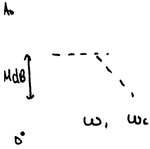
Notes 04-12-10

COMPENSATION

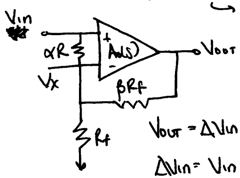
Reduced Gain.

New gain = $(A_0 - M)$ dB New unity gain freq = ω_c

Reduced gain ⇒ Lower DC gain & lower bandwidth



Want P.M. of 50°
↪ phase margin



$V_{OUT} = \Delta V_{in} A_0(s)$

$\Delta V_{in} = V_{in} - V_x$

-originally 0° P.M, changed to approximately 60-70° PM

$$\frac{V_{in}-V_x}{\alpha R} - \frac{V_x}{R_f} - \frac{V_x - V_{OUT}}{\beta R_f} = 0$$

$$x\left[\frac{1}{\alpha R} + \frac{1}{R_f} + \frac{1}{\beta R_f}\right] = \frac{V_{in}}{\alpha R} + \frac{V_{OUT}}{\beta R_f}$$

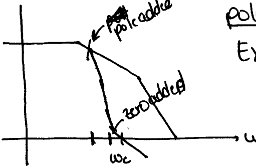
$$V_{in} - \underbrace{\frac{V_{OUT}}{A_0(s)}}_{\Delta V_{in}}\Big)\left[\frac{1}{\alpha R} + \frac{1}{R_f} + \frac{1}{\beta R_f}\right] = \frac{V_{in}}{\alpha R} + \frac{V_{OUT}}{\beta R_f}$$

-Amount of input applied is smaller than original → reducing original gain

$$\left(V_{in} - \frac{V_{OUT}}{A_0(s)}\right)\left[\frac{1}{\alpha R \| R_f \| \beta R_f}\right] = \frac{V_{in}}{\alpha R} + \frac{V_{OUT}}{\beta R_f}$$

$$V_{in}\left[\frac{1}{\alpha R \| R_f \| \beta R_f} - \frac{1}{\alpha R}\right] = V_{OUT}\left[\frac{1}{A_0(s)(\alpha R \| R_f \| \beta R_f)} + \frac{1}{\beta R_f}\right]$$

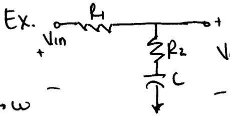
-Is there a way to compensate without killing the gain? (keep unity gain frequency at ω_c)



pole followed by a zero

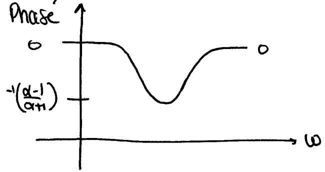
$$\frac{R_2 + 1/sC}{R_1 + R_2 + 1/sC}$$

Ex.

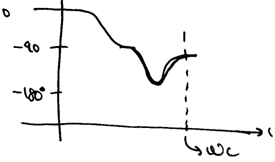


$$\boxed{= \frac{1 + sR_2C}{1 + s(R_1+R_2)C}}$$

Generic TF: $\boxed{\dfrac{V_{out}}{V_{in}} = \dfrac{\tau s + 1}{\alpha \tau s + 1}}$

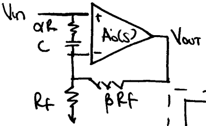


Original system φ



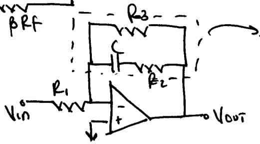
Op amp example

Compensation called <u>LAG</u> compensation



- can live with reduced bandwidth in certain applications

Example:



$$Z_{fb} = R_3 \| R_2 + 1/sC$$

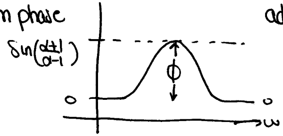
$$= \frac{1 + sR_2R_3C}{1 + s(R_2 + R_3)C}$$

$$\frac{V_{out}}{V_{in}} = \frac{Z_{fb}}{R_1} = \frac{1 + sR_2R_3C}{R_1(1 + s(R_2+R_3)C)} = a_0\left[\frac{\tau s + 1}{\alpha \tau s + 1}\right]$$

If $R_2 = 0 \rightarrow$ proportional integral controller (P.I. controller)

Another option? Kill gain, keep bandwidth

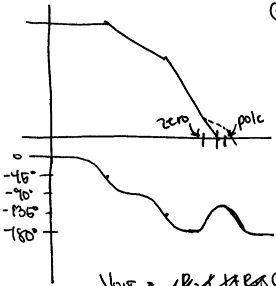
System phase



added φ at crossover to get desired phase margin

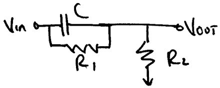
- still want to keep original unity gain frequency ω_0

- Instead add zero first, pole second



Generic TF $= \frac{1}{\alpha}\left[\frac{\alpha \tau s+1}{\tau s+1}\right]$

Example network:



$\frac{R_1(1/sC)}{R_1+1/sC}$

$\frac{R_1}{sR_1C+1}$

$$\frac{V_{out}}{V_{in}} = \frac{R_2}{R_2+\frac{R_1}{1+R_1sC}}$$

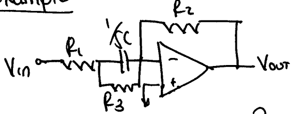
$$\frac{V_{out}}{V_{in}} = \cancel{\frac{R_2(1+R_1sC)}{R_1R_2+R_1 s C}} \qquad \frac{R_2(1+R_1sC)}{R_1+R_2+R_2R_1sC}$$

$$\cancel{V_{out}}\ \frac{V_{out}}{V_{in}} = \frac{R_2}{R_1+R_2}\left[\frac{1+sR_1C}{1+s\underbrace{\left[\frac{R_1R_2}{R_1+R_2}\right]}_{\text{parallel combination smaller}}C}\right]$$

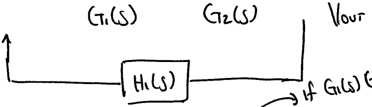
If $R_1=0$ → proportional derivative controller (PD-controller)

Compensation is called <u>LEAD</u> compensatic

<u>Op Amp Example</u>

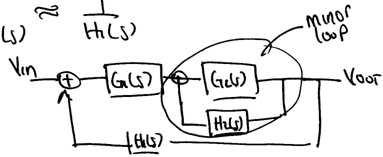


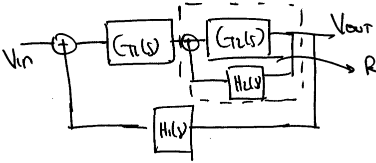
How do you stabilize the plant itself?



→ if $G_1(s)G_2(s)H_1(s) >> 1$

$$\frac{V_{out}}{V_{in}} = \frac{G_1(s)G_2(s)}{1+G_1(s)G_2(s)H_1(s)} \approx \frac{1}{H_1(s)}$$

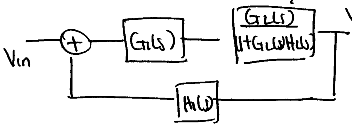




Reduces to $\dfrac{G_2(s)}{1+G_2(s)H_2(s)}$

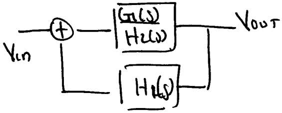
Rewrite as

if $G_2(s)H_2(s) \gg 1$
→ reduce to $\dfrac{1}{H_2(s)}$



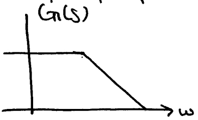
$$\frac{V_{OUT}}{V_{in}} = \frac{G_1(s)/H_2(s)}{1+\frac{G_1(s)H_1(s)}{H_2(s)}}$$

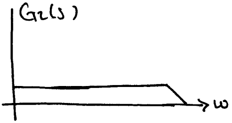
Now →



$\frac{1}{H_2(s)}$, reduction → $\dfrac{V_{OUT}}{V_{in}} = \dfrac{G_1(s)G_2(s)}{1+G_2(s)H_2(s)+G_1(s)G_2(s)H_1(s)}$

Bode plot perspective:





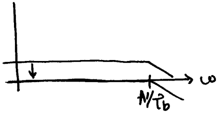
$G_1(s) =$

$G_2(s) = \dfrac{A_1}{\tau_b s+1}$

$A_0\ A_1$

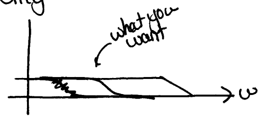
ω

Consider $G_2(s)$ in feedback (unity gain)

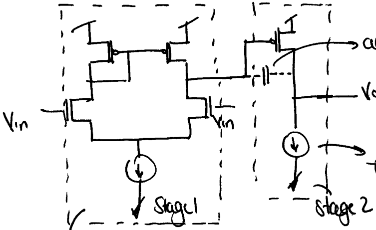


- extending bw but lowered gain

- instead of unity gain at all frequencies want unity gain at high frequencies only



Real example:



adding cap for minor loop compensation

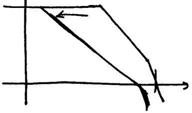
$$\frac{g_{mp} r_{op}}{\tau_b s+1}$$

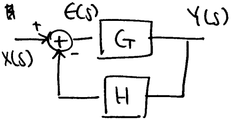
$$\frac{g_{mn}(r_{op} \| r_{on})}{\tau_a s+1}$$

Notes 04-14-10

Compensation: LAG - P.I → high DC gain, lower bandwidth
LEAD - P.D → high + high bandwidth
REDUCED GAIN - Proportional (low gain, low bw)
MINOR LOOP

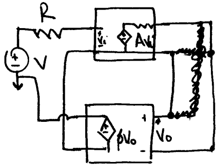
Dominant Pole





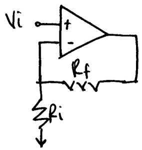
Input	Output	Feedback Transfer
V	V	K - series-shunt
V	I	G - series-series
I	I	K - shunt-series
I	V	R - shunt-shunt

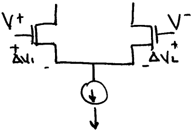
Ex. Series-shunt



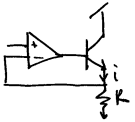
- Understand how to properly feedback different variables

Ex. Voltage-Voltage (Op-Amp)

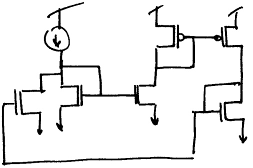




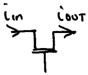
Ex. Voltage-Current



Ex. Current-Current

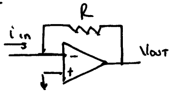


Simpler Choice: cascode



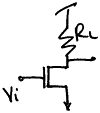
input current
output current

Ex. Current-Voltage



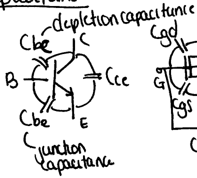
input current, output voltage

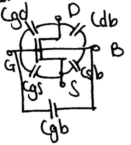
- Most circuits respond in voltage rather than current

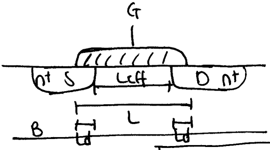


- Device always picks free ~~B~~ variable to ~~...~~ respond with. If current is fixed with a current source, transistor will respond in voltage and vice versa
- Resistor is between current & voltage source, so it will respond with both current & voltage → softer gain

Capacitance:





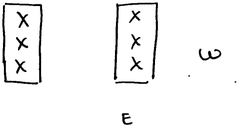


~~...~~ $\boxed{L_{eff} = L_{drawn} - 2L_d}$

- When referring to a design this length is

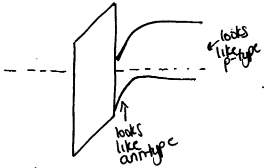
~~...~~

Layout



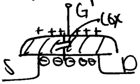
Analog	Digital
3-5x Ldrawn	Ldrawn

Review of Inversion / Accumulation Concepts



- just by applying a potential, change material from p-type to n-type

- In inversion, you will only see the Cox - oxide capacitance



$C_{ox} = \frac{WL\epsilon}{t_{ox}}$

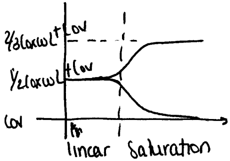
In Linear:

$C_{gs} = \frac{1}{2} C_{ox} WL$
$C_{gd} = \frac{1}{2} C_{ox} WL$ } partition half to each junction

Only in linear region b/c continuous charge from source to drain

In Saturation (channel pinched off)

$C_{gd} = 0$
$C_{gs} = \frac{2}{3} C_{ox} WL$

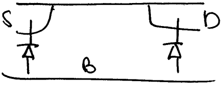


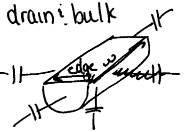
- still must include Cov → overlap capacitance

Actually $C_{gd} = C_{ov}$ or $\frac{1}{2} C_{ox} WL + C_{ov}$

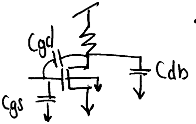
$C_{gs} = \frac{2}{3} C_{ox} WL + C_{ov}$ or $\frac{1}{2} C_{ox} WL + C_{ov}$

Also have diodes b/t source & bulk & drain & bulk





$C_j + (W + 2E) C_{jsw}$



Small-signal model