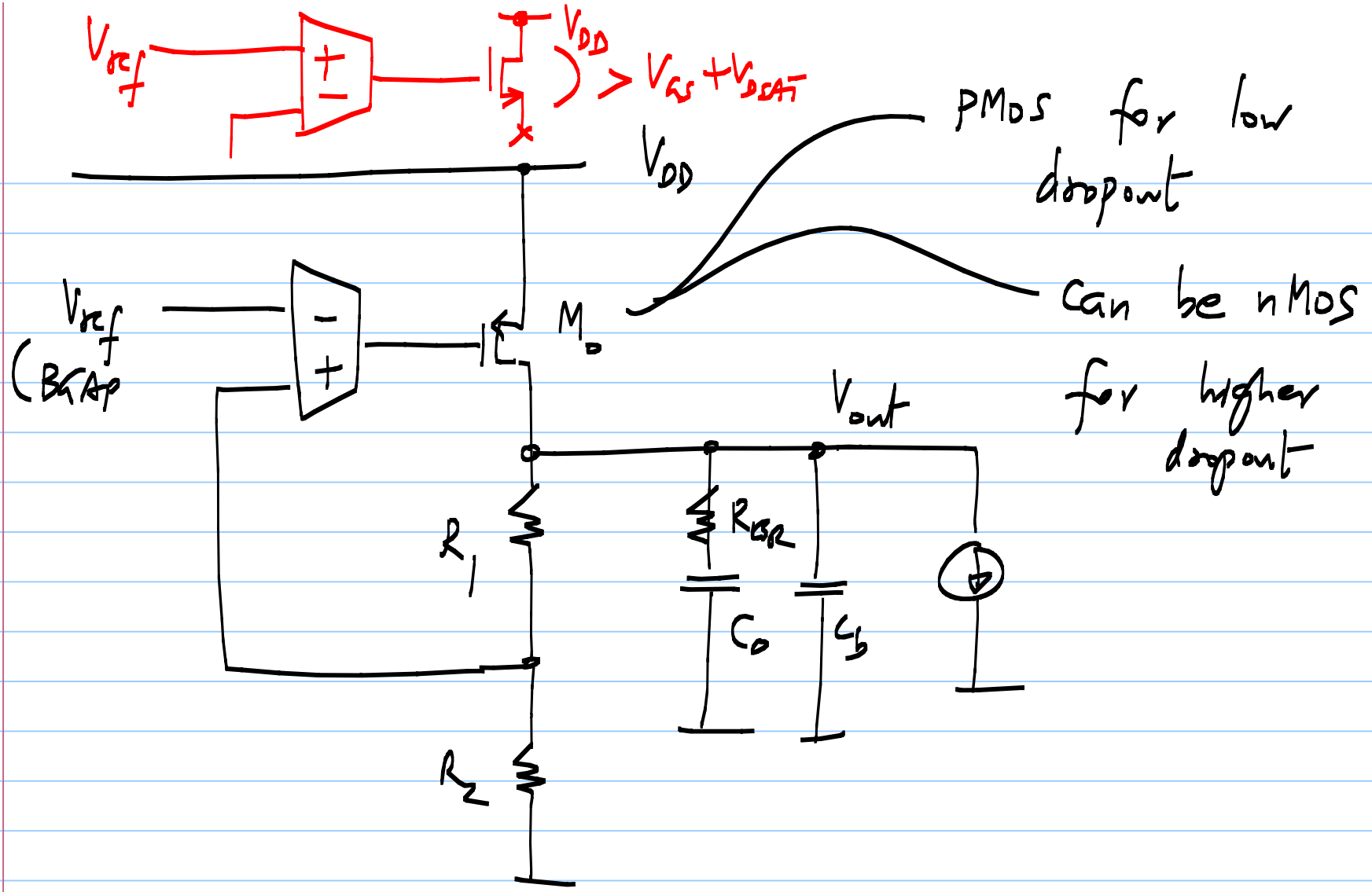
$$r_{o_1} < \sqrt{\frac{C_0 \| C_0}{C_{gs_0}} \cdot g_{m_1} g_{m_0} \cdot \beta}$$

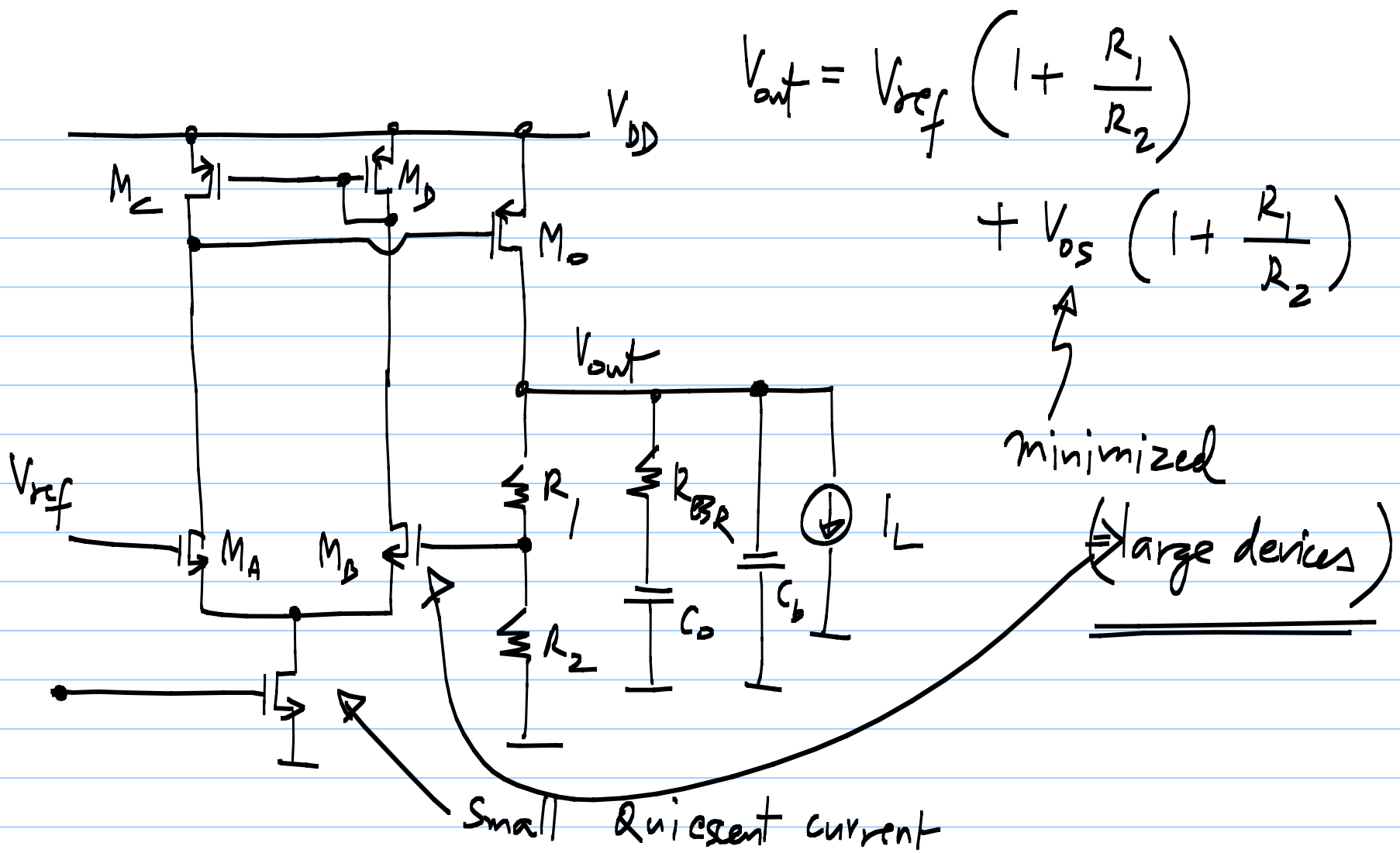
new limit

$$r_{o_1} < \sqrt{\frac{C_0}{C_{gs_0}} \cdot g_{m_1} g_{m_0} \cdot \beta}$$

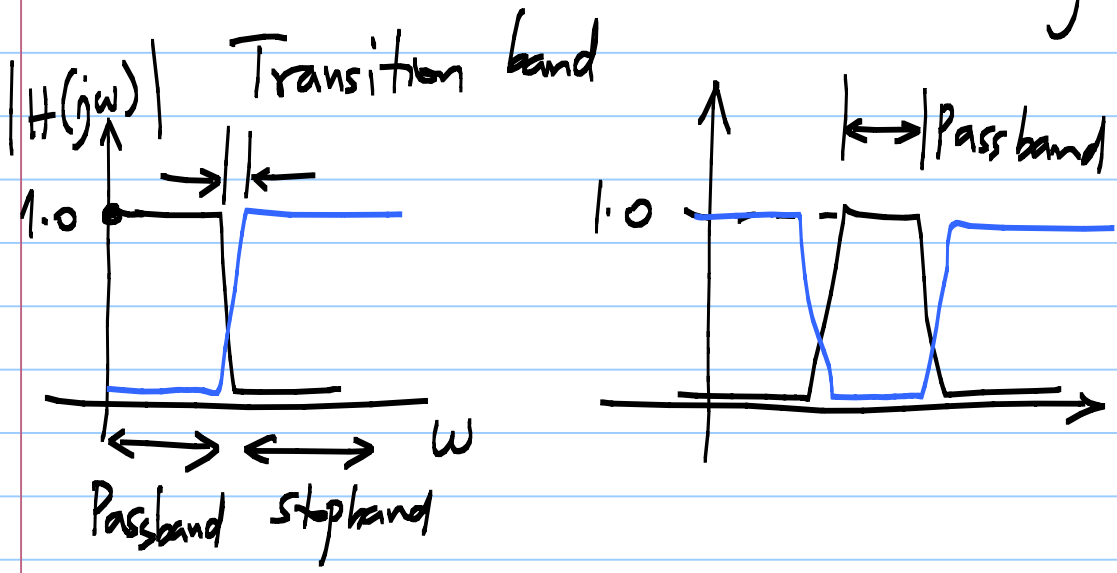
old limit >

* Constraint on r_{o_1} due to stability
* $\Rightarrow$ Constraint on dc loop gain & R_{out} (load regulation)


V_{ref}
V_{DD}
$V_{DD} > V_{GS} + V_{DSAT}$
PMOS for low dropout
V_{DD}
V_{ref} (BGR)
M_0
Can be nMOS for higher dropout
V_{out}
R_1
R_{ESR}
C_0
C_b
R_2


$V_{out} = V_{ref}\left(1 + \frac{R_1}{R_2}\right) + V_{os}\left(1 + \frac{R_1}{R_2}\right)$
minimized
(large devices)
V_{DD}
M_C
M_D
M_O
V_{out}
V_{ref}
M_A
M_B
R_1
R_{BR}
I_L
C_O
C_b
R_2
Small Quiescent current

Continuous time filters – selecting certain frequencies rejecting other frequencies



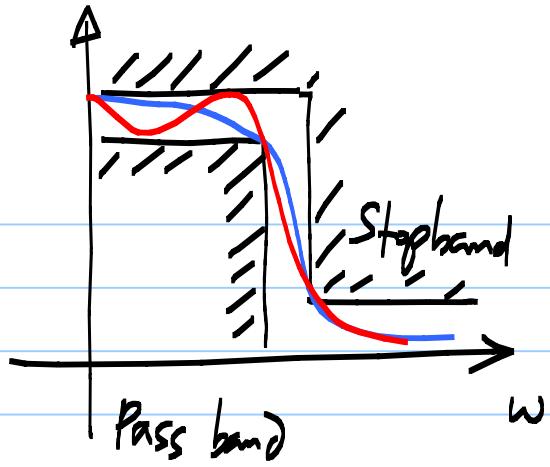
Low pass filter

High pass filter

Bandpass filter

Bandstop (Band reject) filters.

Filter design:



* choosing the type & order from specifications

MatLab Filter tables

Zverev

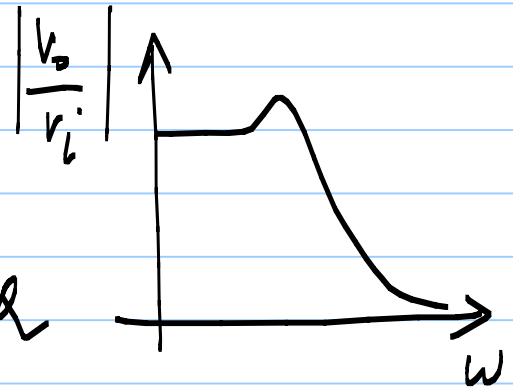
- transfer function H(s)
  - Passive
    - R, L, C
  - Active
    - active + L, C
    - active C
- Passive prototype
  - Butterworth
  - Chebyshev
  - Inv. Chebyshev
  - Elliptic
  - Bessel
- Given

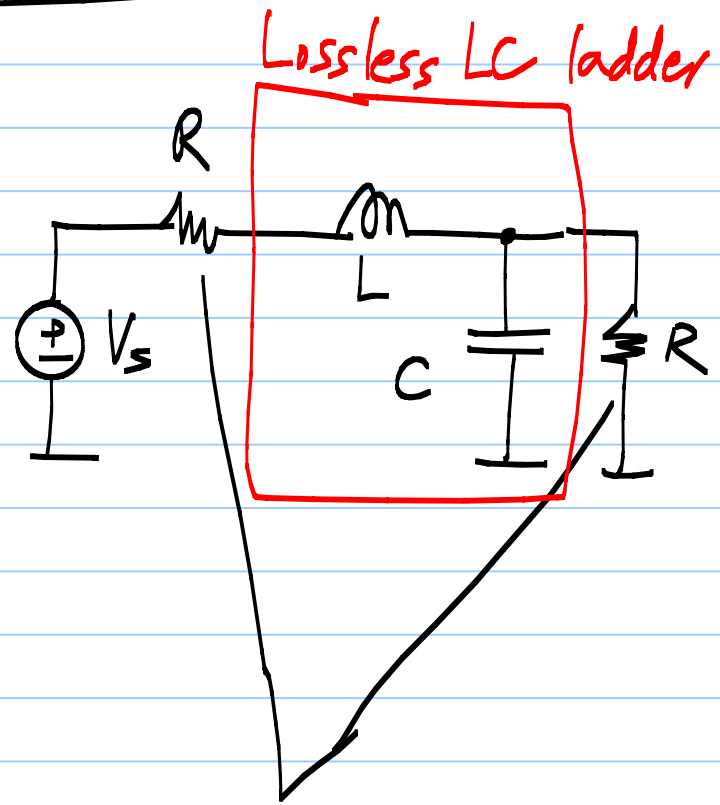
Given a second order transfer function & prototype:

(Low pass)

$$\frac{V_{out}(s)}{V_i(s)} = \frac{1}{\frac{s^2}{\omega_p^2} + \frac{s}{Q\omega_p} + 1}$$

- dc gain : 1
- nat. freq : ω_p
- Quality factor : Q





Doubly terminated

Ladder prototype