Repaso Examen 2

INEL 5207 - 2do Semestre 2008-09

- Respuesta dinámica
  - Ancho de banda
  - *Slew-rate*
- Estabilidad
  - Márgenes de magnitud y fase Φ_m
  - Análisis de estabilidad
  - Compensación

Respuesta dinámica

- Amplificadores con GBP constante
- Ancho de banda
  - Usar β del sin inversión para ambas configuraciones
  - $f_B = \beta \times f_T$ para cada etapa (con o sin inversión)
  - ganancia d.c depende de la configuración

Respuesta dinámica

- Ancho de banda de *n* etapas

$$f_{BW} = \beta f_\tau \sqrt{2^{1/n} - 1}$$

n = numero de etapas

β = factor de retroalimentación de cada una de las *n* etapas sin inversión

f_{BW} = ancho de banda del amplificador

Respuesta dinámica

Escalón

$$v(t) = V_m\left(1 - \exp -t/\tau\right)$$

$$V_m \leq \tau \times SR = \frac{SR}{2\pi f_B}$$

Senosiodal

$$\begin{aligned} f &\leq \frac{SR}{2\pi V_m} \\ V_m &\leq \frac{SR}{2\pi f} \end{aligned}$$

full-power bandwidth = f_{max} para V_m igual al P.S.

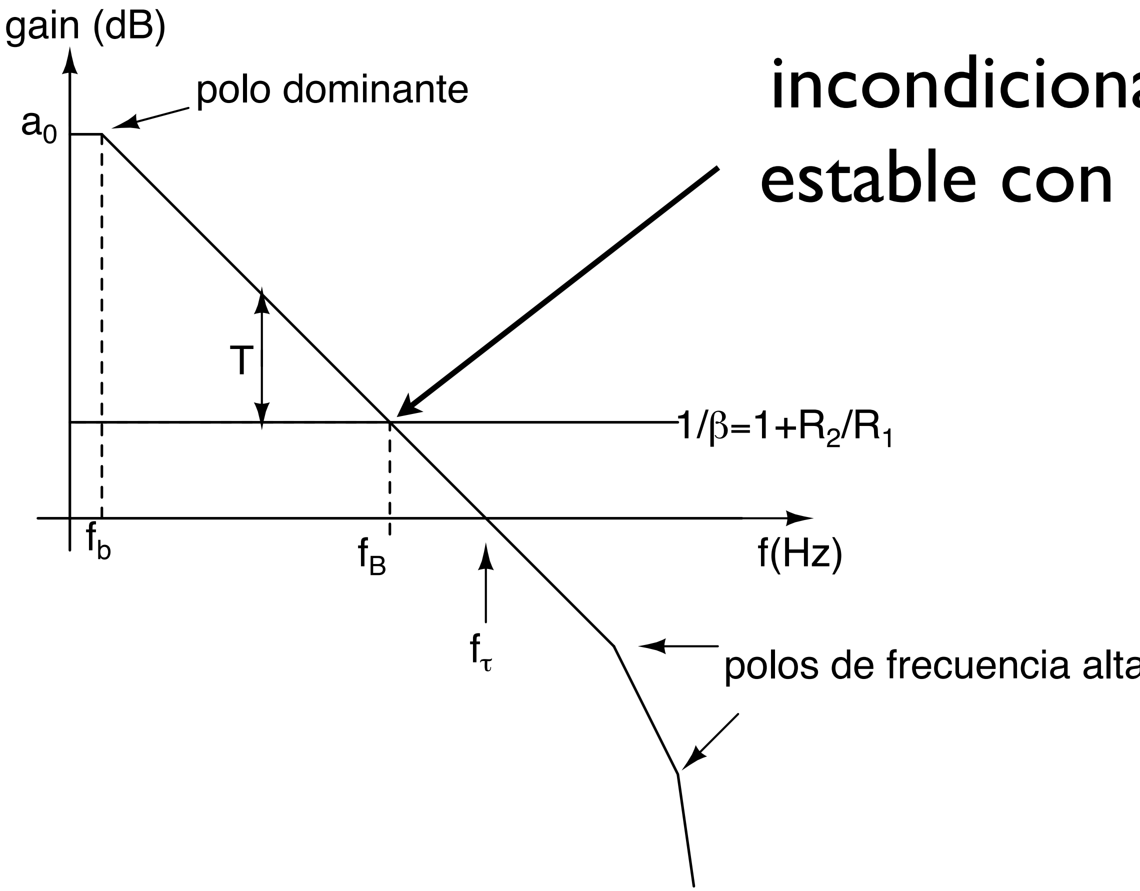
Estabilidad

$$
\begin{aligned}
\mid T \mid_{dB} &= \mid a \mid_{dB} - \mid 1/\beta \mid_{dB} \\
\angle T &= \angle a - \angle 1/\beta
\end{aligned}
$$

Niquist: la estabilidad del amplificador con retroalimentación puede determinarse de la *T*

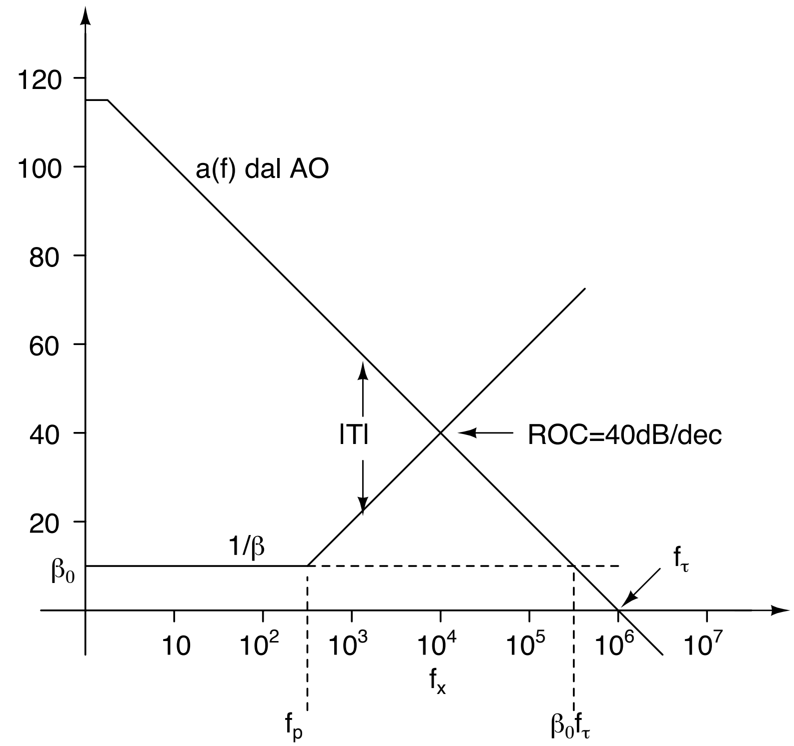
$$
\begin{aligned}
GM &= - \mid T(jf_{180^\circ}) \mid \\
\phi_m &= 180 + \angle T(jf_{0dB})
\end{aligned}
$$

- Capitulo 6: Amplificadores con GBP constante



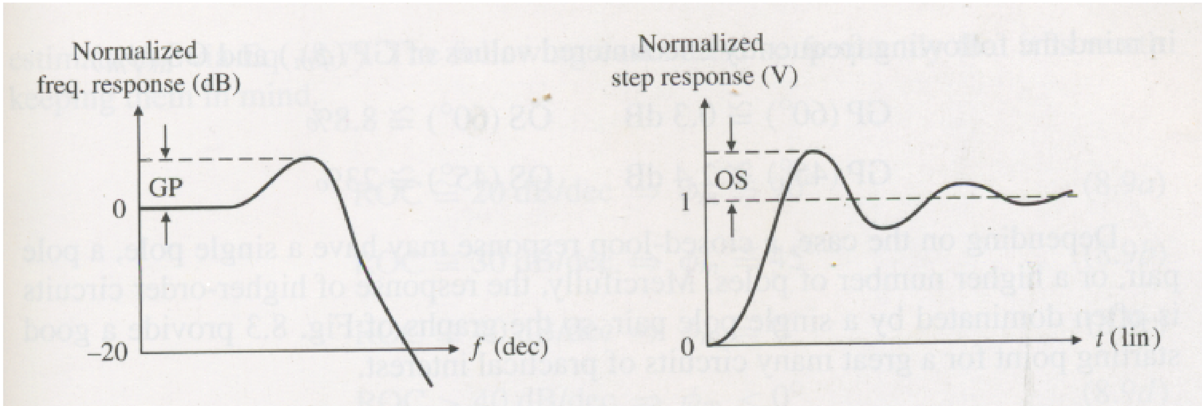
incondicionalmente estable con ϕ_m=90°

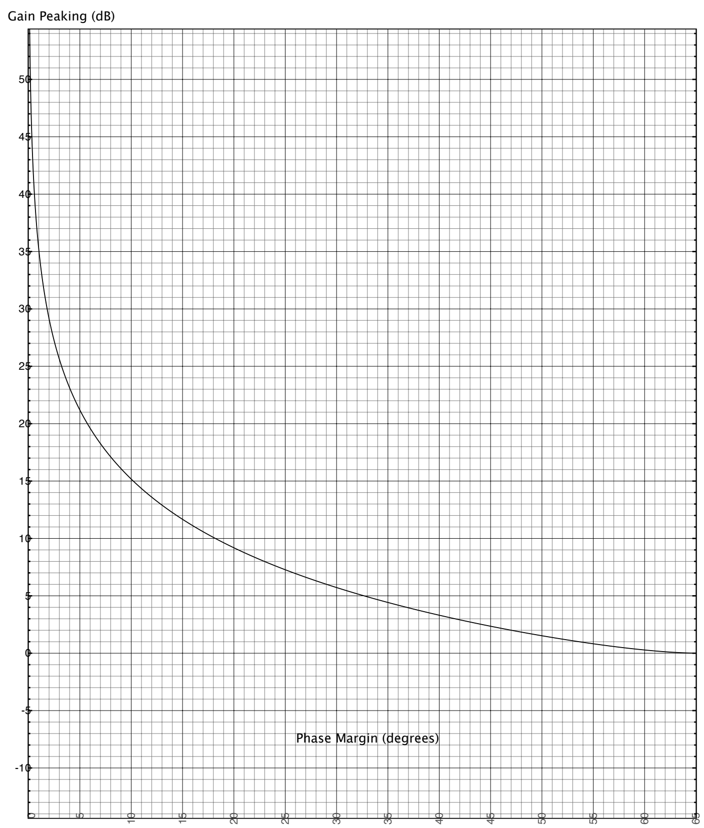
Capitulo 8: tanto el opamp como la red de retroalimentación pueden tener polos que reducen ϕ_m

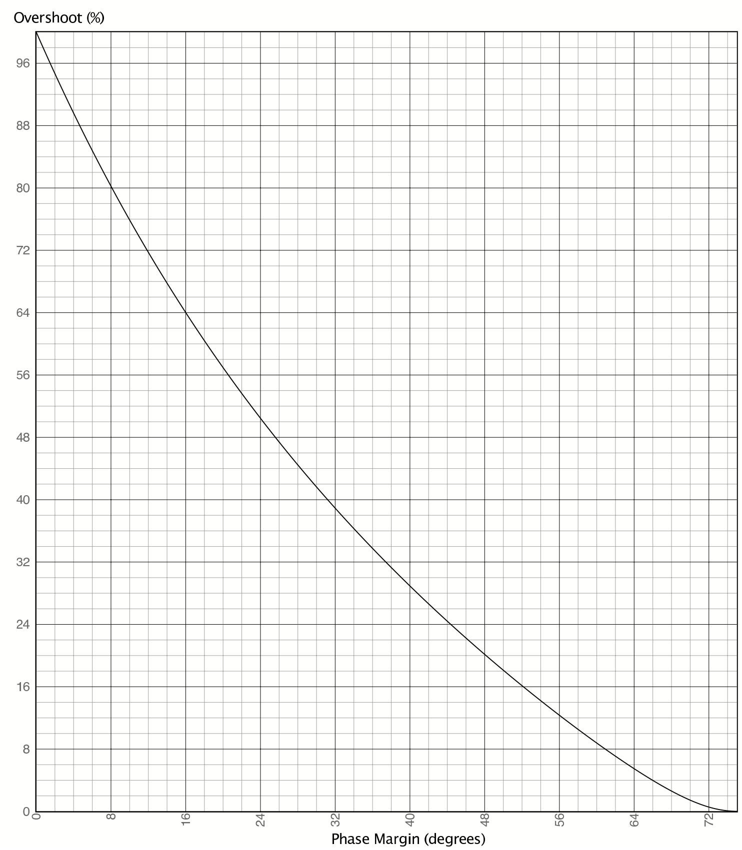


Gráficamente el margen de fase puede calcularse de:

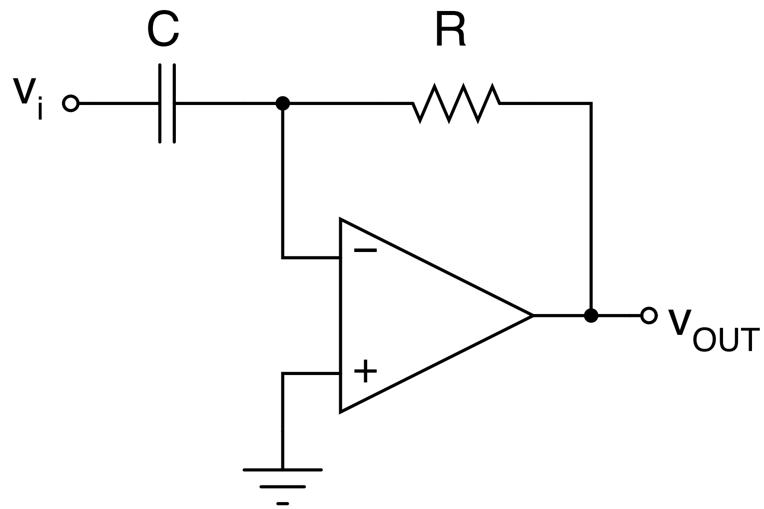
$$ROC = \Delta_a - \Delta_{1/\beta} \qquad \phi = \angle T \approx -4.5 \times ROC$$

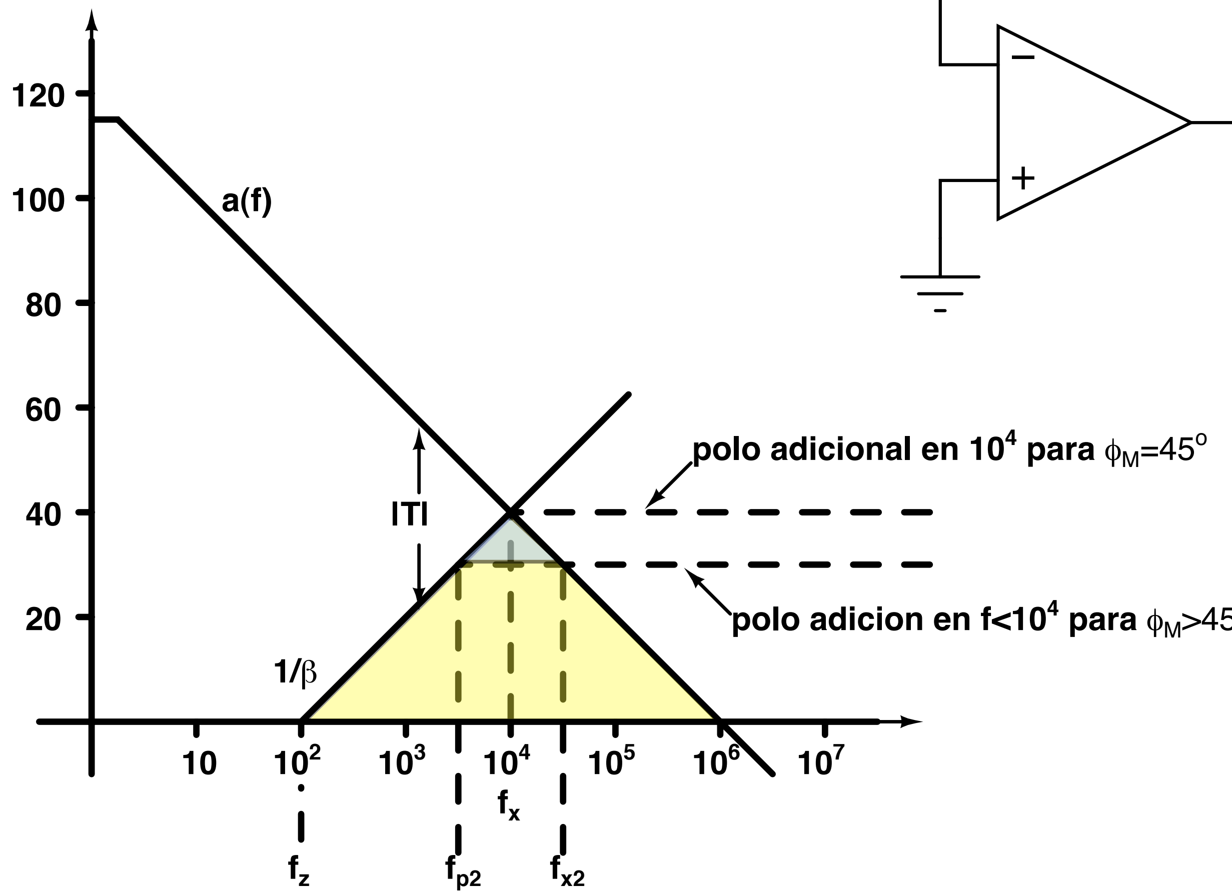

Normalized
freq. response (dB)
GP
0
–20
f (dec)
Normalized
step response (V)
OS
1
0
t (lin)

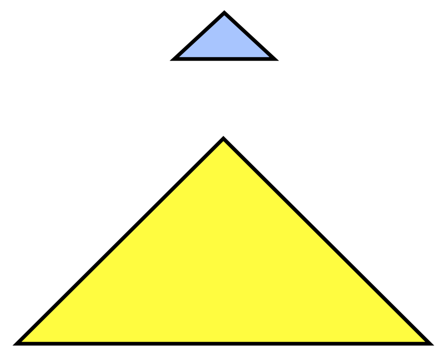

Gain Peaking (dB)
50
45
40
35
30
25
20
15
10
5
0
-5
-10
Phase Margin (degrees)
0
5
10
15
20
25
30
35
40
45
50
55
60
65

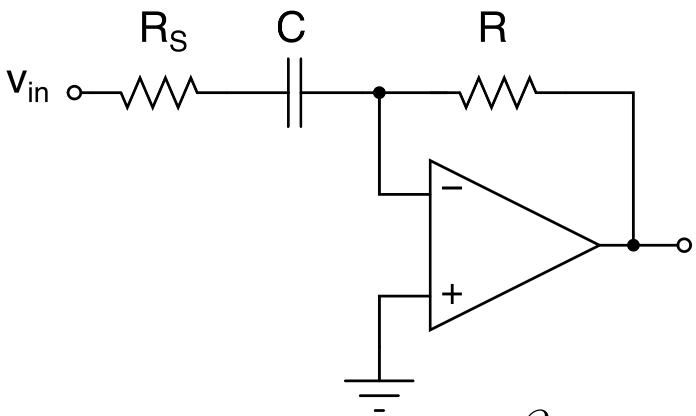

Overshoot (%)
96
88
80
72
64
56
48
40
32
24
16
8
0
0
8
16
24
32
40
48
56
64
72
Phase Margin (degrees)

Diferenciador









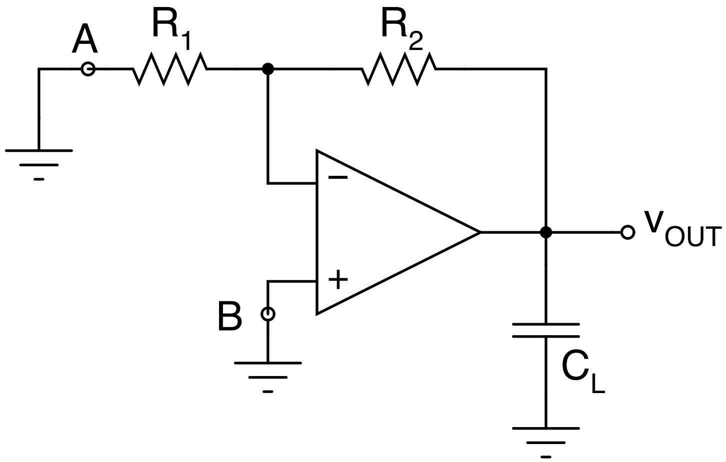
$$\beta_{ni} = \frac{R_S + 1/sC}{R + R_S + 1/sC}$$
$$= \frac{sCR_S + 1}{sC(R + R_S) + 1}$$

Polo de β se mueve de $f_0 = 1/2\pi RC$ a $1/2\pi C(R+R_S)$.

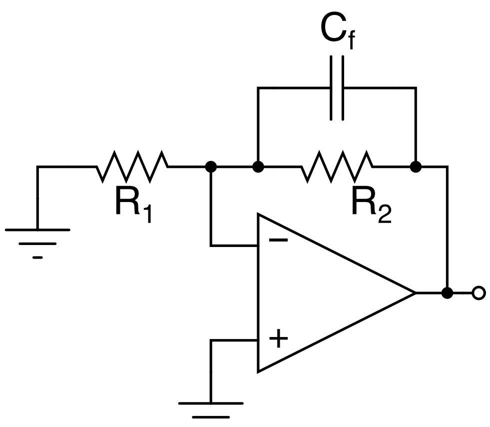
Se introduce un cero en $1/2\pi R_S C$.

Para que el movimiento del polo sea insignificante, escoja $R_S << R$.

Carga capacitiva



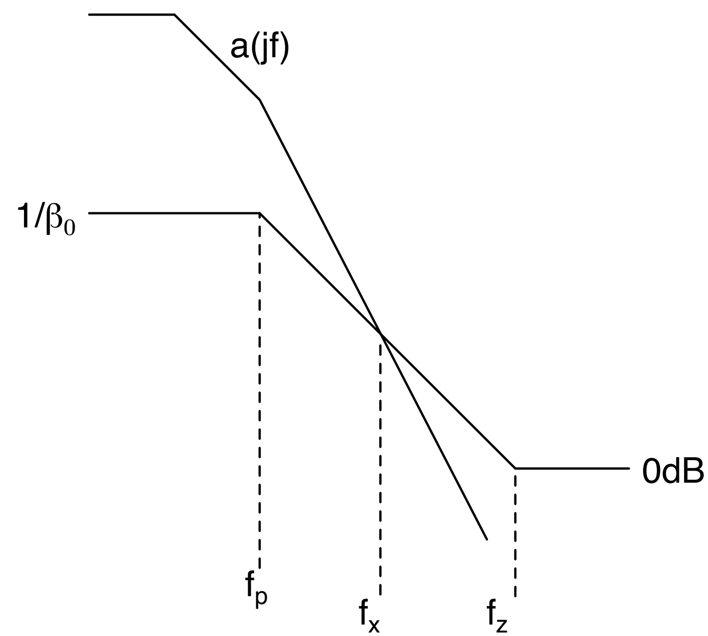
Compensación *feedback-lead*



$$
\begin{aligned}
Z_2 &= \frac{R_2}{sC_f R_2 + 1} \\
\beta &= \frac{R_1}{R_1 + Z_2} \\
1/\beta &= \frac{1}{\beta_0} \times \frac{1 + jf/f_z}{1 + jf/f_p} \\
f_p &= \frac{1}{2\pi C_f R_2} \\
f_z &= \frac{1}{2\pi C_f (R_1 \parallel R_2)} \\
&= f_p \left(1 + \frac{R_2}{R_1}\right)
\end{aligned}
$$

Para maximizar la ϕ aportada, escoja

$$f_x = \sqrt{f_p f_z} = f_p \sqrt{1 + \frac{R_2}{R_1}}$$



Debido a la simetria,

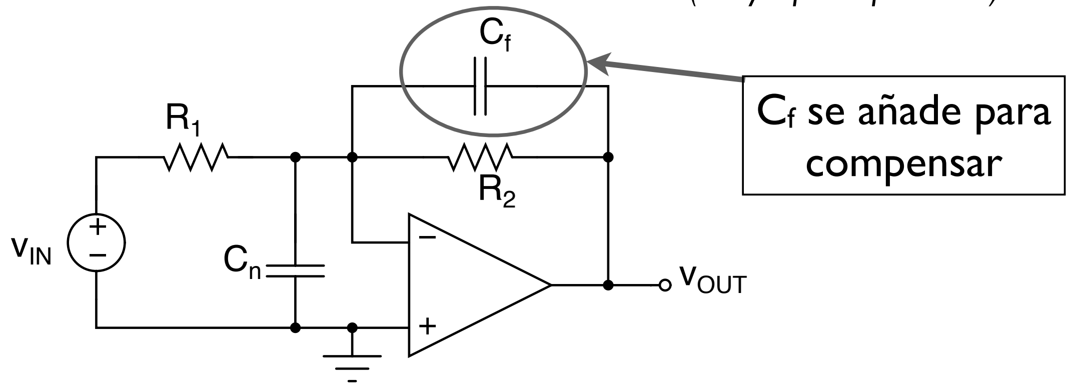
$$| a(jf_x) |= \sqrt{1+\frac{R_2}{R_1}}$$

Con esta ecuación determine f_x y entonces escoja

$$C_f = \frac{1}{2\pi f_p R_2} = \frac{\sqrt{1+\frac{R_2}{R_1}}}{2\pi R_2 f_x}$$

Capacitancia de entrada parasítica C_n

(Stray input capacitance)



$$
\begin{aligned}
Z_1 &= \frac{R_1 \times 1/sC_n}{R_1 + 1/sC_n} = \frac{R_1}{sC_nR_1 + 1} \\
Z_2 &= \frac{R_2 \times 1/sC_f}{R_2 + 1/sC_f} = \frac{R_2}{sC_fR_2 + 1} \\
\beta &= \frac{Z_1}{Z_1 + Z_2} \\
\frac{1}{\beta} &= \left(1 + \frac{R_2}{R_1}\right)\frac{1 + jf/f_z}{1 + jf/f_p} \\
f_p &= 1/2\pi R_2 C_f \\
f_z &= 1/2\pi(R_1 \parallel R_2)(C_n + C_f)
\end{aligned}
$$

Para $f = \infty$

$$R_1 \parallel 1/sC_n \simeq 1/sC_n$$

$$R_2 \parallel 1/sC_f \simeq 1/sC_f$$

$$1/\beta_\infty \simeq 1 + C_n/C_f$$

para añadir un polo en a,

$$\frac{1}{2\pi R_2 C_f} = \beta_\infty f_\tau = \frac{f_\tau}{1 + C_n/C_f}$$

$$a(jf_p) \times f_p = \frac{f_p}{\beta_\infty} = f_\tau$$

Compensation Techniques

Basics

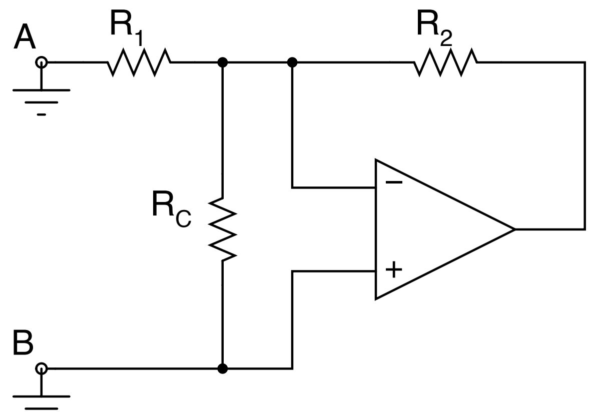
Compensation by pole-addition (dominant pole compensation)

Compensation by pole-shifting
(shunt-capacitance compensation)

Pole-zero compensation
(move first pole to lower frequency and
cancelation of second pole)

Reducing T

R_C reduce la T no afecta la A_{ideal}

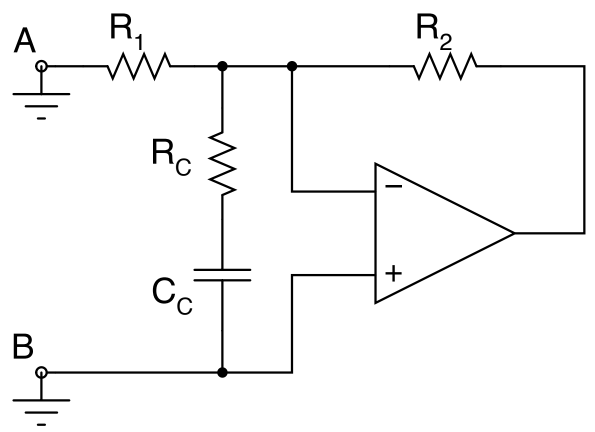


Assuming $r_d = \infty$ and $r_O = 0$, Franco's β becomes

$$\frac{1}{\beta} = 1 + \frac{R_2}{R_1 \,||\, R_C} = 1 + \frac{R_2}{R_1} + \frac{R_2}{R_C}$$

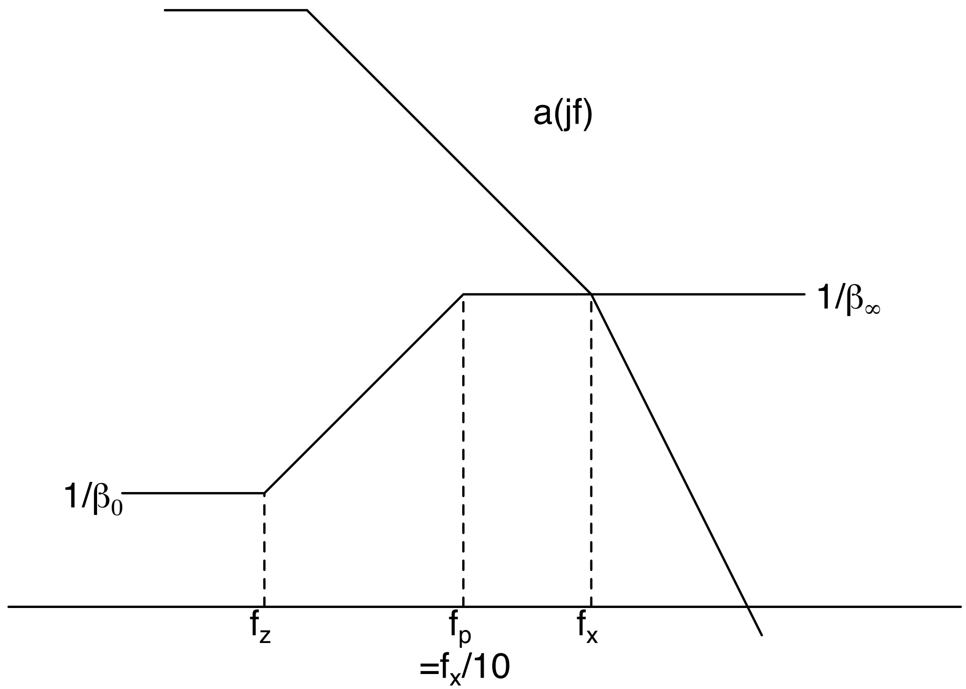
We need to move $\frac{1}{\beta}$to $a(f_2)$, where f_2 is the frequency of the second pole. Since the phase is 135°at this frequency, this would yield a phase margin $\phi_m = 45°$.

Notice that this is equivalent to increasing the closed-loop gain. The problem with this is that then the d.c. gain is increased and therefore the effect of the offsets is greater. To reduce this problem, use the following input-lag circuit:



tt

$$
\begin{aligned}
Z_1 &= R_1 \parallel \left(R_C + \frac{1}{sC_C} \right) = R_1 \frac{1 + sC_C R_C}{1 + sC_C(R_C + R_1)} \\
\beta &= \frac{Z_1}{R_2 + Z_1} = R_1 \frac{1 + sC_C R_C}{R_2 + sC_C(R_C + R_1)R_2 + R_1 + sC_C R_C R_1} \\
&= \frac{R_1}{R_1 + R_2} \frac{1 + sC_C R_C}{1 + sC_C(R_C R_2 + R_1 R_2 + R_C R_1)/(R_1 + R_2)} \\
&= \frac{R_1}{R_1 + R_2} \frac{1 + sC_C R_C}{1 + sC_C(R_1 \parallel R_2 + R_C)} \\
1/\beta &= \left(1 + \frac{R_2}{R_1} \right) \times \frac{1 + jf/f_p}{1 + jf/f_z} \\
f_p &= \frac{1}{2\pi C_C R_C} \\
f_z &= \frac{1}{2\pi C_C(R_1 \parallel R_2 + R_C)} \\
1/\beta_\infty &= \left(1 + \frac{R_2}{R_1} \right) \times \frac{f_p}{f_z} \\
&= \left(1 + \frac{R_2}{R_1} \right) \times \left(1 + \frac{R_1 \parallel R_2}{R_C} \right)
\end{aligned}
$$



- find f_x from $a(jf)$ and the desired ϕ_m
- use magnitude of $a(jf_x)$ to find R_C
- select C_C so that f_p is at least one decade below f_x