# Fully Differential Amplifiers - 4

## Exercises

## TI Precision Labs: Op Amps

# Questions

1. The 1.9 GHz THS4509 fully-differential amplifier is configured in a signal gain of 2V/V (6dB).
   a) What is the output noise contribution due to the amplifiers inherent voltage noise?
   b) How large should the feedback resistor $R_F$ be for the total current noise contribution to be equal to the total amplifier voltage noise?

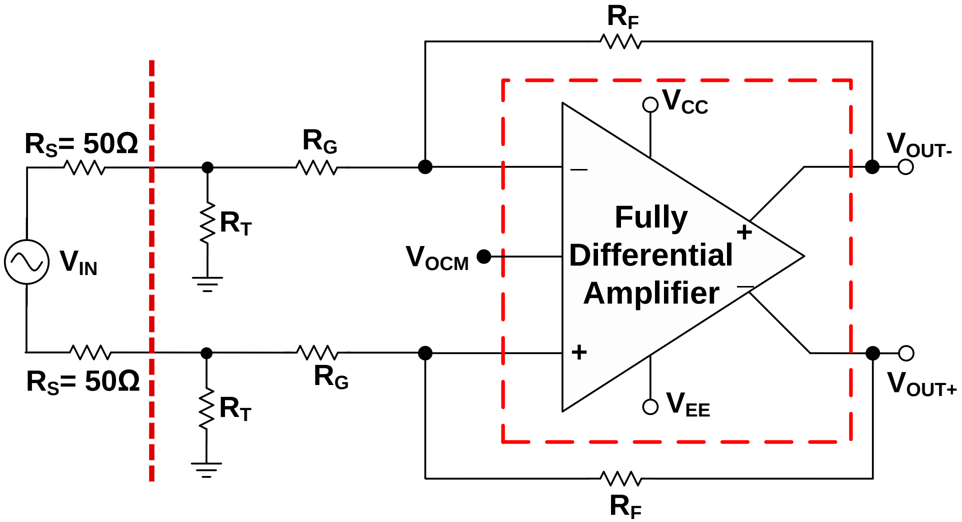
2. For an FDA with the specifications and configuration shown below, at what frequency is the noise gain zero located?

| Parameter | Specification | Units |
|---|---|---|
| Feedback Resistance, $R_F$ | 10 | kΩ |
| Signal Gain | 5 | V/V |
| Amplifier differential input capacitance, $C_{AMP\_D}$ | 2 | pF |
| Amplifier common-mode input capacitance, $C_{AMP\_C}$ | 1 | pF |
| Parasitic PCB capacitance at each amplifier input, $C_{PCB}$ | 0.5 | pF |

3. An FDA is configured as a differential in to differential out amplifier. It is driven by a differential source with 50Ω source impedance (on each side).

a) If the amplifier is configured in a gain of 10V/V, what is the value of $R_T$, $R_G$ and $R_F$?

b) If the amplifier is in a gain of 10V/V and $R_F$ = 10 kΩ what is the value of $R_T$ and $R_G$?



# Answers

1. The 1.9 GHz THS4509 fully-differential amplifier is configured in a signal gain of 2V/V (6dB).
   a) What is the output noise contribution due to the amplifiers inherent voltage noise?
   b) How large should the feedback resistor $R_F$ be for the total current noise contribution to be equal to the total amplifier voltage noise?

a) The THS4509 noise specification from the datasheet is shown below:

| Parameter | Typical value | Unit |
|---|---|---|
| Input voltage noise | 1.9 | nV/√Hz |
| Input current noise | 2.2 | pA/√Hz |

Since the amplifier is in a signal gain of 2V/V, its noise gain is 3V/V and the total output noise is = 3 × 1.9 nV/√Hz = **5.7 nV/√Hz**

b) The output current noise contribution for each side $= I_{NOISE} \times R_F$. Since the noise on each side is uncorrelated the total noise at the output $= \sqrt{2} \times I_{NOISE} \times R_F$.

The value of feedback resistance that would therefore make the total current noise contribution equal the amplifiers voltage noise contribution is given by:

$$\sqrt{2} \times 2.2\ \text{pA}/\sqrt{\text{Hz}} \times R_F = 5.7\ \text{nV}/\sqrt{\text{Hz}}$$

$$\Rightarrow R_F = \frac{5.7\ \text{nV}/\sqrt{\text{Hz}}}{\sqrt{2} \times 2.2\ \text{pA}/\sqrt{\text{Hz}}} = 1832\ \Omega$$

2. For an FDA with the specifications and configuration shown below, at what frequency is the noise gain zero located?

| Parameter | Specification | Units |
|---|---|---|
| Feedback Resistance, $R_F$ | 10 | kΩ |
| Signal Gain | 5 | V/V |
| Amplifier differential input capacitance, $C_{AMP\_D}$ | 2 | pF |
| Amplifier common-mode input capacitance, $C_{AMP\_C}$ | 1 | pF |
| Parasitic PCB capacitance at each amplifier input, $C_{PCB}$ | 0.5 | pF |

The zero is located at : $$\frac{1}{2\pi\left(R_F \,||\, R_G\right)\left(2C_{DIFF\_IN} + C_{CM\_IN}\right)}$$

With $R_F$ = 10kΩ and Gain = 5V/V, $R_G$ = 2kΩ.

The total common-mode capacitance = $C_{AMP\_C}$ + $C_{PCB}$ = 1 pF + 0.5 pF = 1.5 pF

The noise gain zero is located at: $$\frac{1}{2\pi\left(10k\Omega \,||\, 2k\Omega\right)\left(2\cdot 2pF + 1.5pF\right)} = 17.4\text{ MHz}$$

3. An FDA is configured as a differential in to differential out amplifier. It is driven by a differential source with 50Ω source impedance (on each side).
   a) If the amplifier is configured in a gain of 10V/V, what is the value of $R_T$, $R_G$ and $R_F$?
   b) If the amplifier is in a gain of 10V/V and $R_F$ = 10 kΩ what is the value of $R_T$ and $R_G$?

a) The complicated equation shown in the training video is only needed in case of a single-ended to differential configuration. In a differential in to differential out configuration, the amplifiers input pins are fixed and therefore independent of the amplifiers gain configuration.

Therefore in this case $R_G$ = 50 Ω and $R_T$ can be left open. Since the signal gain is 10 V/V - $R_F$ = 50 Ω × 10 V/V = 500 Ω

b) If the amplifier is in a gain of 10V/V and $R_F$ = 10 kΩ what is the value of $R_T$ and $R_G$?

b) In this case the value of the feedback resistance is fixed so we have to work backwards.

With $R_F$ = 10 kΩ and a signal gain of 10 V/V -

$R_G$ = 10 kΩ / 10 V/V = 1 kΩ

The load seen by the source is therefore 1 kΩ. In order for the source to see a load of 50 Ω set the value of $R_T$ such that ($R_T$ || $R_G$) = 50 Ω.

$$\frac{R_T \times 1\ \text{k}\Omega}{R_T + 1\ \text{k}\Omega} = 50\ \Omega$$

$$\Rightarrow R_T = \ 52.6\ \Omega$$