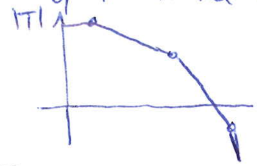
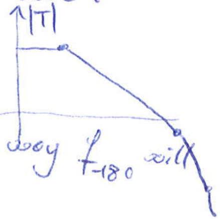
Ch 8. Part 2

- Do the example started last time.
- Discuss the rate of closure (ROC)
- 8.2 Stability in constant GBP OpAmp circuits
  See page 5 of last notes...

The idea is that we do not want two poles of T to the left of f_x:

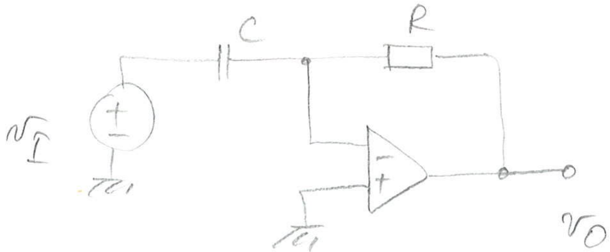


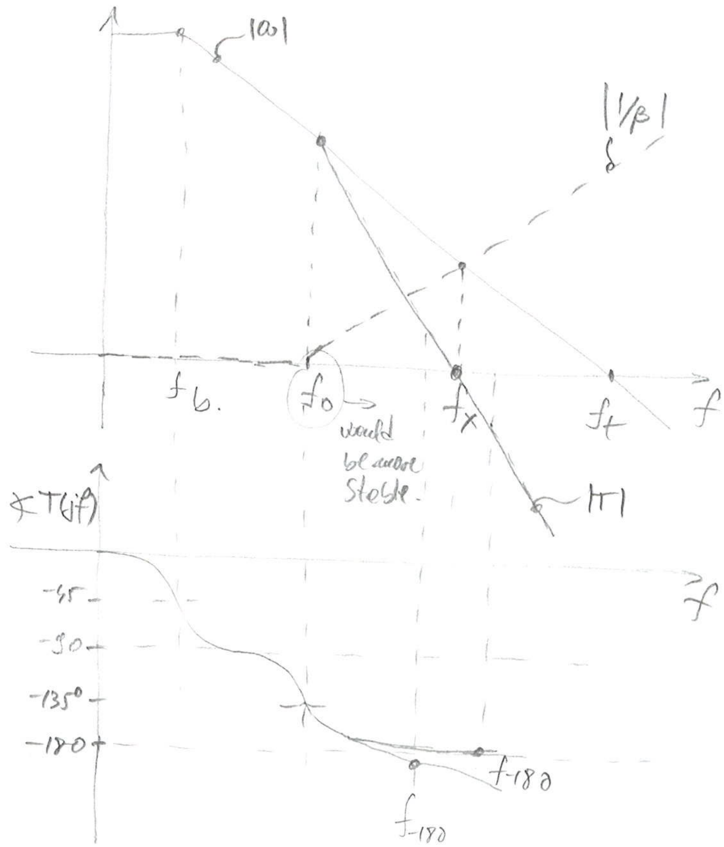
but only one:



because in this way f_{-180} will be for $T<1$.

Example of feedback pole: The Differentiator Circuit





$a \to \infty \Rightarrow H_{ideal} = -jf/f_0$

$\beta = \dfrac{Z_C}{Z_C + R}$, $Z_C = \dfrac{1}{j2\pi f C}$

$\beta(jf) = \dfrac{1}{1 + jf/f_0}$

Using ROC:

$ROC = \left| \text{Slope}\,|a|_{f=f_x} - \text{Slope}\,|1/\beta|_{f=f_x} \right|$

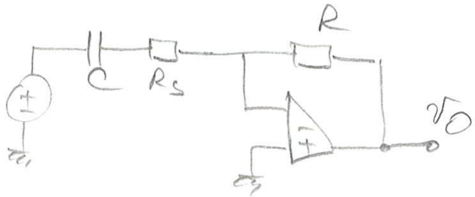
$= |-20 - (+20)| = 40\ \text{dB/dec} \Rightarrow$

$\Rightarrow \phi_m \cong 0^\circ$ unstable!

as long as $f_0 \ll f_t$ (or $f_0 \simeq \frac{f_t}{10}$).

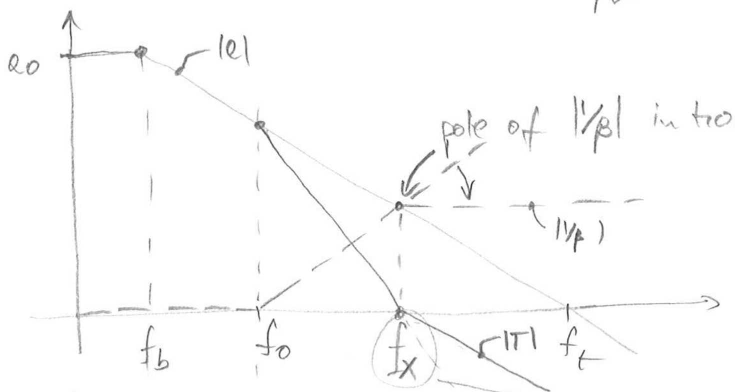
Depending on how small is f_0 compared to f_t the phase margin approaches 0°! $\Rightarrow$ instability.

- To stabilize it $\Rightarrow$ add R_S in series with C:



At LF => R_c no effect because C is open anyway.

At HF => C short, but $\left|\frac{1}{\beta_\infty}\right| = 1 + \frac{R}{R_s}$ => $|1/\beta|$ has a pole (or zero for $|\beta|$)



pole of $|1/\beta|$ introduced by R_s, which is located -intentionally- at f_x

One way of quickly assessing the impact:

$$ROC = |slope\,|a| - slope\,|\tfrac{1}{\beta}||_{f=f_x} = |-20-(-10)| = 30\ dB/dec \Rightarrow \phi_m = 45°$$

Another way is to look at phase plot:

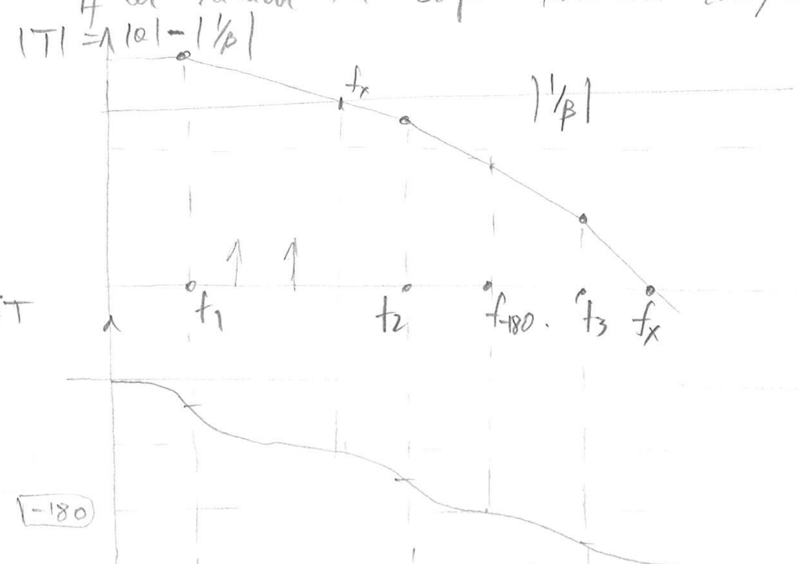
- Stray input capacitance compensation
- Capacitive Load isolation.

: Exercise!

8.3 Internal frequency compensation

if we remove the 30pF internal compensation capacitor =>

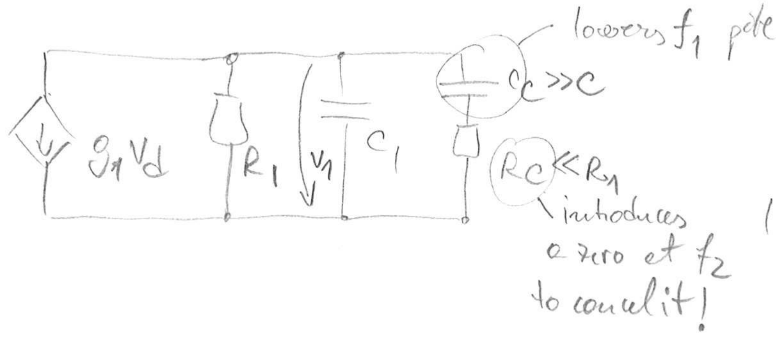
$$a(jf) = \frac{a_0}{(1+jf/f_1)(1+jf/f_2)(1+jf/f_3)}$$

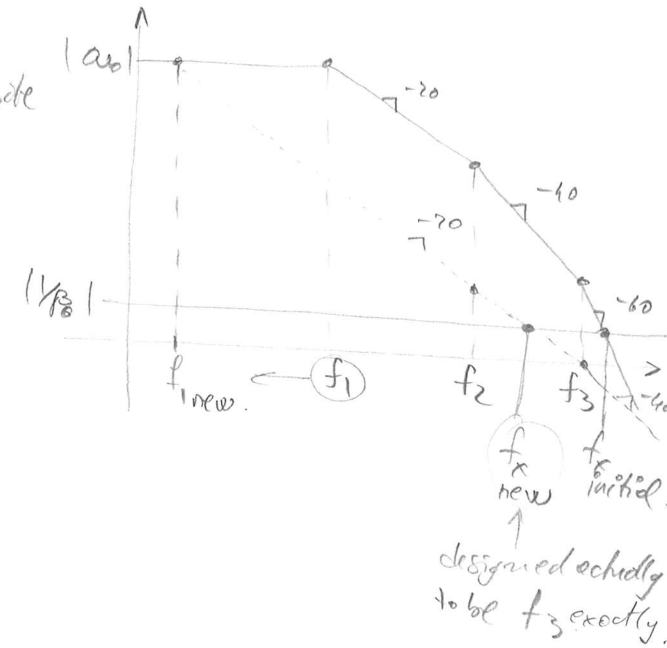


This could be made stable only for $|1/\beta| = (1/\beta_0)$ high enough so that 0dB line of $|T|$ is less than f_2.

- Dominant-pole compensation (new f_d pole is introduced)
- Shunt-capacitance compensation (f_1 is much more dominant)
- Miller compensation (pole splitting)
- Feed-forward compensation
- Pole-zero compensation

Exercise!





This has an effect that:

$$\frac{V_1}{V_d} \cong (-g_1 R_1) \cdot \frac{(1+j\, f/f_z)}{(1+j\, f/f_{1new})(1+j\, f/f_4)}$$

$$f_{1new} \cong \frac{1}{2\pi R_1 C_C} \qquad f_z \cong \frac{1}{2\pi R_C C_C} \qquad f_4 \cong \frac{1}{2\pi R_C C_1} > f_3$$

If we make $f_z = f_2$ => zero-pole cancellation:

$$\text{and } a(jf) = \frac{a_0}{(1+j\, f/f_{1new})(1+j\, f/f_3)(1+j\, f/f_4)}$$

Also let $f_x = f_3$ => $\boxed{\phi_m = 45^\circ}$

8.4 External frequency compensation

idea: modify the feedback factor $\beta \rightarrow \beta(jf)$

- Reducing the loop-gain => shift $|1/\beta|$ upward! Exercise!
- Input-lag compensation => shift $|1/\beta|$ upward only at HF! (smarter!)
- Feedback-lead compensation => introduce a zero for $|1/\beta|$ => phase of T will go upward, away from -180°!
- Decompensated Op Amps