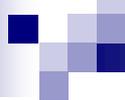




Opamp stability

[AN-NS92, apex_AN19]

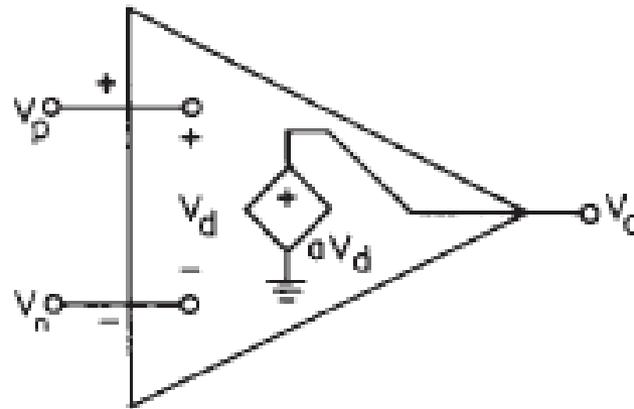


Stability in opamp

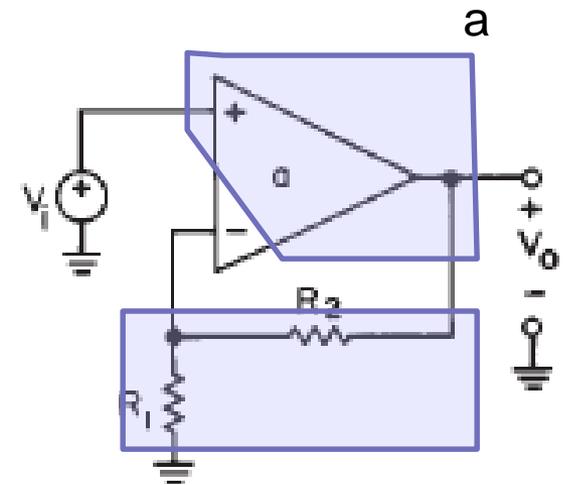
Two major categories for stability considerations:

- *Loop Stability*: concerned with using negative feedback around the amplifier and ensuring that the voltage fed back to the amplifier is less than an additional -180 phase shifted from the input voltage
- *Non-Loop Stability*: covers design areas not related to feedback around the op amp, such as layout, power supply bypassing, and proper grounding
 - we'll see them later

The conventional (“voltage feedback”, VFB) opamp



(a)



(b)

Fig. 1: Circuit model of the conventional op amp, and connection as a noninverting amplifier.

$$A = \frac{a}{1 + ab} = \frac{\frac{1}{b}}{\frac{1}{ab} + 1} = \frac{1}{b} \frac{1}{1 + \frac{1}{T}}$$

There is ab , i.e. the loop gain *without* the subtractor

$$A(jf) \triangleq \frac{V_o}{V_i} = \left(1 + \frac{R_2}{R_1} \right) \frac{1}{1 + 1/T(jf)}$$

$$T(jf) = \frac{a(jf)}{1 + R_2/R_1}$$

Note: the cutoff frequency for $A(jf)$ is where $|T(jf)|=1$

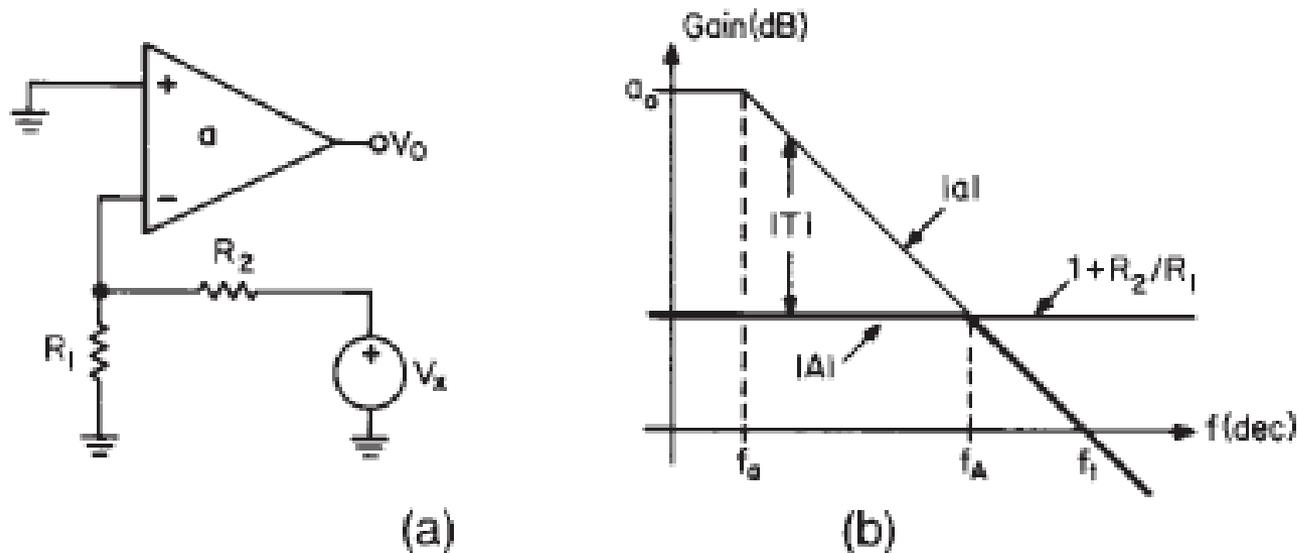


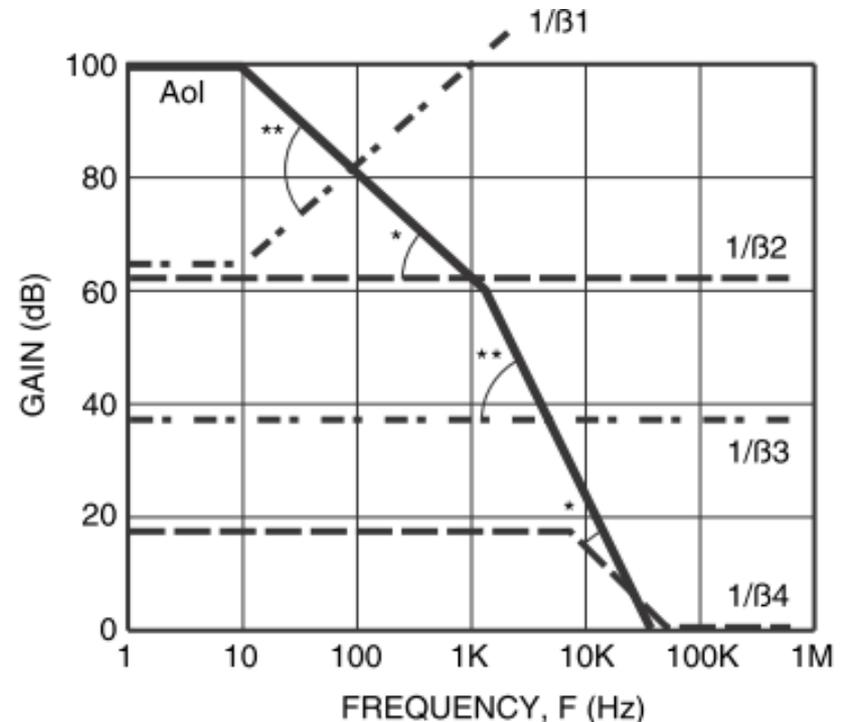
Fig. 2: Test circuit to find the loop gain, and graphical method to determine the closed-loop bandwidth f_A .

$$T = ab = a / (1/b) \rightarrow \log(T) = \log(a) - \log(1/b)$$

Difference between the A_{ol} curve and the $1/\beta$ curve is the “*loop gain*”

First order check for instability: when loop gain goes to 0 (i.e. where $1/\beta$ curve intersects the A_{ol} curve)

- open loop phase shift is (much) less than 180 degrees
- i.e., the difference in the slopes of the two curves, i.e. the *rate of closure*, is ≤ 20 dB/decade



* 20 dB/ DECADE RATE OF CLOSURE —> “STABILITY”

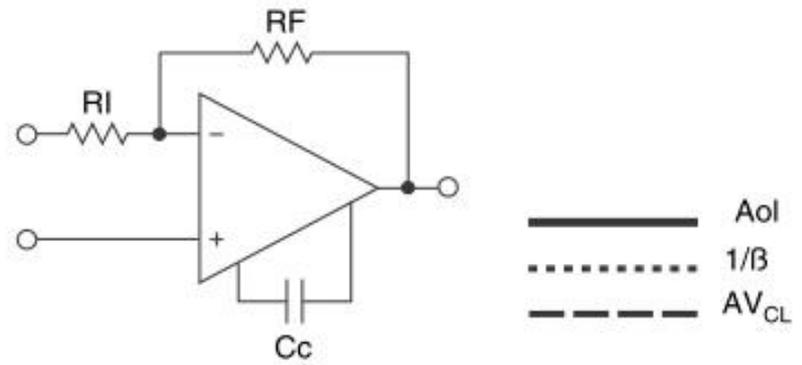
** 40 dB/ DECADE RATE OF CLOSURE —> “MARGINAL STABILITY”

External phase compensation is often available on opamps

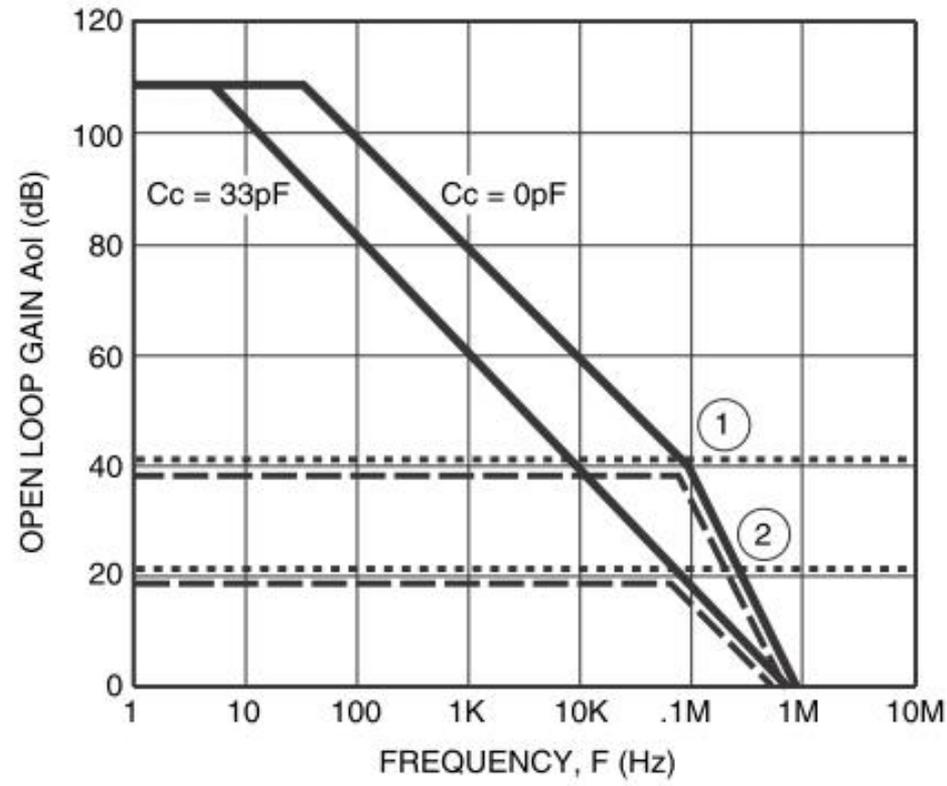
- the lower the value of C_c , the higher the SR
- but poor signal stability

- Curve 1: $1/\beta = 40$ dB
 - phase margin
 - ~ 45 deg with $C_c=0$ pF
 - ~ 90 deg with $C_c=33$ pF

- Curve 2: $1/\beta = 20$ dB
 - phase margin
 - ~ 0 deg with $C_c=0$ pF
 - ~ 90 deg with $C_c=33$ pF



SMALL SIGNAL RESPONSE

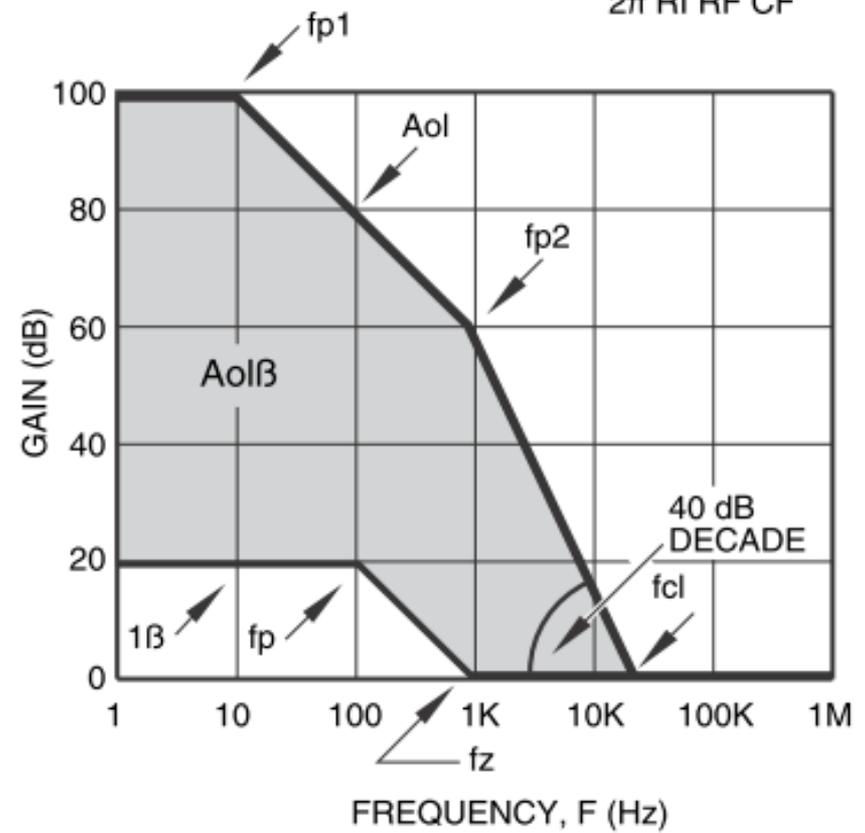
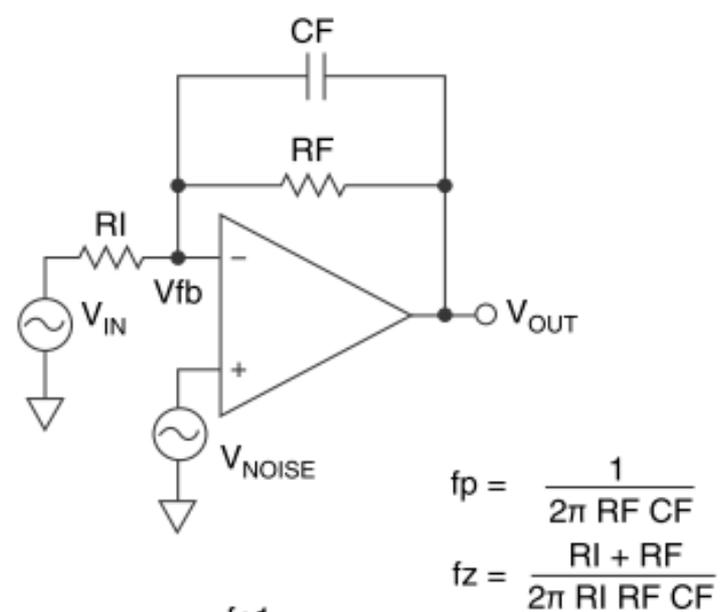


Note that

- poles of β appear as zeroes in the $1/\beta$ plot
- zeroes of β appear as poles in the $1/\beta$ plot

In this figure,

- f_p and f_z are poles and zeros of $1/\beta$



1: opamp open loop gain

In case of a (relatively) large C_i :

5: with negligible C_f

2: adding a small C_f

3: with (higher) C_f so that $C_i/C_f = R_f/R_i$

4: with still higher C_f : opamp must be unity gain stable!

C_f and C_i may be stray capacitances!

