Fully Differential Amplifiers - 1

TIPL 2021

TI Precision Labs: Op Amps

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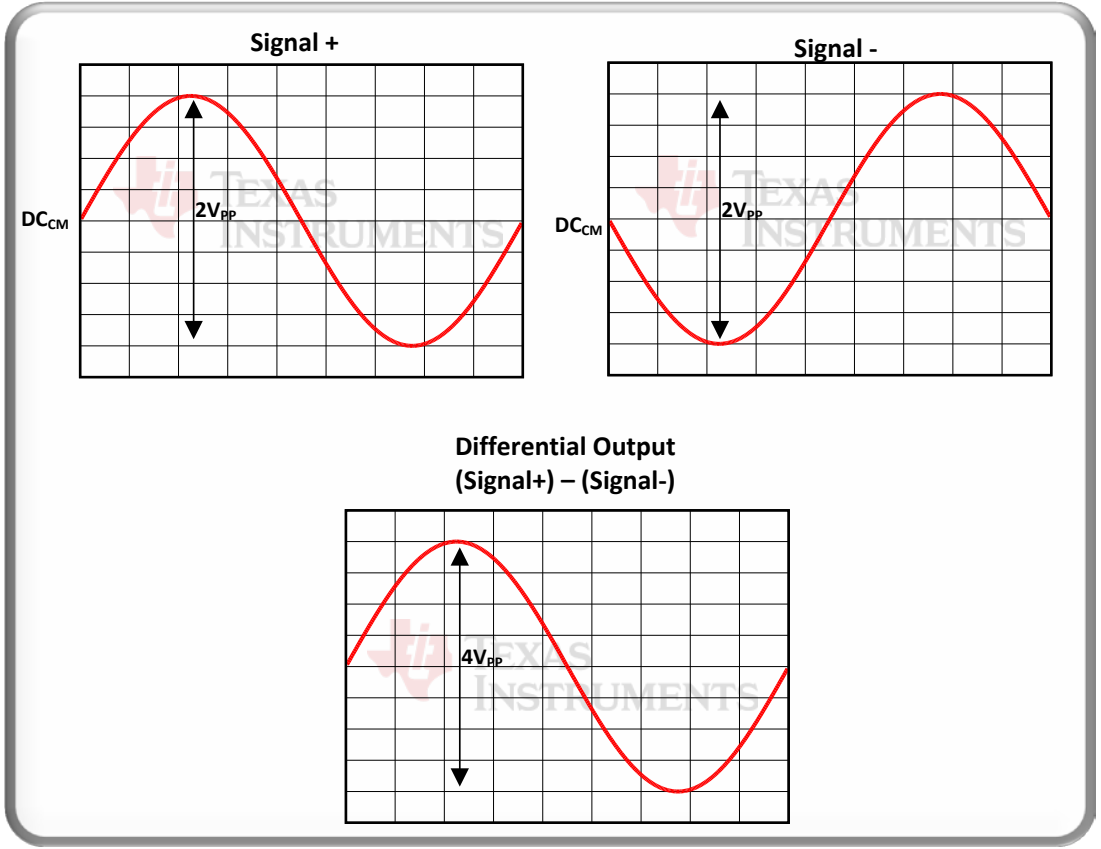
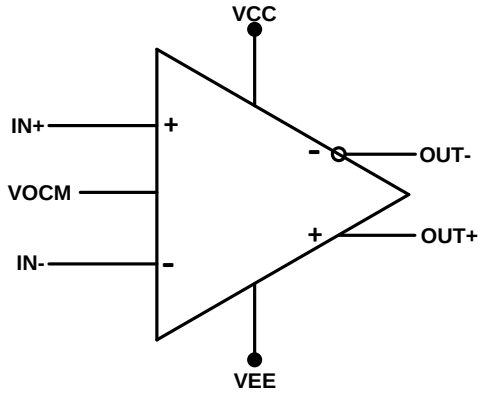
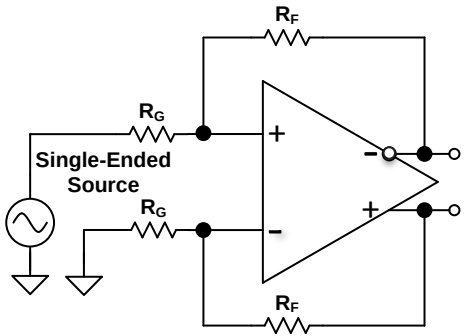
Fully-differential Signals and Their Advantages

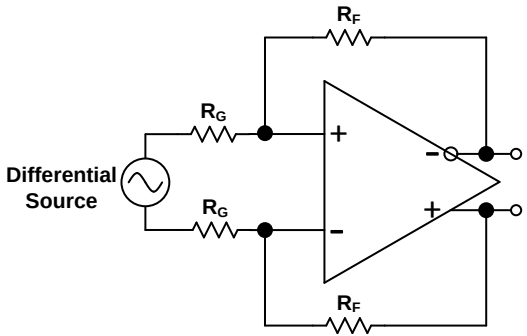
- Improved rejection of common-mode perturbations and noise.
- Improved even-order Harmonic Distortion performance.
- Improved dynamic range: 2x differential-output signal swing.



Fully-differential Amplifier (FDA): Introduction

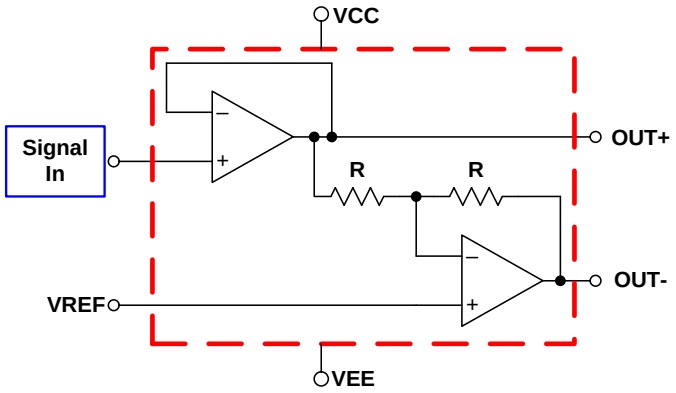






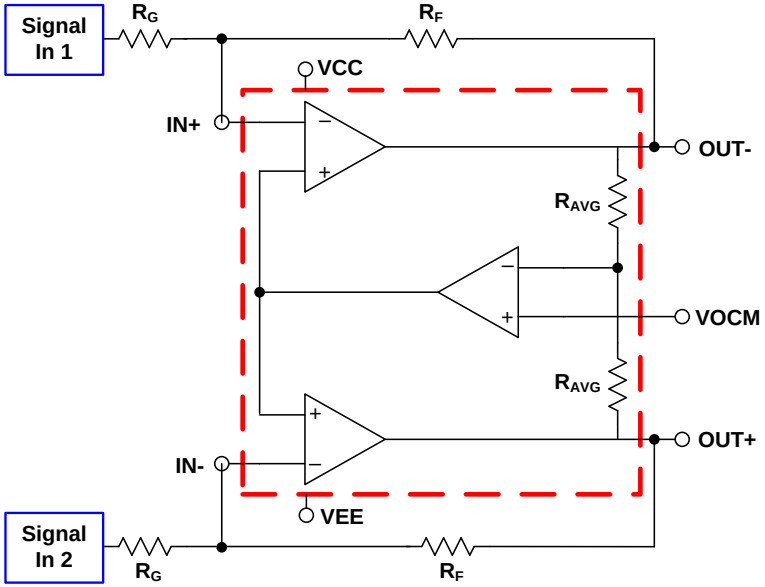
- Converts single-ended input to differential output.
- Converts differential input to differential output.
- Independent common-mode and differential gain control allows for output common-mode level shift

FDA: Discrete-amplifier Realization



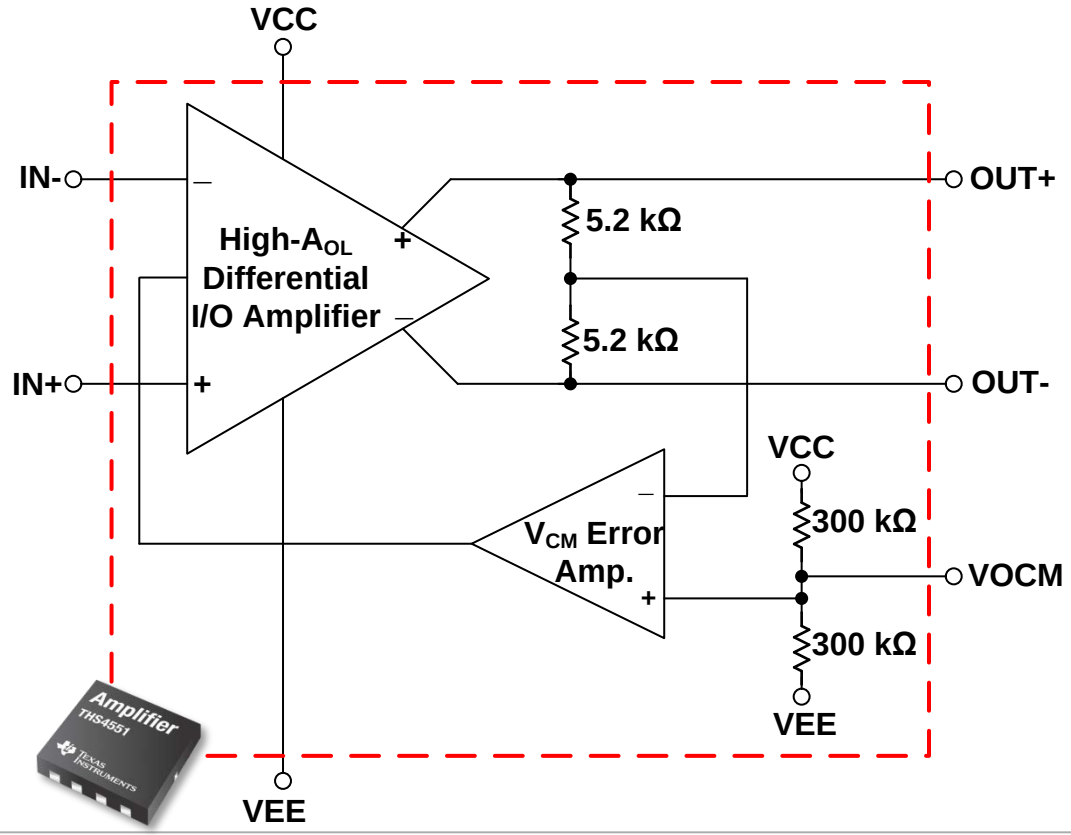
- High input impedance.
- Phase difference between inverting and noninverting outputs results in balance error.

$$E_{n\_Out} = \sqrt{E_{n\_Amp1}^2 + 4 \times E_{n\_Amp2}^2}$$



- Integrated solution can offer lower noise for same power consumption and better matching for reduced balance error.

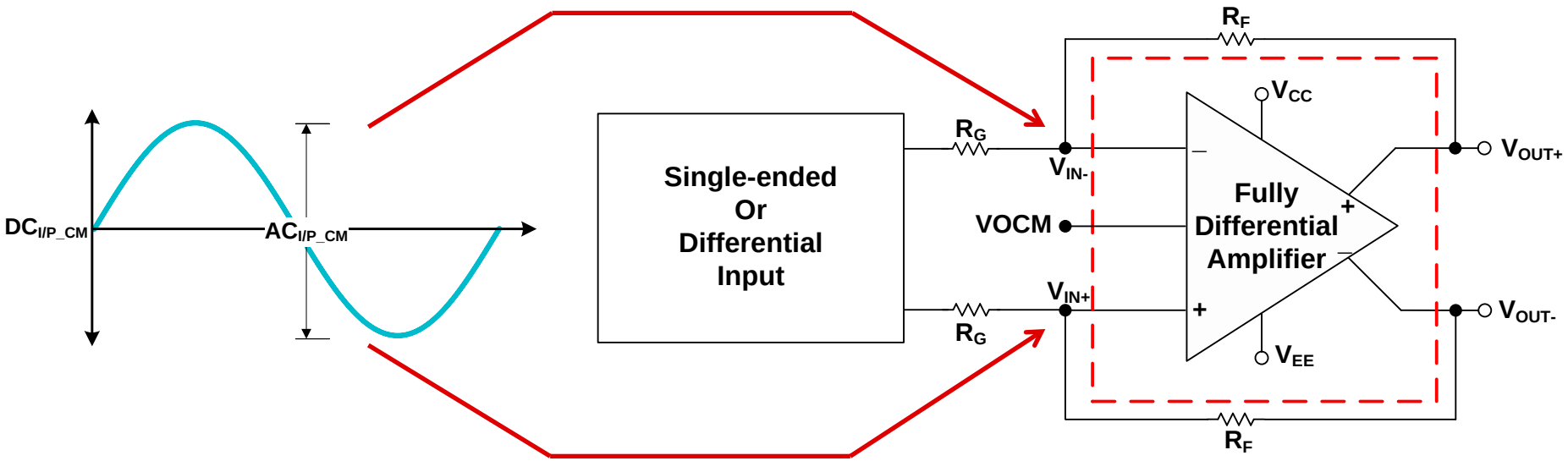
Integrated FDA: THS4551 Block Diagram



- Integrated fully-differential, high-A_{OL} amplifier.
- Integrated wide-bandwidth, common-mode feedback, error amplifier.
- Integrated resistors to detect the average output common-mode voltage.
- Integrated mid-supply, common-mode set resistors.

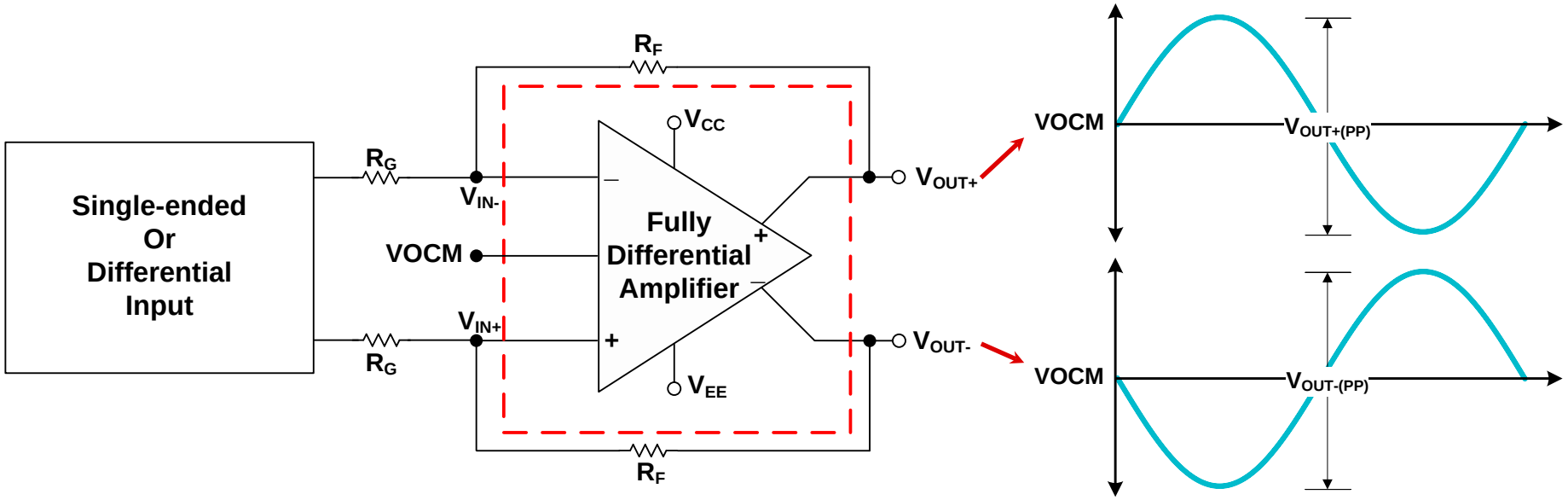
How an FDA Works: Rule 1 of 3

There are Three Golden Rules that determine how an FDA works



1 The voltage (DC and AC) at the inputs track each other exactly, similar to an op-amp's virtual short across its inputs.

How an FDA Works: Rules 2 and 3



2 The two outputs are 180º out of phase, AND

3 The two outputs have the same DC offset voltage equal to VOCM.

$$V_{OUT+}(t) - VOCM = -\left(V_{OUT-}(t) - VOCM\right)$$

$$VOCM = \frac{V_{OUT+}(t) + V_{OUT-}(t)}{2}$$

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Exercises

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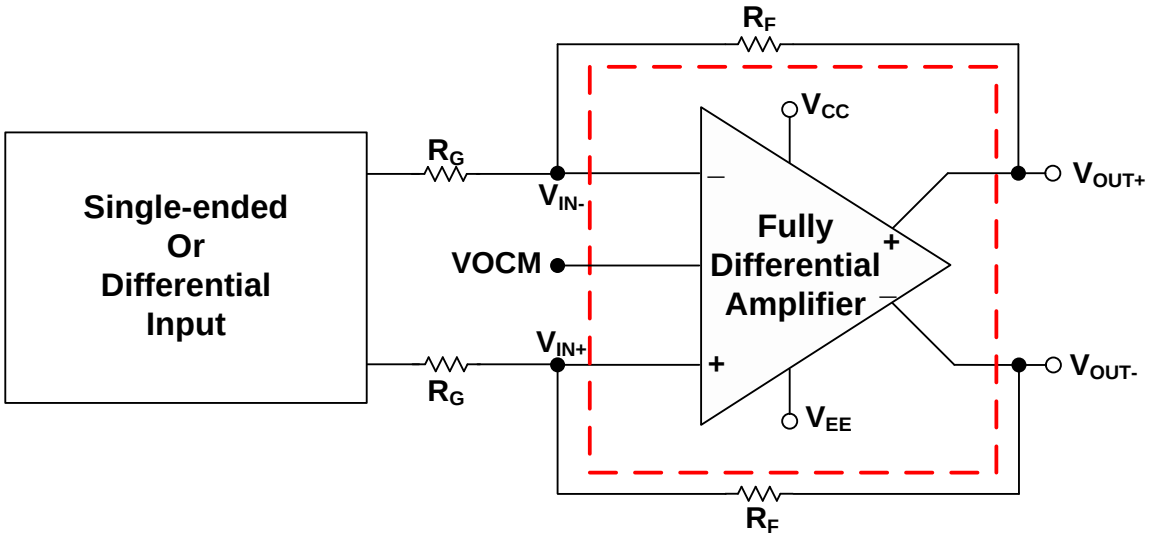
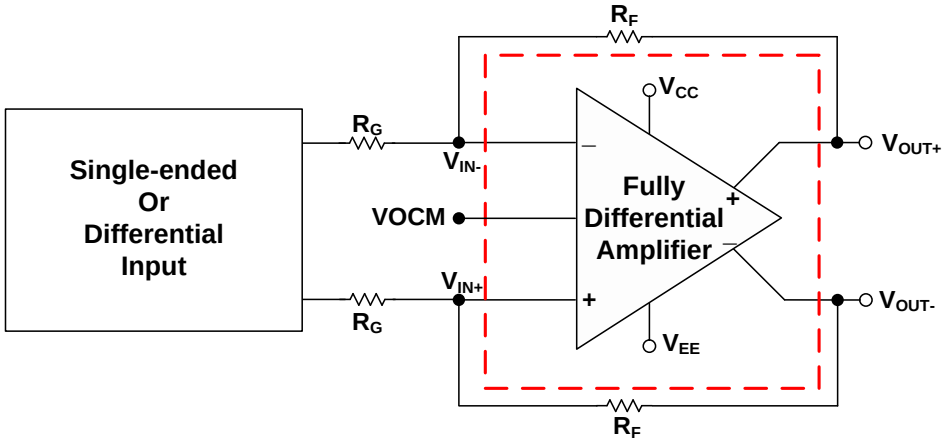
Questions

1. An FDA circuit has VOCM = 3V and its instantaneous differential output is equal to 0.5V. What is the instantaneous voltage at Vout+ and Vout-?



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.



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 and VOCM at mid-supply)?

Answers

1. An FDA circuit has VOCM = 3V and its instantaneous differential output is equal to 0.5V.

   What is the instantaneous voltage at Vout+ and Vout-?

VOCM by definition is the average of the two output voltages, so

$$VOCM = \frac{V_{OUT+}(t) + V_{OUT-}(t)}{2} = 3V$$

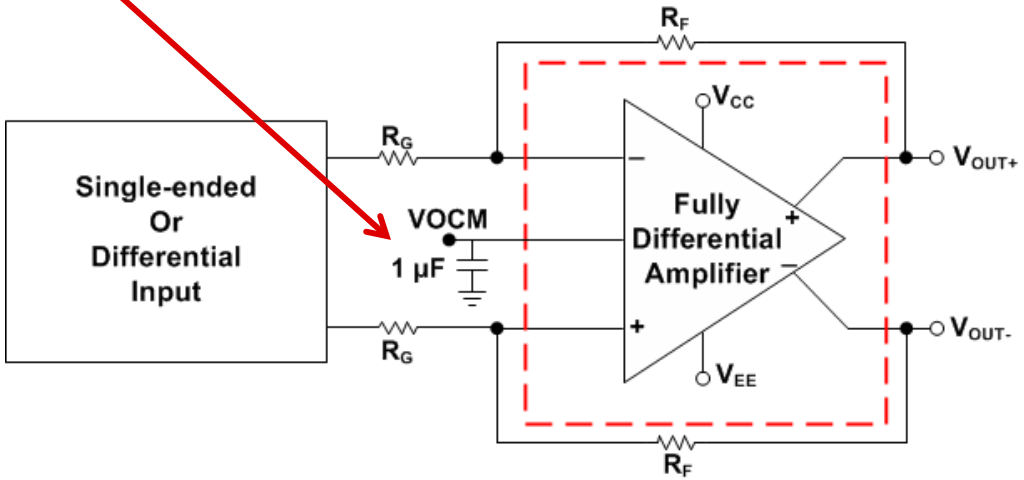
Also, the problem states that

$$V_{OUT+}(t) - V_{OUT-}(t) = 0.5V$$

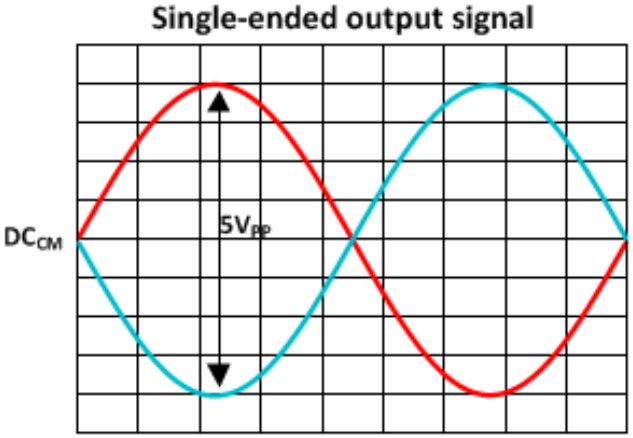
Solving the above two equations gives Vout+ and Vout- as 3.25V and 2.75V respectively.

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)?



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* $5V_{PP}$ =$10V_{PP}$**