

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



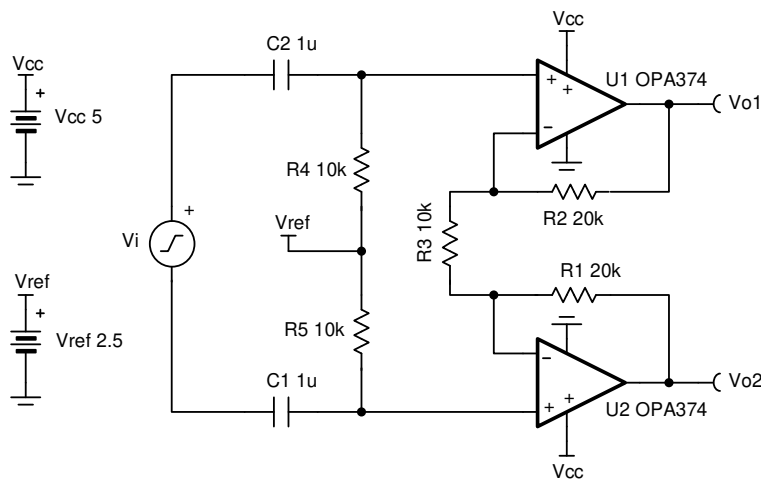
Design Goals

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.

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

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

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

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

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

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

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

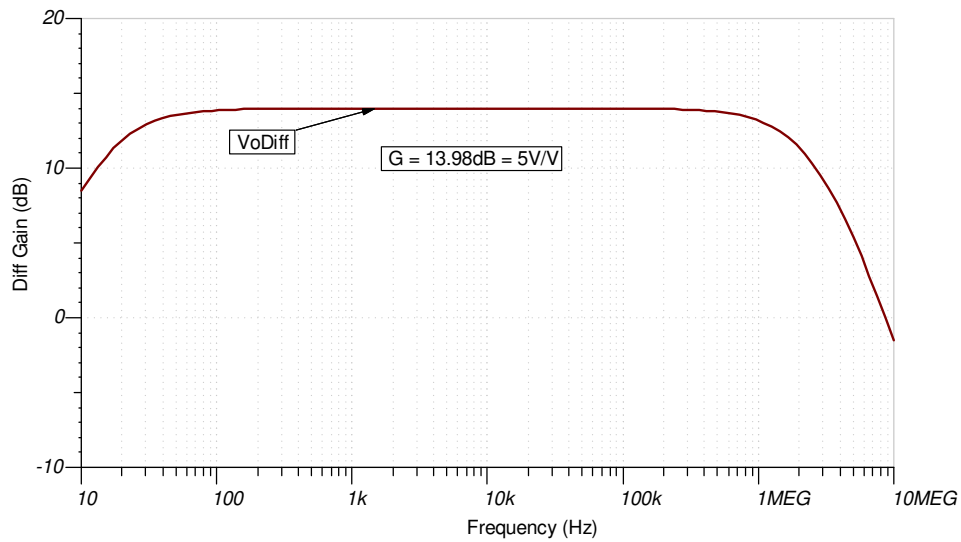
$$R_4 = R_5 = 10 \text{ k}\Omega$$

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

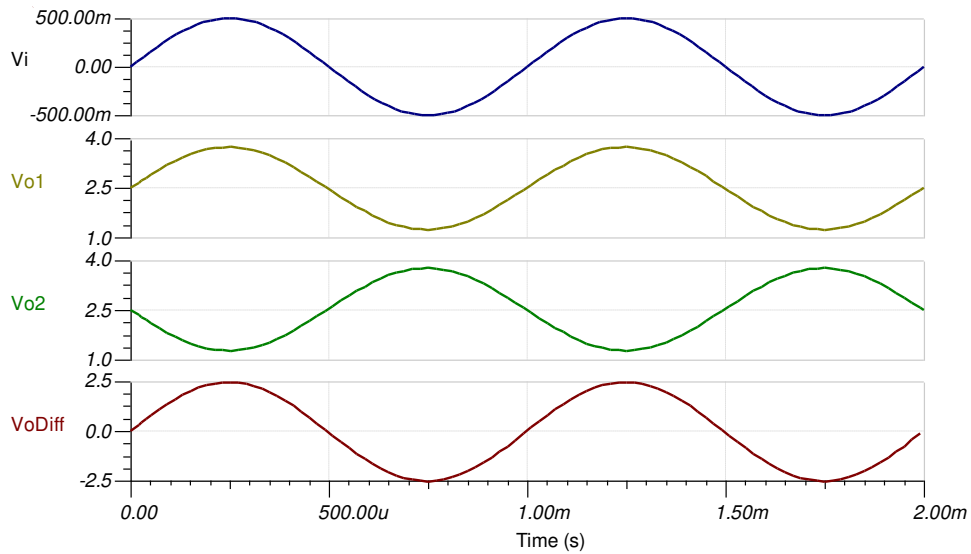
Design Simulations

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 μ A/Ch
I_b	0.5pA
UGBW	6.5MHz
SR	5V/ μ s
#Channels	1,2,4
www.ti.com/product/opa374	

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
UGBW	10MHz
SR	6.5V/ μ s
#Channels	1,2,4
www.ti.com/product/tlv9061	

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2023, Texas Instruments Incorporated