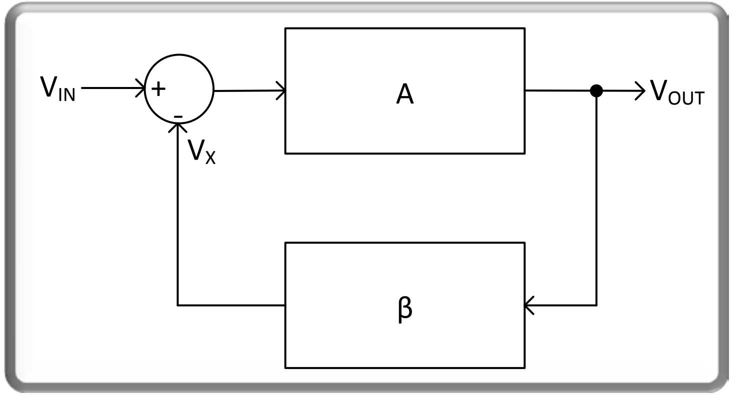
Fully Differential Amplifiers - 3

TIPL 2023

TI Precision Labs: Op Amps

Prepared and Presented by Samir Cherian

Control loop theory refresh



A ⇒ Forward open-loop gain of system

β ⇒ Reverse transfer function of feedback path

V_X ⇒ Fraction of system output fed back to input

$$V_{OUT} = A\left(V_{IN} - V_X\right)$$ 1

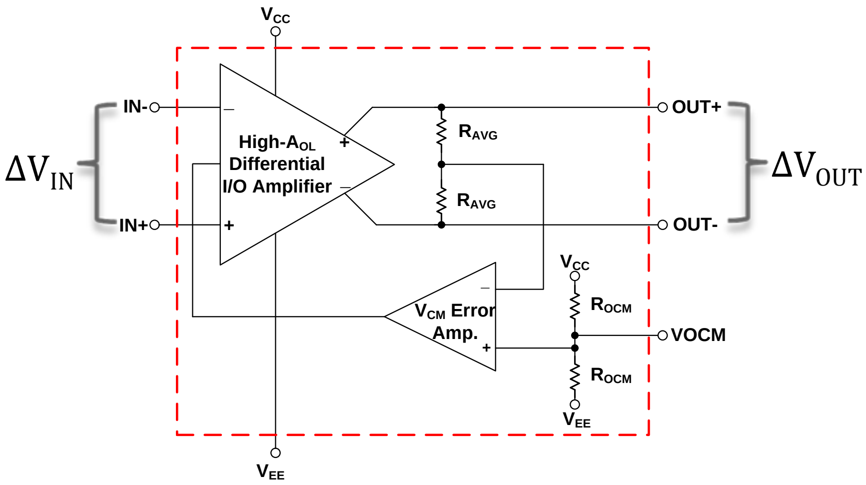
$$V_X = \beta \cdot V_{OUT}$$ 2

$$V_{OUT} = A\left(V_{IN} - \beta \cdot V_{OUT}\right)$$ 3

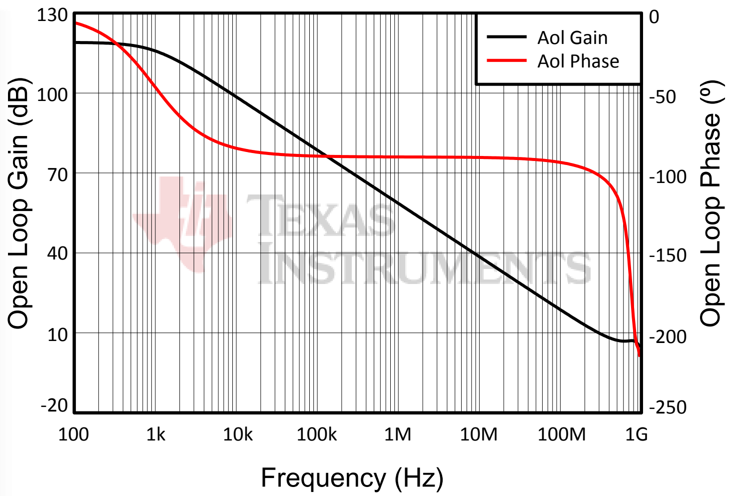
$$V_{OUT}\left(1 + A \cdot \beta\right) = V_{IN}$$

$$Gain = \frac{V_{OUT}}{V_{IN}} = \frac{A}{\left(1 + A \cdot \beta\right)}$$

Open-loop Gain (A_{OL}) of an FDA



THS4541 A_{OL} Curve



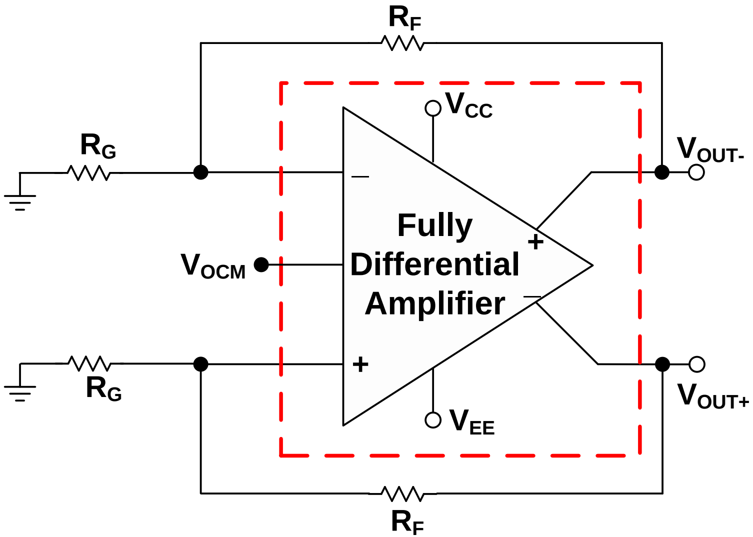
$$A_{CL} = \frac{A_{OL}}{1 + A_{OL}\beta},$$

A_{OL} and A_{CL} are the amplifiers open and closed-loop gain respectively,

β is the Feedback factor (AND) $\frac{1}{\beta}$ is the Noise Gain.

Gain-bandwidth product	V_{OUT} = 100 mV_{PP}, G = 20	850	MHz

Signal Gain vs. Noise Gain



$$\text{Signal Gain} = -\frac{R_F}{R_G}$$

$$\beta = R_G/(R_F+R_G)$$

$$A_{CL} = \frac{A_{OL}}{1+A_{OL}\beta}, \text{ As } A_{OL} \to \infty, \quad A_{CL} = \frac{1}{\beta}.$$

$$A_{OL}\beta \to \text{Loop Gain.}$$

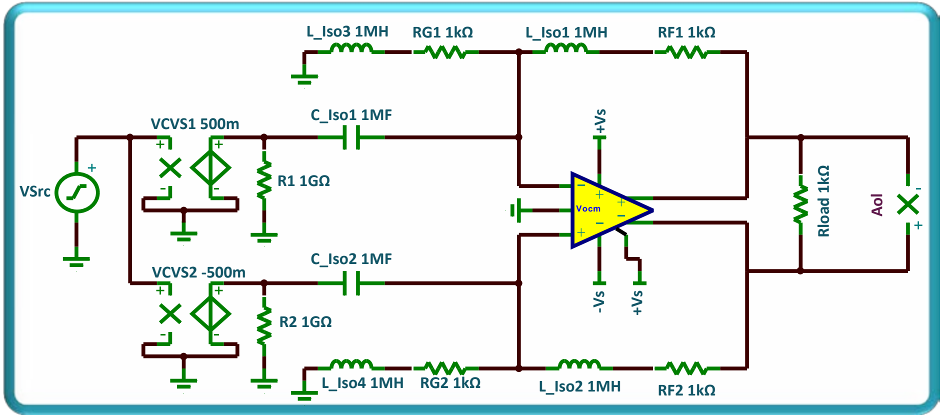
Frequency @ which $|A_{OL}\beta| = 1$, is the (A_{CL}) -3dB BW

$$\text{Noise Gain} = \frac{1}{\text{Feedback Factor}}$$

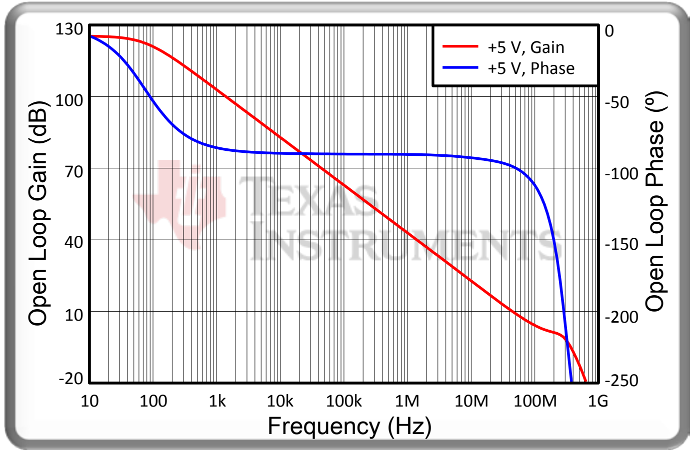
$$\text{Noise Gain} = \frac{1}{\beta} = 1+\frac{R_F}{R_G}$$

$$\text{Signal Gain} \neq \text{Noise Gain}$$

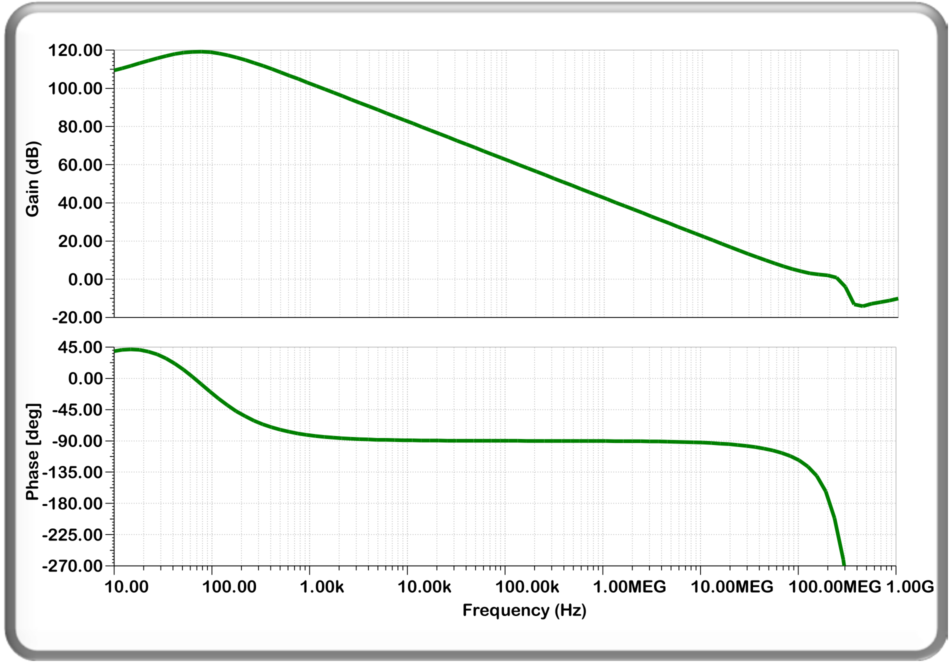
Simulating the A_{OL} of an FDA



THS4551 A_{OL} Curve



TINA Simulated THS4551 A_{OL} Curve



Loop Gain

Barkhausen Stability Criterion

$$A_{CL} = \frac{A_{OL}}{1 + A_{OL}\beta},$$

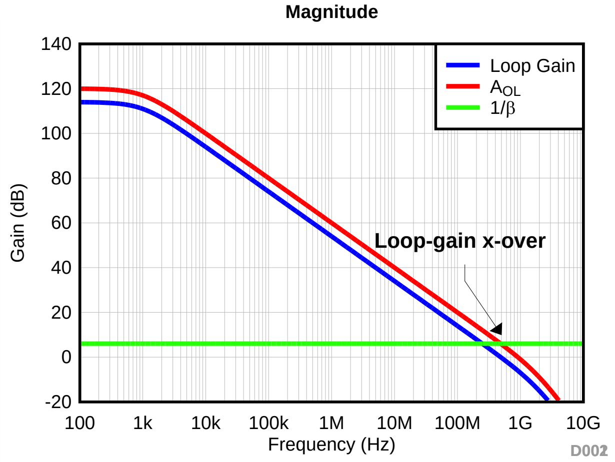
When $|A_{OL}\beta| = 1$, and phase shift around the loop is 180°,

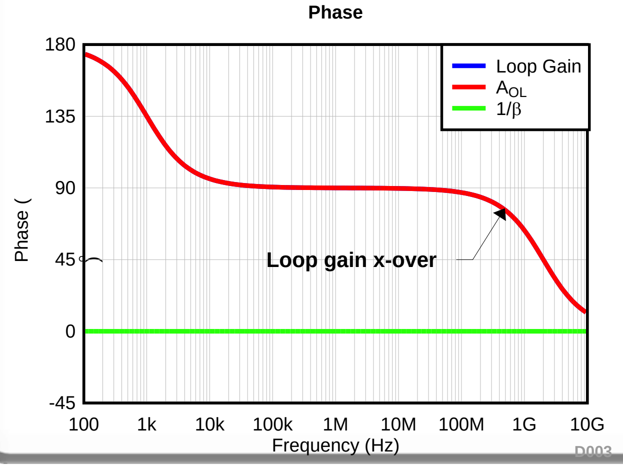
$$A_{CL} = \frac{A_{OL}}{1-1} = \infty$$

the denominator is unbounded and the system is unstable.

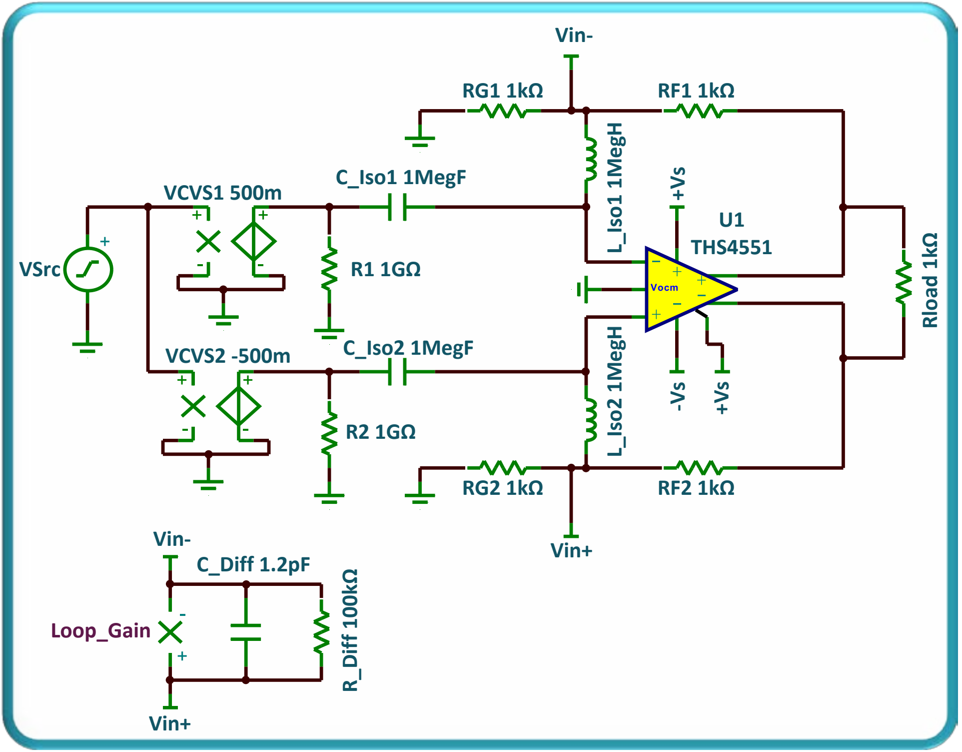
$$\text{Loop Gain } = A_{OL}\beta = \frac{A_{OL}}{\left(\frac{1}{\beta}\right)} = \left(\left(A_{OL}\right) - \left(\frac{1}{\beta}\right)\right)_{dB}$$

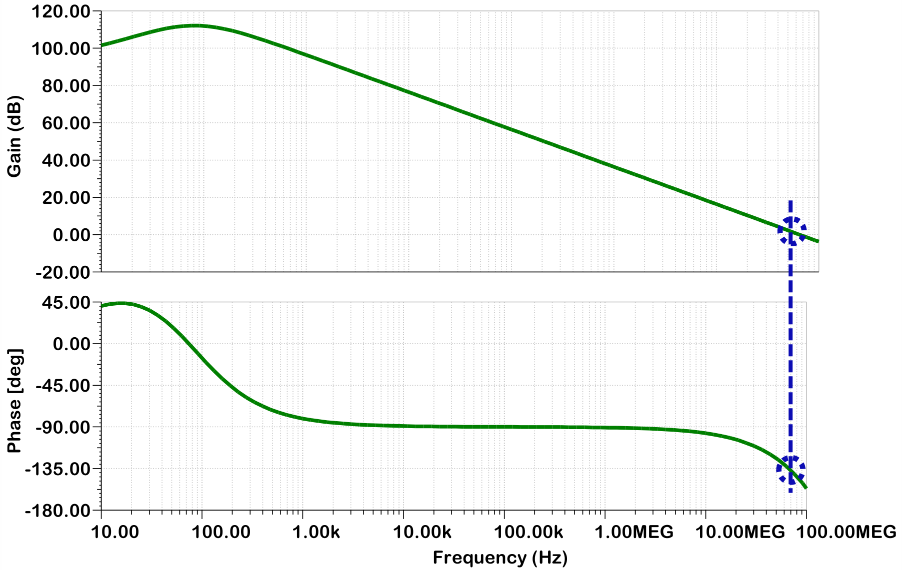
Loop Gain crossover occurs when $|A_{OL}\beta| = 1, \Rightarrow |A_{OL}| = \left|\frac{1}{\beta}\right|$





Simulating the Loop Gain in TINA-TI





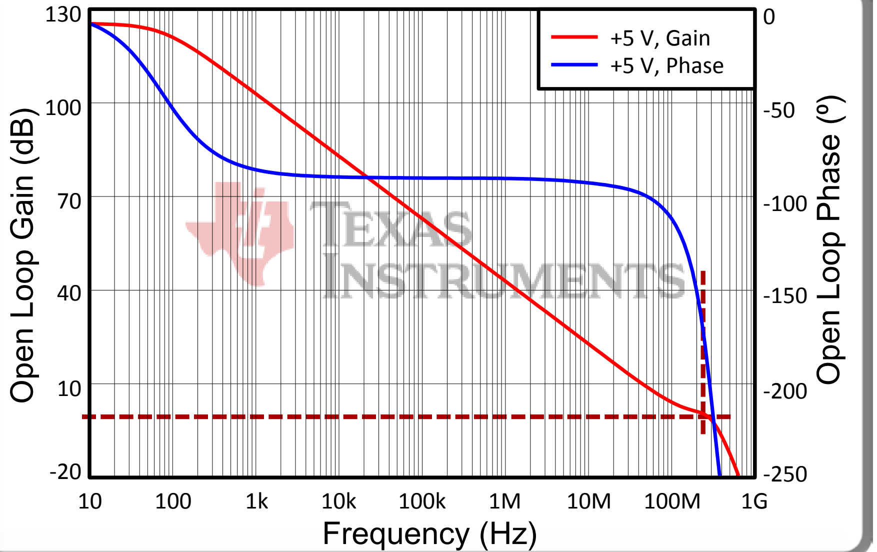
Input Impedance Differential Mode	Input pins at $[(V_{S+})-(V_{S-})]/2$	100‖1.2	kΩ ‖ pF

FDAs Configured as Attenuators

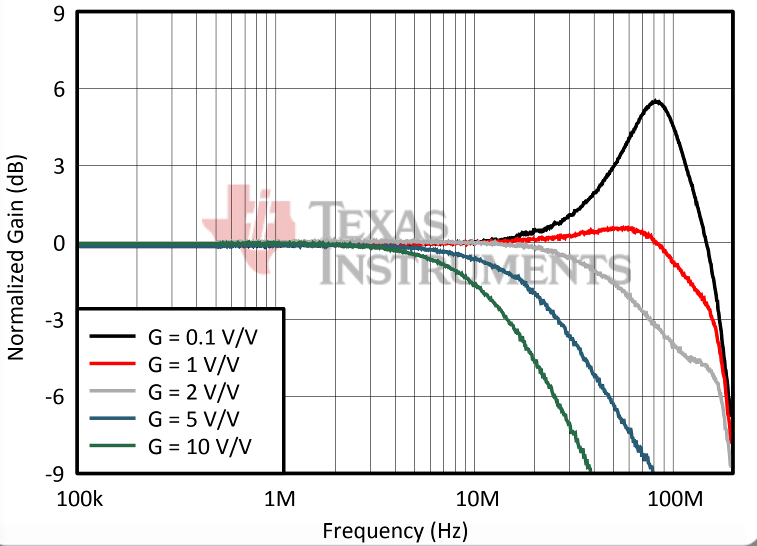
Signal Gain $=-R_F/R_G = -0.1$ V/V

Noise Gain $= 1+R_F/R_G = 1.1$ V/V

THS4551 A_{OL} Curve

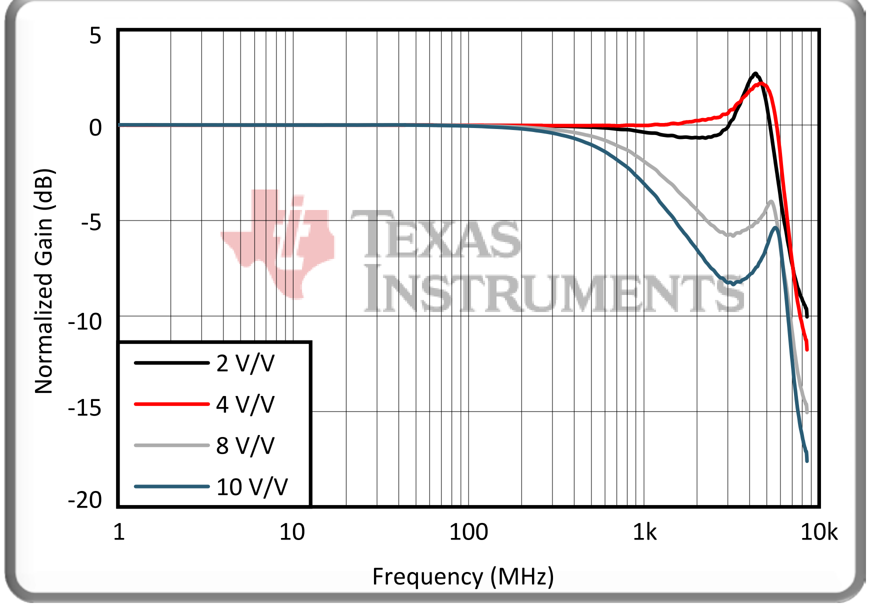


THS4551 Frequency Response



Decompensated FDAs

LMH5401 Frequency Response



	OPA656	OPA657
I_Q (mA)	14	14
Voltage Noise (nV/√Hz)	7	4.8
Bandwidth G = 10V/V (MHz)	23	275
Slew Rate (V/µs)	290	700

TIDesigns

TI Designs: TIDA-00522 Reference Guide

Stabilizing Differential Amplifiers as Attenuators

TIDA-00522

Texas Instruments

Fully Differential Amplifiers - 3

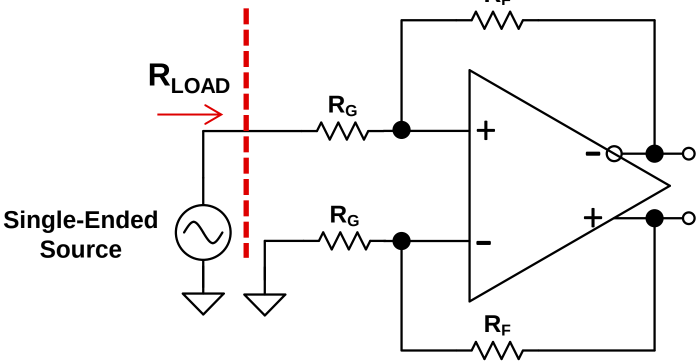
Exercises

TI Precision Labs: Op Amps

Questions

1. How would you AC couple a single-ended input source to an FDA?

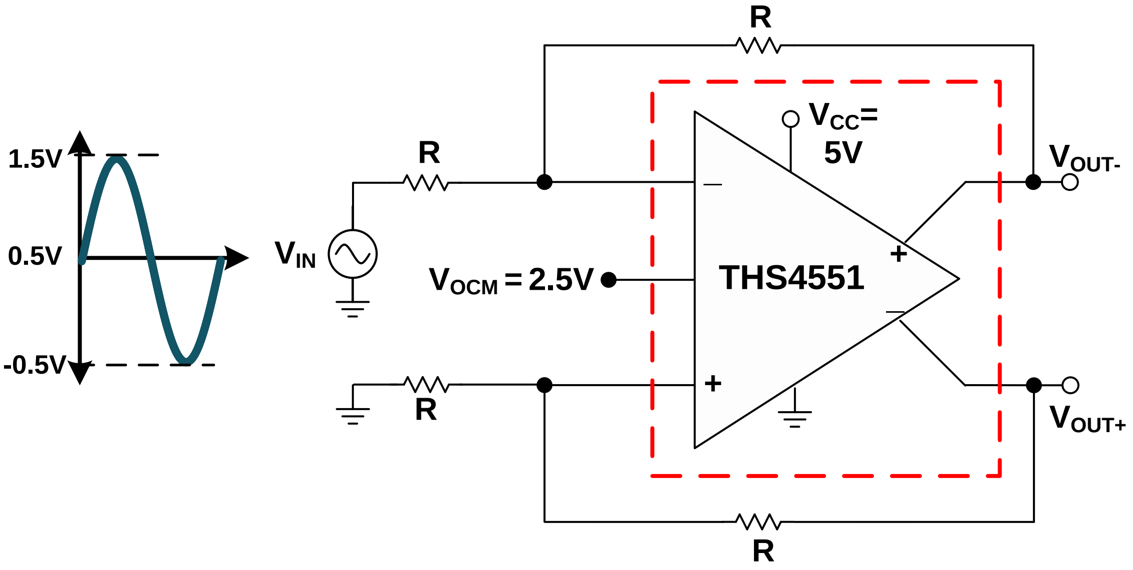
2. What is the load seen by the single-ended input source? (HINT: It is not R_G). Assume that both the VOCM = 0V and the input signal common-mode is 0V.



3. For the circuit shown below what is the,

- Output signal (differential and common-mode), and
- Input signal (differential and common-mode)

(HINT: The signal input common-mode is 0.5V while the non-driven input is at GND.)



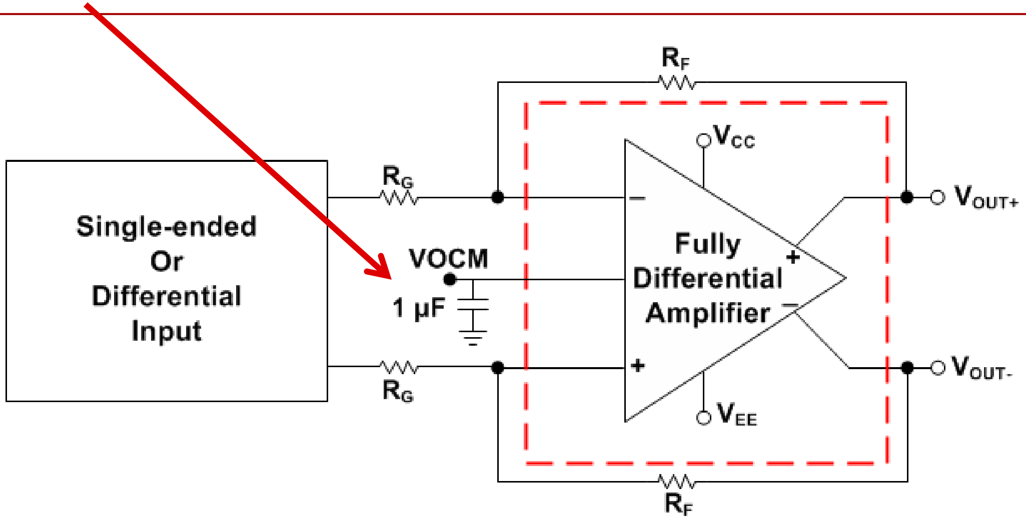
Answers

1. How would you AC couple a single-ended input source to an FDA?

The circuit is shown below. This circuit configuration is useful when the DC and low-frequency signal content can be ignored. If the single-ended input common-mode is not GND, then using this circuit configuration precludes the need for a 2nd opamp to match the common-mode of the input signal.

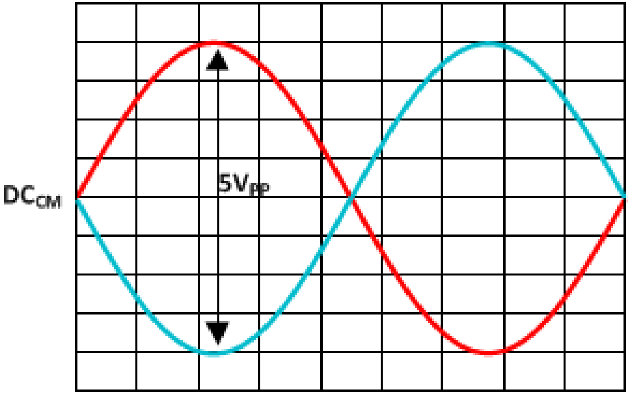
2. An FDA circuit is setup as shown below. The desired VOCM is equal to mid-supply which occurs by default due to the internal resistors. What would you change in the design in order to minimize the noise from the internal resistors.

Answer: Add a large external capacitor (1nF to 1μF) to the VOCM pin. This will act as a low impedance path at high frequencies and shunt the noise from the internal resistors to GND.



3. An FDA is operating on 5V supplies and its outputs have the ability to swing rail-to-rail. What is the maximum differential output voltage of the FDA (assume a sinusoidal signal)?

Single-ended output signal



Answer: Since each single-ended output signal can swing completely between the amplifiers supplies, each output's is capable of a $5V_{PP}$ swing.

Since the two outputs are 180^0 out of phase with each other the **Differential Output Swing = 2* $5V_{PP}$ = $10V_{PP}$**