



Current Feedback Amplifiers - 1

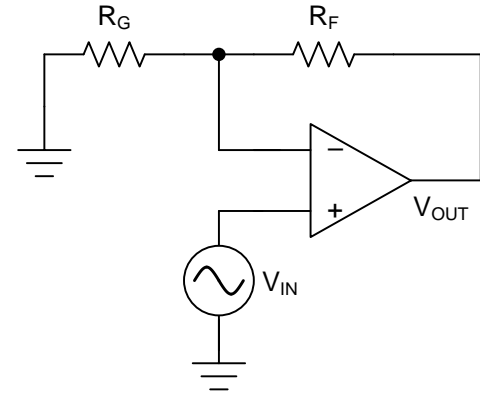
TIPL 2011

TI Precision Labs: High-Speed Operational Amplifiers

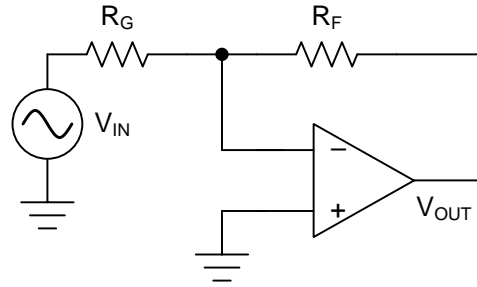
Prepared and Presented by Samir Cherian

No Change in Basic Op-amp Concepts!

Non-inverting and Inverting Configurations



$$\frac{V_{OUT}}{V_{IN}} = 1 + \frac{R_F}{R_G}$$



$$\frac{V_{OUT}}{V_{IN}} = -\frac{R_F}{R_G}$$

- CFB is still in a negative-feedback loop
- Virtual-ground concept still holds and $V_{IN+} = V_{IN-}$

VFB: Voltage-Feedback Amplifier

CFB: Current-Feedback Amplifier



Benefits of Current Feedback Amplifiers

- No constant gain bandwidth product relationship like in VFBs.

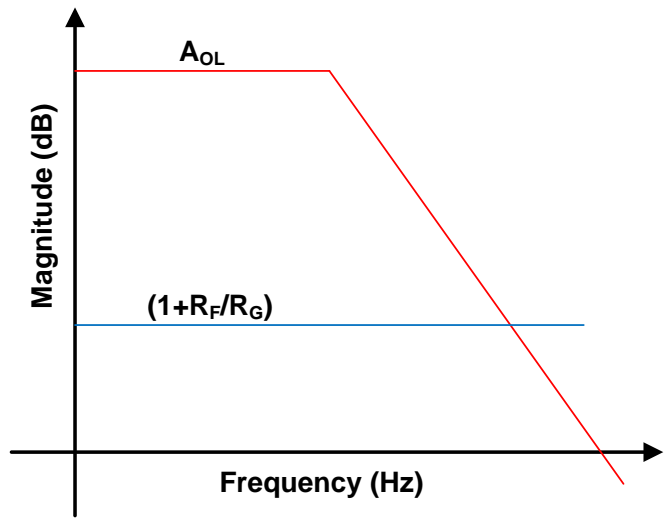
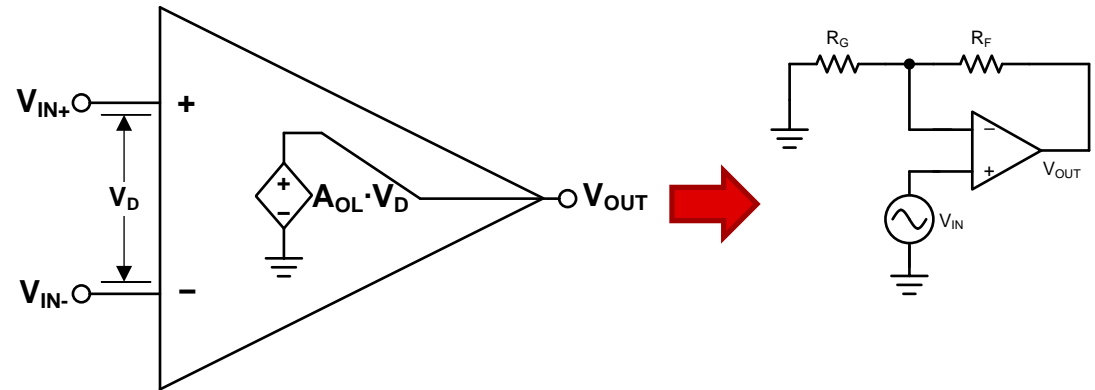
	Ideal VFB	Ideal CFB
Gain = 1 V/V	100 MHz	100 MHz
Gain = 10 V/V	10 MHz	100 MHz

- The CFB architecture can achieve much higher slew rates relative to VFBs.

$$\text{Slew Rate} = V_{\text{PEAK}} \cdot 2\pi \cdot f_{\text{MAX}}$$

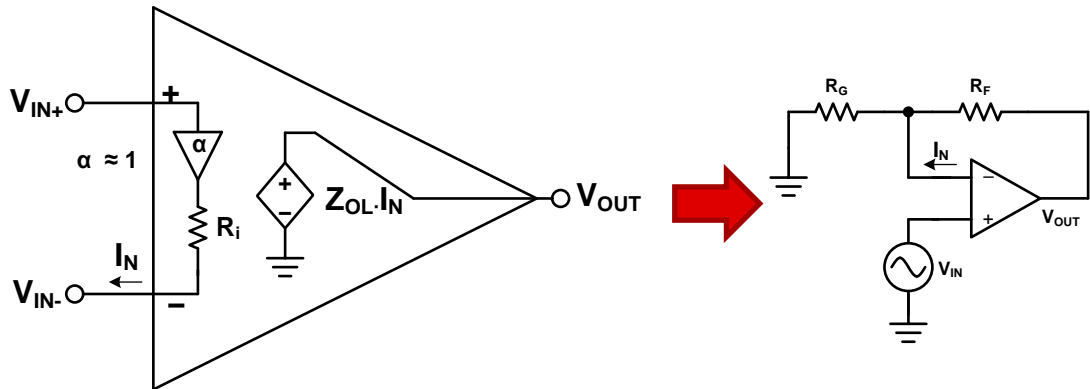
where f_{MAX} is the amplifiers full-power bandwidth

VFB: Bandwidth Depends on Gain



$$A_{CL} = \frac{V_{OUT}}{V_{IN}} = \left(1 + \frac{R_F}{R_G}\right) \cdot \frac{1}{\left(1 + \frac{R_F}{R_G} \cdot \frac{1}{A_{OL}}\right)}$$

CFB: Bandwidth Independent of Gain



Loop gain is a function of the open-loop transimpedance, Z_{OL} , and the **feedback transimpedance**, $(R_F + R_i \cdot \text{Noise Gain})$, of the amplifier.

If $R_F = 1 \text{ k}\Omega$ and $R_i = 50\Omega$, and the amplifier is configured in a gain of 5V/V , then the feedback transimpedance is $(1000\Omega + 5\text{V/V} \cdot 50\Omega) = 1250 \Omega$

The noise gain scaling term $(5\text{V/V} \cdot 50\Omega = 250 \Omega)$ has a relatively insignificant effect on the magnitude of the numerator in the loop gain equation.

$$I_N + \frac{V_{OUT} - V_{IN-}}{R_F} = \frac{V_{IN-}}{R_G}$$

Also,

$$V_{IN-} = \alpha \cdot V_{IN+} - I_N \cdot R_i$$

$$\text{and, } V_{OUT} = I_N \cdot Z_{OL}$$

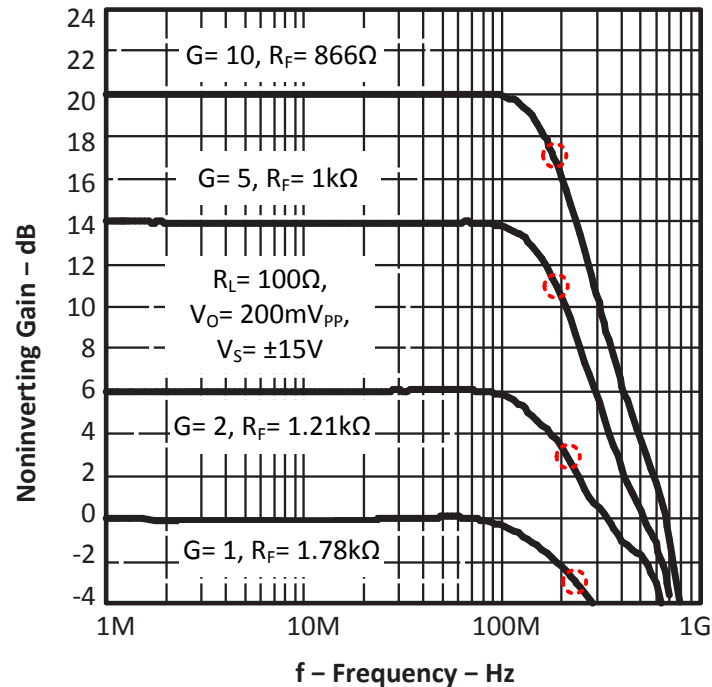
After further simplification,

$$\text{Closed Loop Gain, } A_{CL} = \frac{V_{OUT}}{V_{IN+}} = \frac{\alpha \cdot (1 + \frac{R_F}{R_G})}{1 + \frac{R_F + R_i \cdot (1 + \frac{R_F}{R_G})}{Z_{OL}}}$$

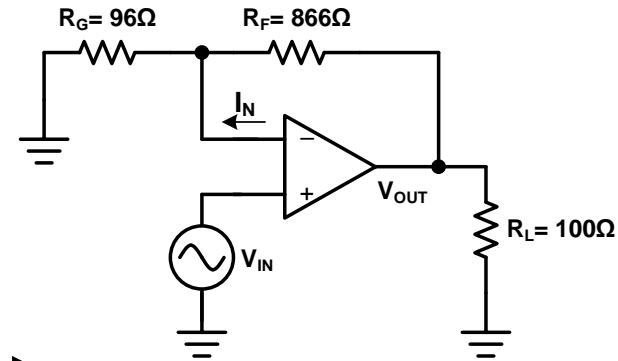
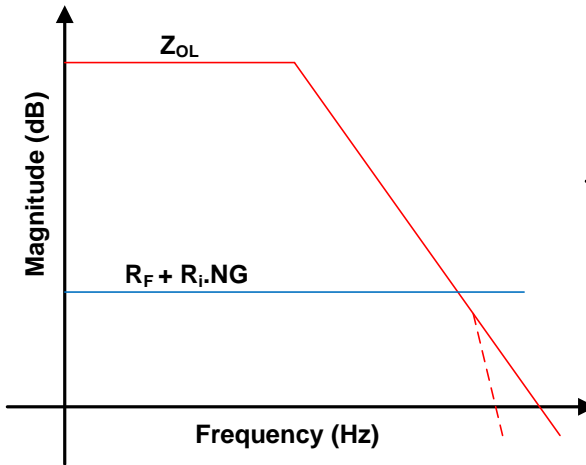
$$\alpha \approx 1 \text{ and } (1 + \frac{R_F}{R_G}) = \text{Noise Gain, NG}$$

$$A_{CL} = (1 + \frac{R_F}{R_G}) \cdot \frac{1}{1 + \frac{(R_F + R_i \cdot \text{NG})}{Z_{OL}}}$$

CFB: Bandwidth versus Gain and R_F



THS3091 Small-Signal Frequency Response versus Gain and R_F

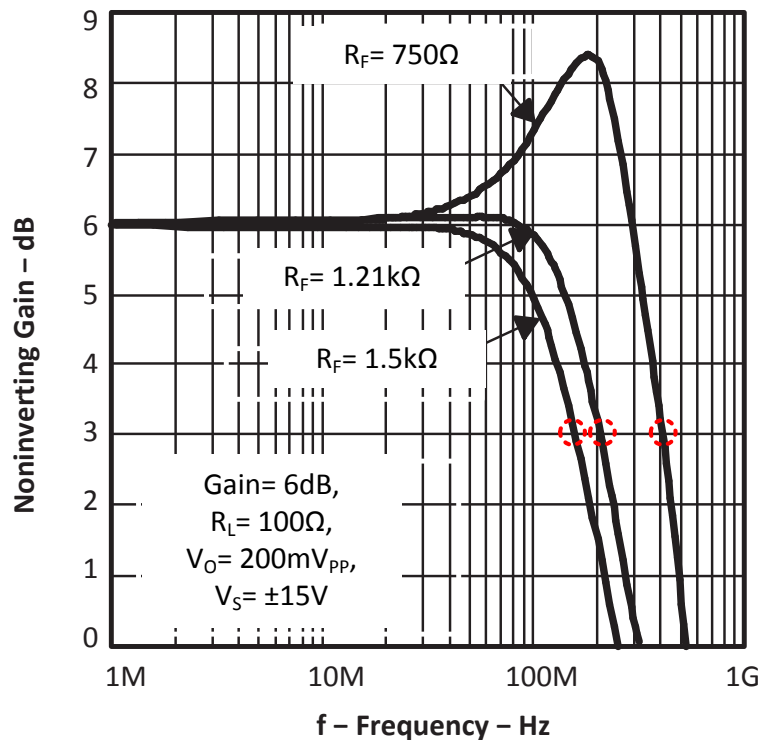


$$R_{LOAD} \parallel (R_F + (R_G \parallel R_i)) = 89.6\Omega$$

, assuming $R_i \ll R_G$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
AC PERFORMANCE					
Small-signal bandwidth, -3 dB	G = 1, R _F = 1.78 kΩ, V _O = 200 mV _{PP} , T _A = 25°C		235		MHz
	G = 2, R _F = 1.21 kΩ, V _O = 200 mV _{PP} , T _A = 25°C		210		
	G = 5, R _F = 1 kΩ, V _O = 200 mV _{PP} , T _A = 25°C		190		
	G = 10, R _F = 866 Ω, V _O = 200 mV _{PP} , T _A = 25°C		180		
0.1-dB Bandwidth flatness	G = 2, R _F = 1.21 kΩ, V _O = 200 mV _{PP} , T _A = 25°C		95		
Large-signal bandwidth	G = 5, R _F = 1 kΩ, V _O = 4 V _{PP} , T _A = 25°C		135		

CFB: Bandwidth versus Gain and R_F (Cont.)

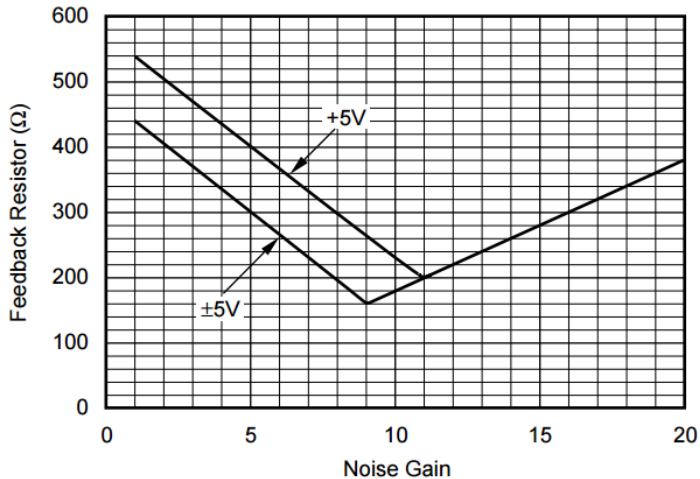


PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
AC PERFORMANCE						
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	$G = 10, R_F = 866 \Omega, V_O = 200 mV_{PP}$	$T_A = 25^\circ C$		180		
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Large-signal bandwidth	$G = 5, R_F = 1 k\Omega, V_O = 4 V_{PP}$	$T_A = 25^\circ C$		135		

$$\text{Feedback Transimpedance} = (R_F + R_i \times \text{NoiseGain})$$

THS3091 Small-Signal Frequency Response versus R_F

OPA691 Recommended Gain vs. R_F



$$\text{Feedback Transimpedance} = (R_F + R_i \times \text{NoiseGain})$$

Using the Feedback transimpedance equation for gains of 2V/V and 5V/V:

$$400\Omega + (2 \cdot R_i) = 300\Omega + (5 \cdot R_i)$$

$$\Rightarrow R_i = 33.33 \Omega$$

Target Feedback transimpedance for OPA691:

$$400\Omega + (2 \cdot 35 \Omega) = 470\Omega$$

INPUT

Common-Mode Input Range⁽⁵⁾

Common-Mode Rejection

Noninverting Input Impedance

Inverting Input Resistance (R_i)

$V_{CM} = 0V$

Open-Loop

± 3.5
56
100 || 2
35

± 3.4
52

± 3.3
51

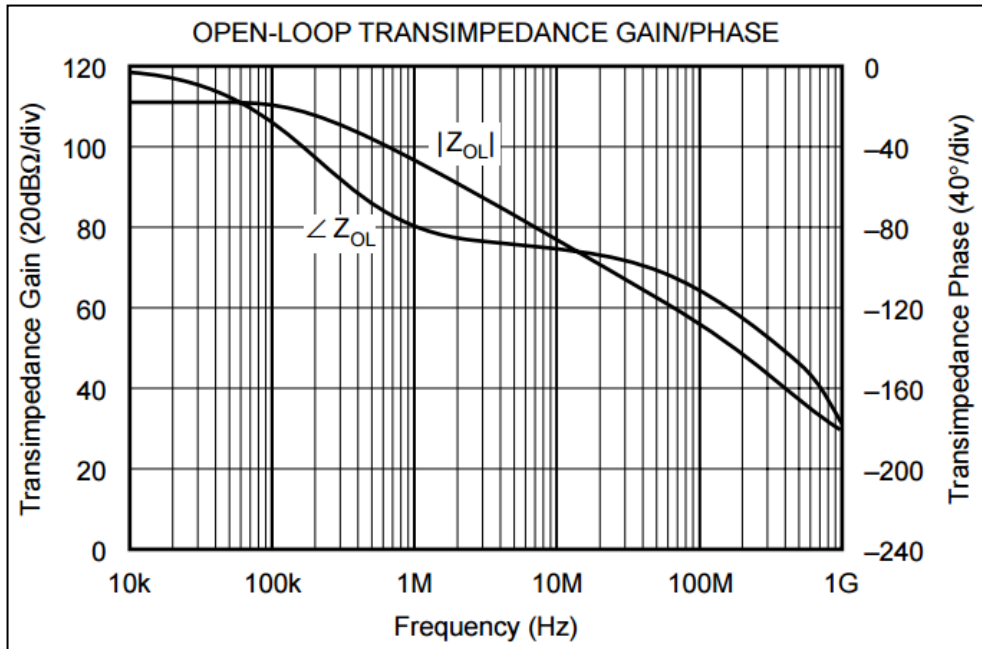
± 3.2
50

V
dB
k Ω || pF
 Ω

min
min
typ
typ

A
A
C
C

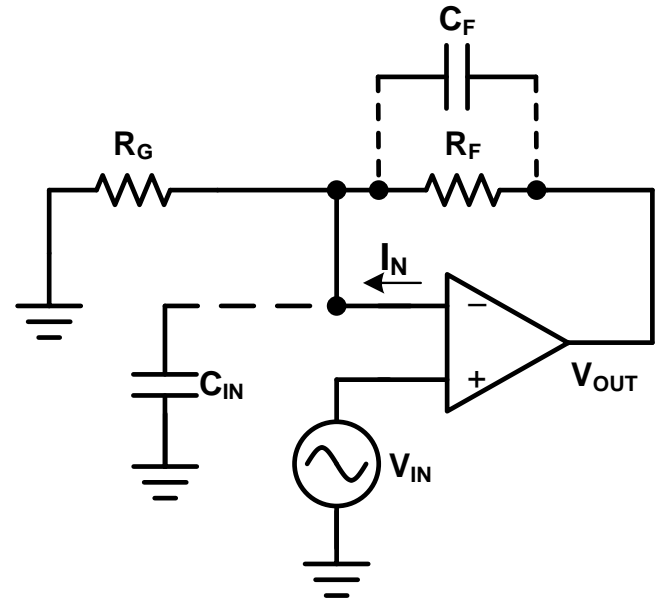
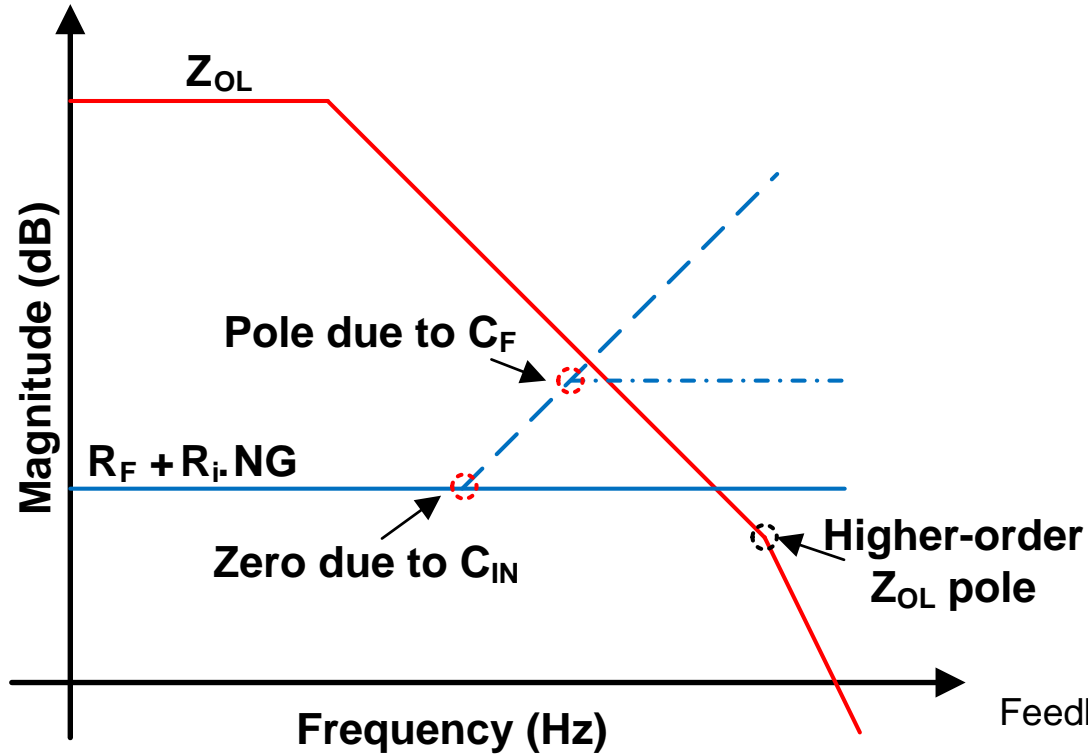
Estimating f_{-3dB} from Z_{OL} curve



Target Feedback transimpedance for OPA691:
 $400\Omega + (2 \cdot 35\Omega) = 470\Omega = 53.4\text{ dB}\Omega$

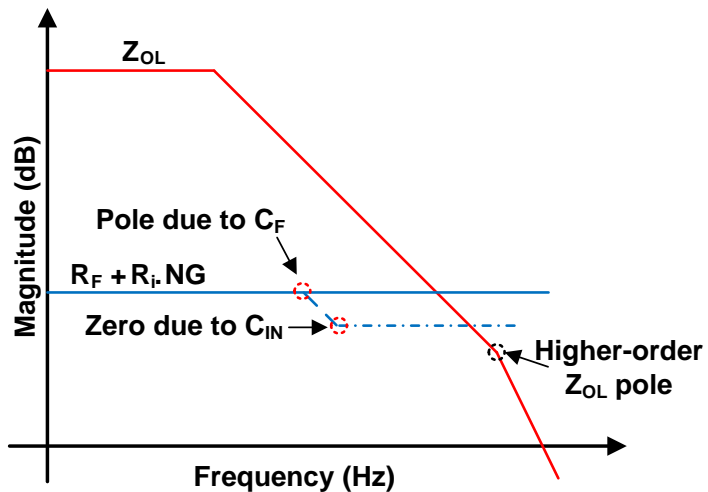
AC PERFORMANCE (see Figure 2)								
Small-Signal Bandwidth ($V_O = 0.5V_{PP}$)	$G = +1, R_F = 499\Omega$	210				MHz	typ	C
	$G = +2, R_F = 453\Omega$	190	168			MHz	min	B
	$G = +5, R_F = 340\Omega$	180		160		MHz	typ	C
	$G = +10, R_F = 180\Omega$	155			140	MHz	typ	C

Effect of Input and Feedback Capacitance

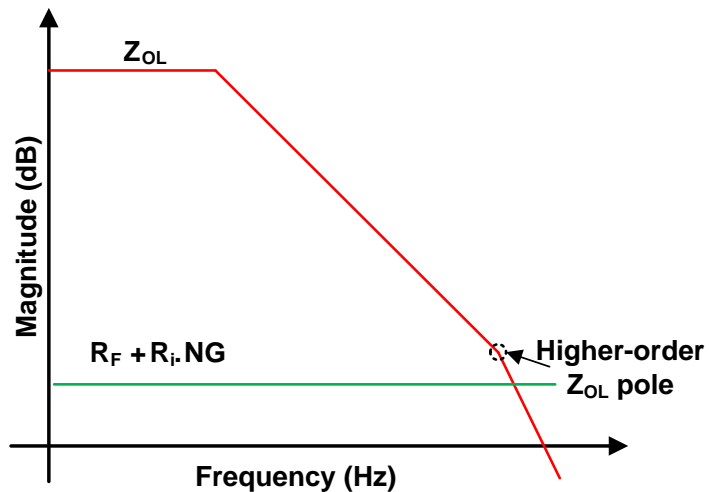


Feedback Transimpedance = $(R_F + R_i \times \text{NoiseGain})$

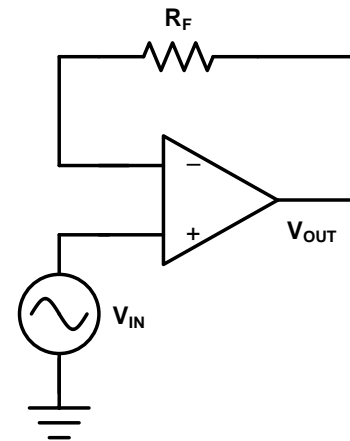
Effect of Non-Ideal R_F and C_F



Effect of $C_F \gg C_{IN}$



Effect of $R_F \ll$ Recommended datasheet value



Unity Gain Config.



Thanks for your time and please
take the quiz!