Lecture 2 - B

Analog Signal Conditioning

EE 521: Instrumentation and Measurements

Lecture Notes Update on September 9, 2009

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1 Frequency Response

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

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

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Open-loop Gain Magnitude

See Figure 1

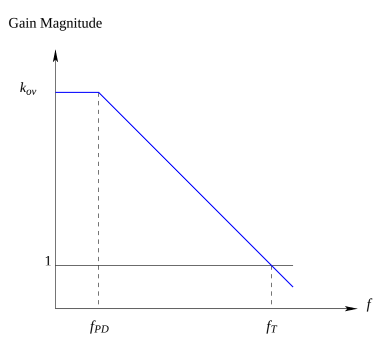

Figure 1: Bode plot

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Close-loop Frequency Response

For non-inverting amplifier

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

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

$$f_{3dB} = f_{PD}\beta k_{ov} \tag{4}$$

and

$$GBWP = f_T \tag{5}$$

See Figure 2

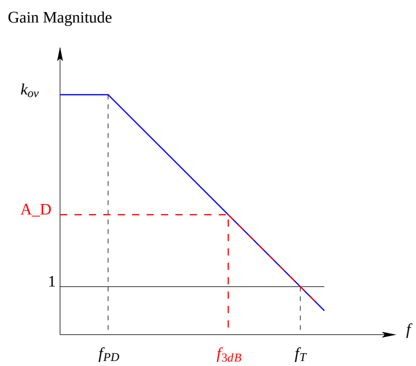

Figure 2: Bode plot

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2 Current Feedback Op-amps

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. See Figure 3

$$\Omega_s = \Omega_o/(\tau s + 1) \tag{6}$$

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

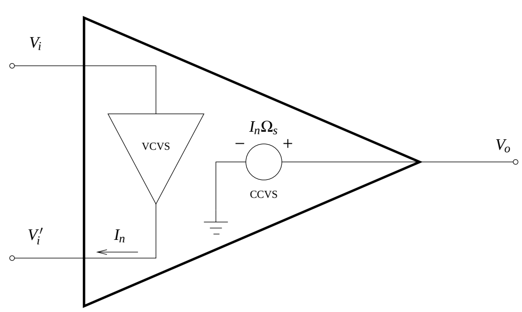

Figure 3: Current Feedback Op-amp model

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Non-inverting

See Figure 4

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

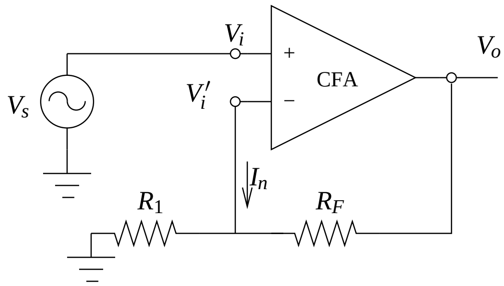

Figure 4: Non-inverting current feedback amplifier

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Non-inverting

- Transfer function:

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

if we assume that $G_F \Omega_o \gg 1$

$$V_o/V_s = \frac{1 + R_F/R_1}{s\tau R_F/\Omega_o + 1} \tag{10}$$

- dc gain:

$$A_{vo} = (R_1 + R_F)/R_1 \tag{11}$$

- *GBWP*:

$$GBWP = \frac{\Omega_o(R_F + R_1)}{2\pi R_F R_1} = \Omega_o A_{vo}/(2\pi\tau R_F) \tag{12}$$

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Non-inverting Current Feedback Op-amps - Remarks

- The -3dB frequency is given by

$$f_{3dB} = (\Omega_o + R_f)/(2\pi\tau R_F) \approx \Omega_o/(2\pi\tau R_F) \tag{13}$$

- 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.

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Inverting

See Figure 5

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

Assuming $\Omega_o G_F \gg 1$

$$V_o/V_s = \frac{-R_F/R_1}{s(\tau R_F/\Omega_o) + 1} \tag{15}$$

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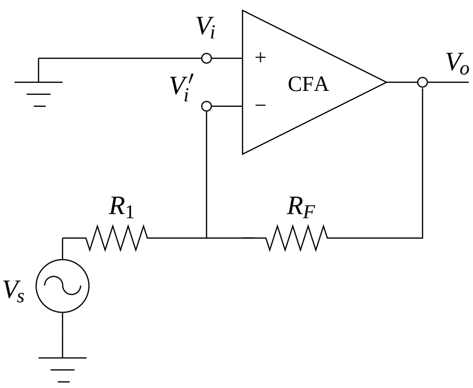

Figure 5: Inverting current feedback amplifier

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'.

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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.

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3 CFA Circuit Examples

Integrator using C instead of R_f

$$I_n = -(V_sG_1 + V_osC) \tag{16}$$

and

$$V_o/V_s = \frac{-\Omega_oG_1}{s(\tau + C\Omega_o) + 1} \tag{17}$$

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 2 - B.13

Integrator

See Figure 6 2 - B.14

General

See Figure 7

$$V_o/V_s = \frac{Y_1\Omega_1G_{o1}}{Y_1 + Y_2[(1 + \Omega_1\Omega_2G_{o1}G_A)/(G_F\Omega_2)]} \tag{18}$$

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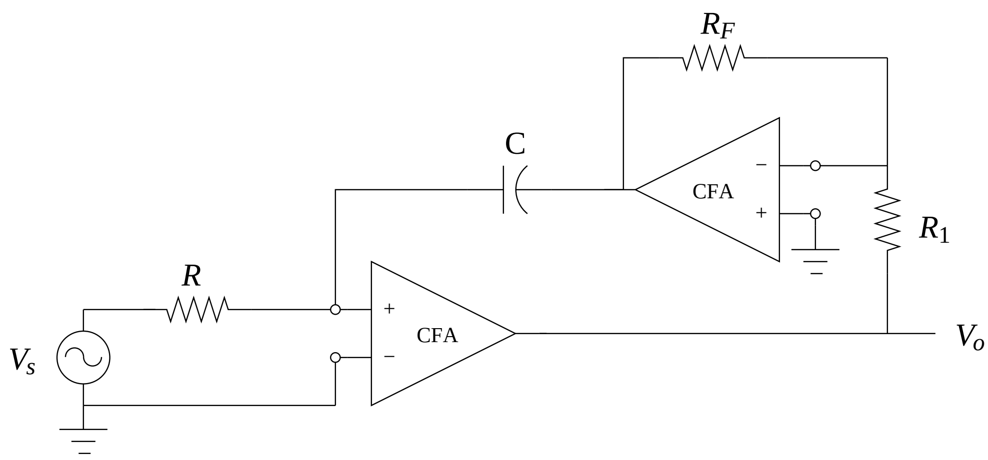

Figure 6: Non-inverting integrator using CFA

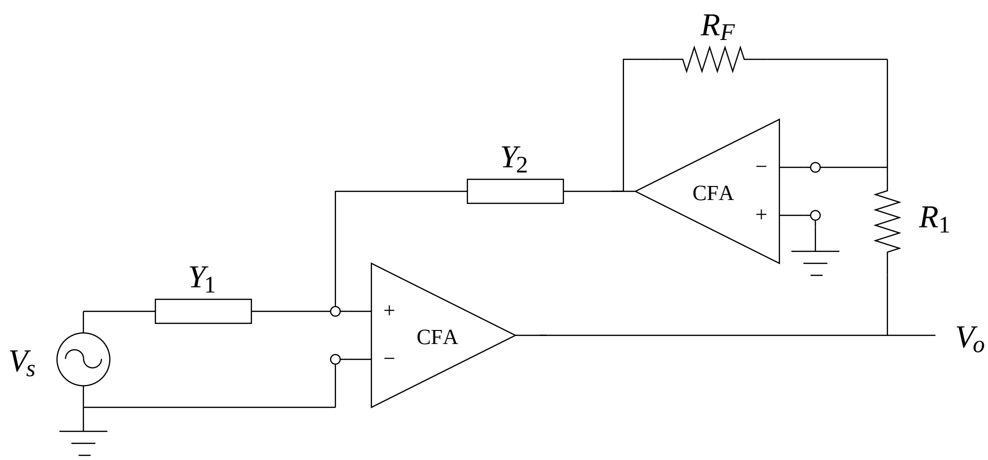

Figure 7: General non-inverting CFA circuit

4 Additional References

- 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

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