Analog Engineer's Circuit

Single-Ended Input to Differential Output Circuit Using a Fully-Differential Amplifier

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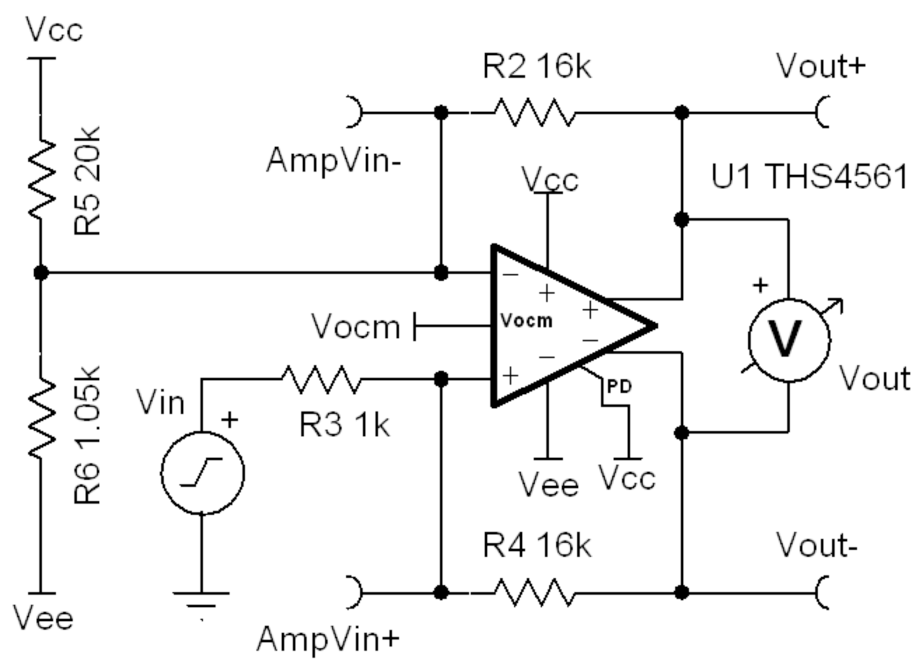
Design Goals

Input	Output	Supply	
Single-Ended	Differential	V_{cc}	V_{ee}
0 V to 1 V	16 Vpp	10 V	0 V

Output Common-Mode	3 dB Bandwidth	AC Gain (Gac)
5 V	3 MHz	16 V/V

Design Description

This design uses a fully-differential amplifier (FDA) as a single-ended input to differential output amplifier.



Design Notes

1. The ratio R_4/R_3, equal to $R_2/(R_5||R_6)$, sets the gain of the amplifier.
2. The main difference between a single-ended input and a differential input is that the available input swing is only half. This is because one of the input voltages is fixed at a reference.
3. It is recommended to set this reference to mid-input signal range, rather than the min-input, to induce polarity reversal in the measured differential input. This preserves the ability of the outputs to crossover, which provides the doubling of output swing possible with an FDA.
4. The impedance of the reference voltage must be equal to the signal input resistor. This can be done by creating a resistor divider with a Thevnin equivalent of the correct reference voltage and impedance.

Design Steps

- Find the resistor divider with that produces a 0.5V, 1-kΩ reference from Vs = 10V.

$$\frac{R_6}{R_5+R_6} \quad F \quad \frac{0.5V}{10V} \qquad \frac{R_5 \cdot R_6}{R_5+R_6} \quad E = 1\,k\Omega$$

$$R_6 \quad FR_5 + FR_6$$

$$R_6(1-F) \quad FR_5$$

$$R_5 \quad \frac{R_6(1-F)}{F}$$

$$\frac{R_6(1-F)/F \cdot R_6}{R_6(1-F)/F + R_6} \quad E$$

$$\frac{{R_6}^2 \cdot (1-F)/F}{(R_6/F - R_6) + R_6} \quad E$$

$$\frac{{R_6}^2 \cdot (1-F)/F}{R_6/F} \quad E$$

$$R_6 \cdot (1-F) \quad E$$

$$R_6 \quad \frac{E}{1-F} \quad \frac{1k\Omega}{1-0.05} = 1.05k\Omega$$

$$R_5 \quad \frac{1.05\Omega(1-0.05)}{0.05} \quad 20k\Omega$$

- Verify that the minimum input of 0 V and the maximum input of 1 V result in an output within the 9.4 V range available for V_{ocm} = 5 V.

  Since the resistor divider acts like a 0.5 V reference, the measured differential input for a 0 V V_{IN} is:

$$V_{IN} \quad 0V - 0.5V \quad -0.5V$$

- The output is:

$$-0.5V \cdot \frac{16V}{V} \quad -8V > -9.8V$$

- Likewise, for a 1 V input:

$$V_{IN} = 1V - 0.5V = 0.5V$$

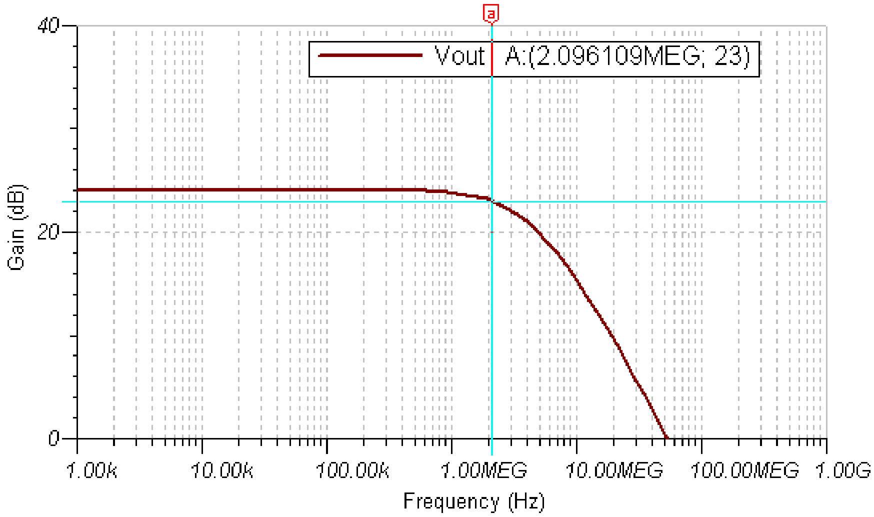
$$0.5V \cdot \frac{16V}{V} \quad 8V < 9.8V$$

Note

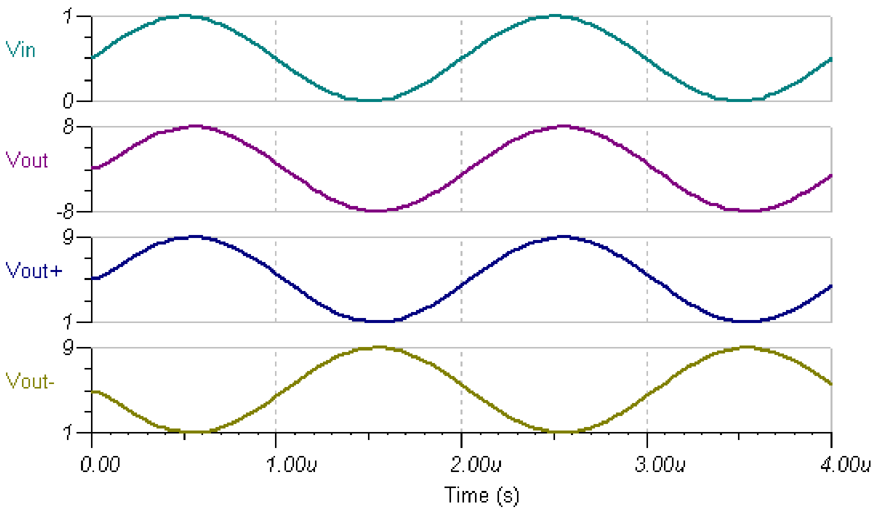
With a reference voltage of 0 V, a 1 V input results in an output voltage greater than the maximum output range of the amplifier.

Design Simulations

AC Simulation Results



Transient Simulation Results



Design References

See *Analog Engineer's Circuit Cookbooks* for TI's comprehensive circuit library.

See the TI Precision Labs video – Op Amps: Fully Differential Amplifiers – Designing a Front-End Circuit for Driving a Differential Input ADC, for more information.

Design Featured Op Amp

THS4561	
V_{ss}	3 V to 13.5 V
V_{inCM}	V_{ee}-0.1 V to V_{cc}-1.1 V
V_{out}	V_{ee}+0.2 V to V_{cc}-0.2
V_{os}	TBD
I_q	TBD
I_b	TBD
UGBW	70 MHz
SR	4.4 V/µs
#Channels	1
THS4561	

Design Alternate Op Amp

THS4131	
V_{ss}	5 V to 33 V
V_{inCM}	V_{ee}+1.3 V to V_{cc}-0.1 V
V_{out}	Varies
V_{os}	2 mV
I_q	14 mA
I_b	2 µA
UGBW	80 MHz
SR	52 V/µs
#Channels	1
THS4131	

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