EE 521: Instrumentation and Measurements

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Open-Loop Frequency Response

$$A_D(f) = \frac{k_{ov}}{1 + j\frac{f}{f_{PD}}} \tag{1}$$

where f_{PD} is the dominant-pole frequency and k_{ov} is the low frequency open-loop gain. In addition, the unity-gain bandwidth is given by

$$f_T = f_{PD} k_{ov} \tag{2}$$

Open-loop Gain Magnitude

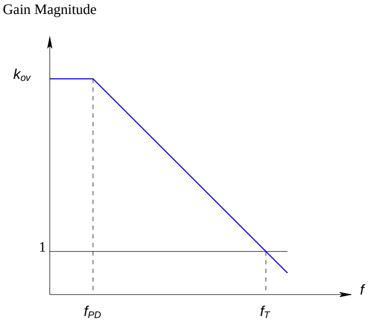

Figure: Bode plot

Close-loop Frequency Response

For non-inverting amplifier

$$A_D(f) = \frac{1/\beta}{1 + j\frac{f}{f_{PD}\beta k_{ov}}} \qquad (3)$$

where $\beta = R_1/(R_1 + R_F)$, the 3dB frequency is

$$f_{3dB} = f_{PD}\beta k_{ov} \qquad (4)$$

and

$$GBWP = f_T \qquad (5)$$

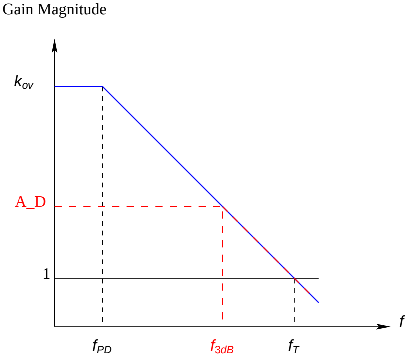

Figure: Bode plot

Unlike Voltage Feedback Amplifiers (VFA), in Current Feedback Amplifiers (CFA) the inverting input is sensitive to current. CFAs offer much higher slew rates as compared to voltage feedback op-amps.

$$\Omega_s = \Omega_o/(\tau s + 1) \quad (6)$$

$$V_o = I_n[\Omega_o/(\tau s + 1)] \quad (7)$$

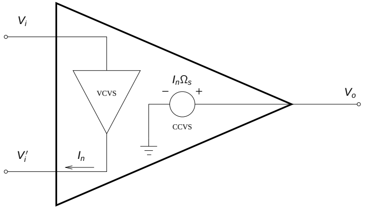

Figure: Current Feedback Op-amp model

Non-inverting

$$I_n = V_s G_1 + (V_s - V_o) G_F \tag{8}$$

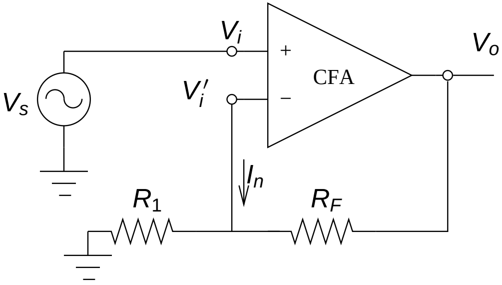

Figure: Non-inverting current feedback amplifier

Non-inverting

- Transfer function:

$$V_o/V_s = \frac{(G_1 + G_F)\Omega_o/(1 + G_f\Omega_o)}{s[\tau/(1 + G_F\Omega_o)] + 1} \tag{9}$$

- dc gain:

$$A_{vo} = (R_1 + R_F)/R_1 \tag{10}$$

- $GBWP$:

$$GBWP = \frac{\Omega_o(R_F + R_1)}{2\pi R_F R_1} = \Omega_o A_{vo}/(2\pi\tau R_F) \tag{11}$$

Non-inverting Current Feedback Op-amps - Remarks

- The -3dB frequency is given by

$$f_{3dB} = (\Omega_o + R_f)/(2\pi\tau R_F) \approx \Omega_o/(2\pi\tau R_F) \qquad (12)$$

- f_{3dB} is only dependent on R_F, therefore unlike conventional non-inverting amplifiers, the dc gain is set with only R_1 and holding the f_{3dB} constant with R_F.
- High slew rate.
- Not flexible in terms of stability and ability to synthesize transfer functions.

Inverting

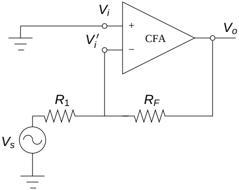

Figure: Inverting current feedback amplifier

Assuming $\Omega_o G_F \gg 1$

$$V_o/V_s = \frac{-R_F/R_1}{s(\tau R_F/\Omega_o) + 1} \tag{13}$$

Inverting Current Feedback Op-amps - Remarks

- dc gain is $-R_F/R_1$.
- -3dB frequency is $\Omega_o/(2\pi\tau R_F)$.
- $GBWP$ is $\Omega_o/(2\pi\tau R_1)$.
- Avoid applying capacitor directly in a feedback between V_o and V_i'.

Summary

- Stability is affected by R_F, therefore caution must be used if different feedback resistance, other than the one specified by the manufacturer is used.
- Inverting input impedance is very high.
- Non-inverting input impedance is very low.
- Stray capacitance on the inverting input or in the feedback connection leads to oscillations.

Integrator using C instead of R_f

$$I_n = -(V_s G_1 + V_o sC) \tag{14}$$

and

$$V_o/V_s = \frac{-\Omega_o G_1}{s(\tau + C\Omega_o) + 1} \tag{15}$$

If $R_1 = 1\text{M}\Omega$, $C = 1\mu\text{F}$ and $\Omega_o = 10^8\Omega$, then

$$V_o/V_s = -100/(s100 + 1)$$

which is not an integrator but rather an inverting low-pass filter with a cutoff frequency of 10^{-2}rad/s

Integrator

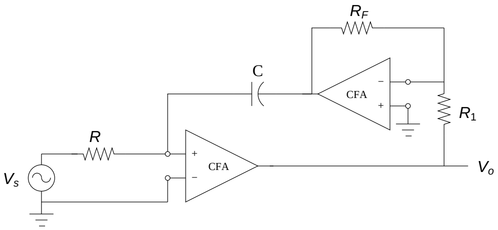

Figure: Non-inverting integrator using CFA

General

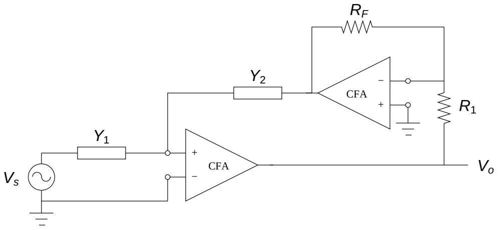

Figure: General non-inverting CFA circuit

$$V_o/V_s = \frac{Y_1 \Omega_1 G_{o1}}{Y_1 + Y_2[(1 + \Omega_1 \Omega_2 G_{o1} G_A)/(G_F \Omega_2)]} \tag{16}$$

- Donald A. Neamen, "*Electronic Circuit Analysis and Design*", Irwin, Chicago, 1996.
- Operational Amplifiers, http://www-s.ti.com/sc/psheets/slod006b/slod006b.pdf
- Current Feedback Op-Amp Applications Circuit Guide, http://www.national.com/an/OA/OA-07.pdf