

## Single-supply diff-in to diff-out AC amplifier circuit

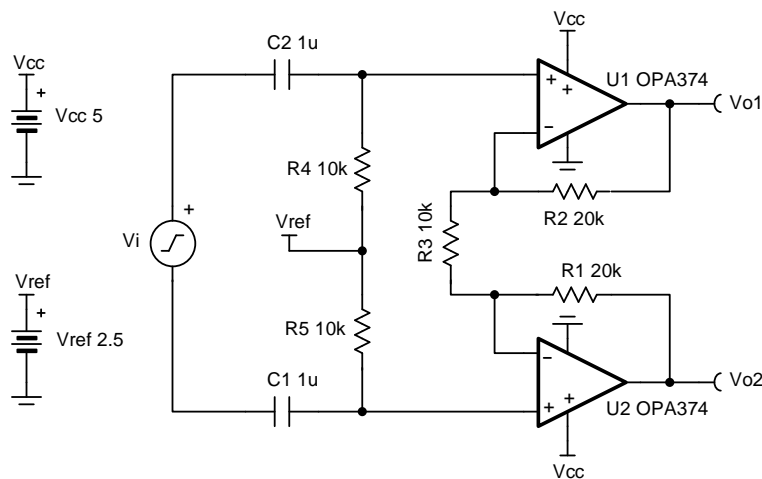
### Design Goals

Diff. Input $V_i$		Diff. Output ( $V_{o1} - V_{o2}$ )		Supply		
$V_{iMin}$	$V_{iMax}$	$V_{oMin}$	$V_{oMax}$	$V_{cc}$	$V_{ee}$	$V_{ref}$
-500mV	+500mV	-2.5V	+2.5V	+5	0V	+2.5V

Lower Cutoff Freq.	Upper Cutoff Freq.
16Hz	> 1MHz

### Design Description

This circuit uses 2 op amps to build a discrete, single-supply diff-in diff-out amplifier. The circuit converts a differential signal to a differential output signal.



### Design Notes

1. Ensure that  $R_1$  and  $R_2$  are well matched with high accuracy resistors to maintain high DC common-mode rejection performance.
2. Increase  $R_4$  and  $R_5$  to match the necessary input impedance at the expense of thermal noise performance.
3. Bias for single-supply operation can also be created by a voltage divider from  $V_{cc}$  to ground.
4.  $V_{ref}$  sets the output voltage of the instrumentation amplifier bias at mid-supply to allow the output to swing to both supply rails.
5. Choose  $C_1$  and  $C_2$  to select the lower cutoff frequency.
6. Linear operation is contingent upon the input common-mode and the output swing ranges of the discrete op amps used. The linear output swing ranges are specified under the Aol test conditions in the op amps data sheets

### Design Steps

1. The transfer function of the circuit is shown below.

$$V_{oDiff} = V_i \times G + V_{ref}$$

where  $V_i$  = the differential input voltage

$V_{ref}$  = the reference voltage provided to the amplifier

$$G = 1 + 2 \times \left(\frac{R_1}{R_3}\right)$$

2. Choose resistors  $R_1 = R_2$  to maintain common-mode rejection performance.

Choose  $R_1 = R_2 = 20 \text{ k}\Omega$  (Standard value)

3. Choose resistors  $R_4$  and  $R_5$  to meet the desired input impedance.

Choose  $R_4 = R_5 = 10 \text{ k}\Omega$  (Standard value)

4. Calculate  $R_3$  to set the differential gain.

$$\text{Gain} = 1 + \left(\frac{2 \times R_1}{R_3}\right) = 5 \frac{V}{V}$$

$$R_1 = R_2 = 20 \text{ k}\Omega$$

$$G = 1 + \frac{2 \times 20 \text{ k}\Omega}{R_3} = 5 \frac{V}{V} \rightarrow 5 \frac{V}{V} - 1 = \frac{40 \text{ k}\Omega}{R_3} = 4 \rightarrow R_3 = \frac{40 \text{ k}\Omega}{4} = 10 \text{ k}\Omega \text{ (Standard value)}$$

5. Set the reference voltage  $V_{ref}$  at mid-supply.

$$V_{ref} = \frac{V_{cc}}{2} = \frac{5V}{2} \rightarrow V_{ref} = 2.5V$$

6. Calculate  $C_1$  and  $C_2$  to set the lower cutoff frequency.

$$f_c = \frac{1}{2 \times \pi \times R_4 \times C_1} = 16 \text{ Hz}$$

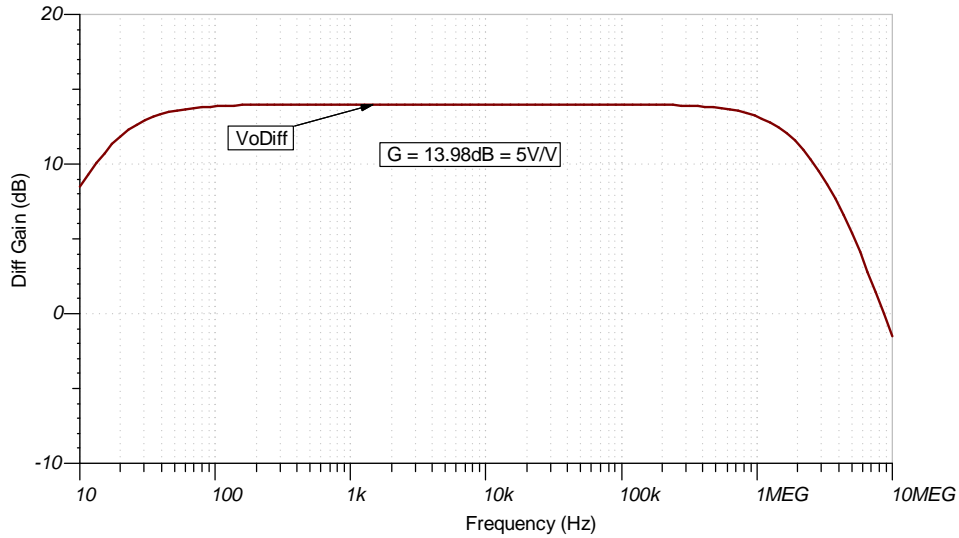
$$R_4 = R_5 = 10 \text{ k}\Omega$$

$$f_c = \frac{1}{2 \times \pi \times 10 \text{ k}\Omega \times C_1} = 16 \text{ Hz} \rightarrow C_1 = \frac{1}{2 \times \pi \times 10 \text{ k}\Omega \times 16 \text{ Hz}} = 0.99 \mu\text{F} \rightarrow C_1 = C_2 = 1 \mu\text{F} \text{ (Standard value)}$$

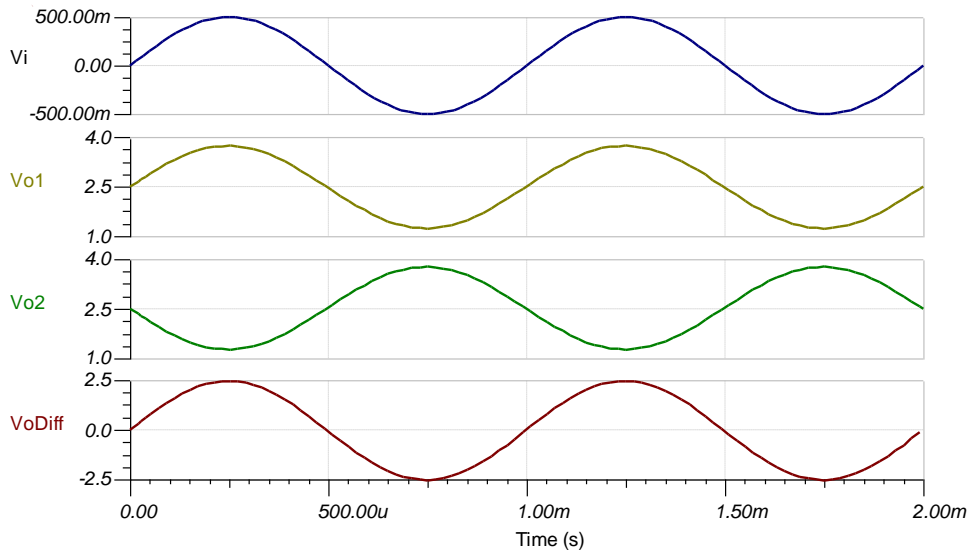
## Design Simulations

### AC Simulation Results

In the following figure, notice the lower  $-3$ -dB cutoff frequency is approximately 16Hz and the upper cutoff frequency is  $> 1$ MHz as required for this design.



### Transient Simulation Results



## References

1. [Analog Engineer's Circuit Cookbooks](#)
2. SPICE Simulation File [SBOMAU5](#).
3. [TI Precision Labs](#)

## Design Featured Op Amp

OPA374	
$V_{ss}$	2.3V to 5.5V
$V_{inCM}$	Rail-to-rail
$V_{out}$	Rail-to-rail
$V_{os}$	1mV
$I_q$	585 $\mu$ A/Ch
$I_b$	0.5pA
<b>UGBW</b>	6.5MHz
<b>SR</b>	5V/ $\mu$ s
<b>#Channels</b>	1,2,4
<a href="http://www.ti.com/product/opa374">www.ti.com/product/opa374</a>	

## Design Alternate Op Amp

TLV9061	
$V_{ss}$	1.8V to 5.5V
$V_{inCM}$	Rail-to-rail
$V_{out}$	Rail-to-rail
$V_{os}$	0.3mV
$I_q$	0.538mA
$I_b$	0.5pA
<b>UGBW</b>	10MHz
<b>SR</b>	6.5V/ $\mu$ s
<b>#Channels</b>	1,2,4
<a href="http://www.ti.com/product/tlv9061">www.ti.com/product/tlv9061</a>	

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