Introduction to Feedback

November 9, 2017 16:06

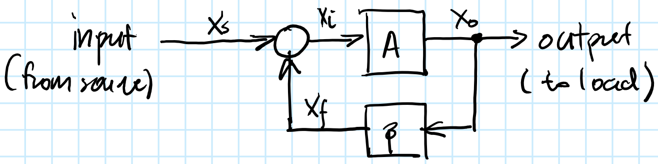
- Desensitize gain
- Reduce Distortion
- Extend BW
- Control I/O impedence
- ↑ Signal to noise ratio.

Recall OPAmps has: BW ~ 10Hz
Gain ~ 1×10^6

By having a gain of 100, BW would be 100kHz.

- Voltage amplifier: High R_i. Low R_o
- Current amplifier: Low R_i. High R_o.
- Transconductance amplifier: Feedback drives up both R_i, R_o.
- Transimpedance —: low R_i, R_o.

Basic Feedback Configuration



Ideally: $x_o = A x_i$

$x_f = \beta x_o$

$x_i = x_s - x_f$

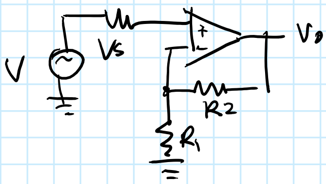
$A_f = \frac{x_o}{x_s}$ $\qquad A_f = \frac{A}{1+A\beta}$

If $A \gg \beta$, then $A_f \approx \frac{1}{\beta}$, so $x_f = \beta x_o = A\beta x_i = A\beta(x_s - x_f)$

$\rightarrow x_f = \frac{A\beta x_s}{1+A\beta} \approx x_s$. for $A\beta \gg 1$.

output follows the input.

Consider OPAMP with negative feedback (non-inverting)



$\rightarrow$ For $A \rightarrow \infty$, $V_p = V_s$ and $V_n = V_o \cdot \frac{R_1}{R_1+R_2}$

Negative feedback: $V_n = V_p$

So $A_f = \frac{V_o}{V_s} = \frac{\left(\frac{V_n(R_1+R_2)}{R_2}\right)}{V_p} = \frac{R_1+R_2}{R_1} = \frac{1}{\beta}$

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

$\rightarrow$ For $A = 10^4$ (gain), and $A_f = 100$ (gain of feedback)

→ For $A = 10^4$ (gain), and $A_f = 100$ (gain of feedback)

$$A_f = 100 = \frac{A}{1+A\beta} = \frac{10^4}{1+10^4 \cdot \frac{R_1}{R_1+R_2}}$$

$$\Rightarrow \frac{R_2}{R_1} = \frac{10000}{99} - 1 = 100.01$$

→ If the open loop gain is only 7500, then:

$$A_f = \frac{7500}{1+\frac{7500}{1+100.01}} = 99.67$$

We see that we changed base gain by 25%, but the output gain didn't change that much.

→ Amount of feedback for $A_f = 100$. ?

$$\begin{aligned} 1+A\beta &= 100 \\ &= 20\log_{10}\left(1+\frac{10^4}{1+100.01}\right) \\ &\approx 40\text{dB} \end{aligned}$$

Properties of Negative Feedback

Gain Desensitivity:

Recall that changing A by 25% → 0.33% change in A_f

Thus $$\frac{dA_f}{dA} = \frac{1}{1+A\beta} - \frac{A\beta}{(1+A\beta)^2}$$

$$= \frac{1}{(1+A\beta)^2}$$

$$\frac{dA_f}{A_f} = \frac{\frac{dA}{(1+A\beta)^2}}{A_f}$$

$$\frac{dA_f}{A_f} = \frac{1}{1+A\beta}\frac{dA}{A}$$

$\boxed{1+A\beta}$: desensitivity factor.

Bandwidth Extension.

Consider open loop gain $A(s) = A_m \frac{\omega_H}{s+\omega_H}$ (Low pass, single pole)

$$= \frac{A_m}{\frac{s}{\omega_H}+1}$$

Then $$A_f(s) = \frac{A(s)}{1+\beta A(s)} = \frac{A_m}{1+\frac{s}{\omega_H}+A_m\beta}$$

$$A_{mf} = \frac{A_m}{1+A_m\beta}$$