Single-ended input to differential output circuit using a fully-differential amplifier

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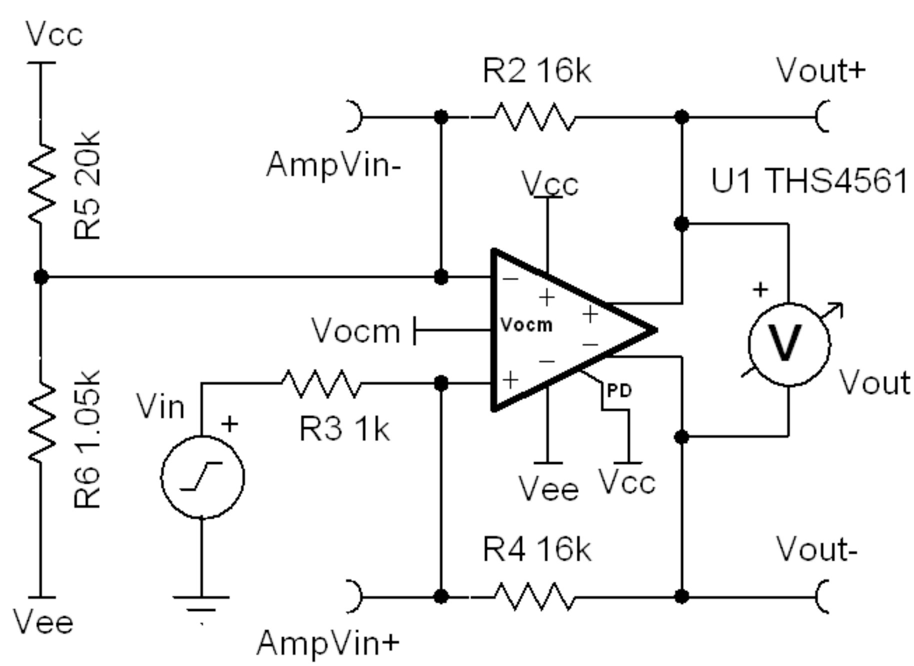
Design Goals

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

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

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

$$R_6 = FR_5 + FR_6$$

$$R_6(1-F) = FR_5$$

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

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

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

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

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

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

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

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

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

$$V_{IN} = 0V - 0.5V = -0.5V$$

- The output is:

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

- Likewise, for a 1-V input:

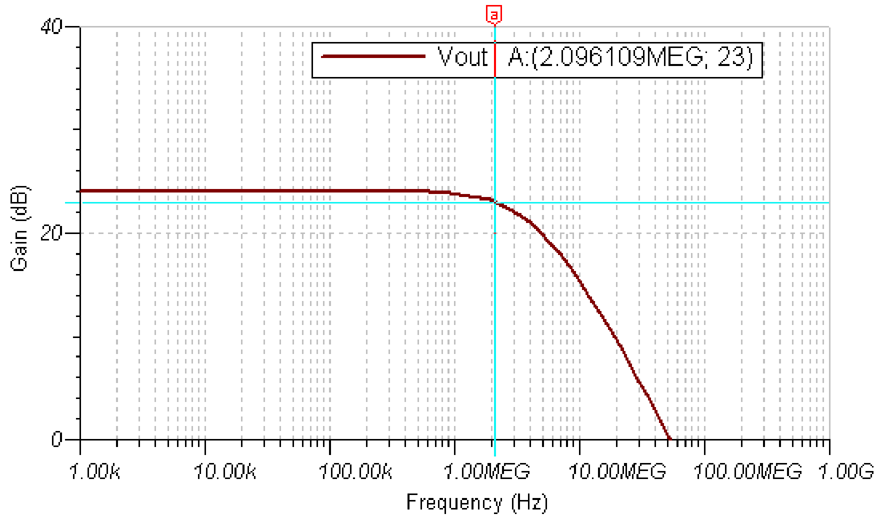
$$V_{IN} = 1V - 0.5V = 0.5V$$

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

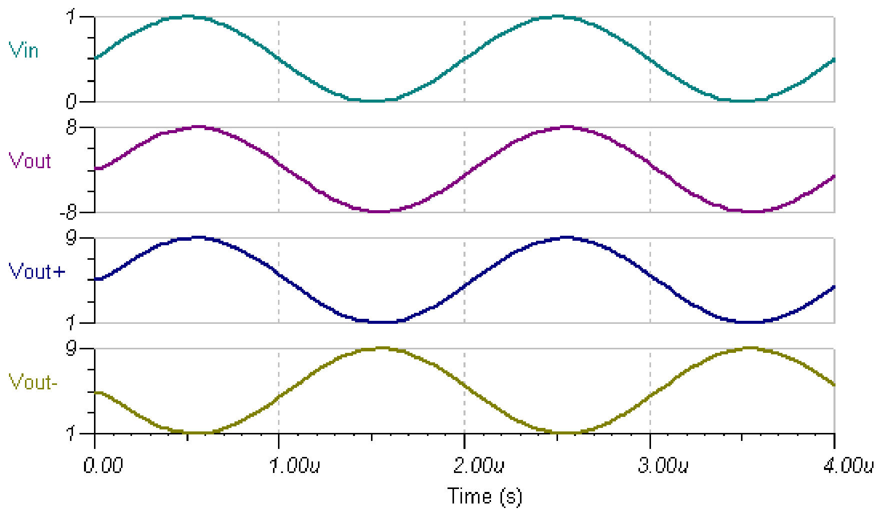
NOTE: With a reference voltage of 0V, a 1-V input results in an output voltage greater than the maximum output range of the amplifier.

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}	3V to 13.5V
V_{inCM}	Vee-0.1V to Vcc-1.1V
V_{out}	Vee+0.2V to Vcc-0.2
V_{os}	TBD
I_q	TBD
I_b	TBD
UGBW	70MHz
SR	4.4V/µs
#Channels	1
http://www.ti.com/product/THS4561	

Design Alternate Op Amp

THS4131	
V_{ss}	5V to 33V
V_{inCM}	Vee+1.3V to Vcc-0.1V
V_{out}	Varies
V_{os}	2mV
I_q	14mA
I_b	2uA
UGBW	80MHz
SR	52V/µs
#Channels	1
http://www.ti.com/product/THS4131	