Differential input to differential output circuit using a fully-differential amplifier

Sean Cashin

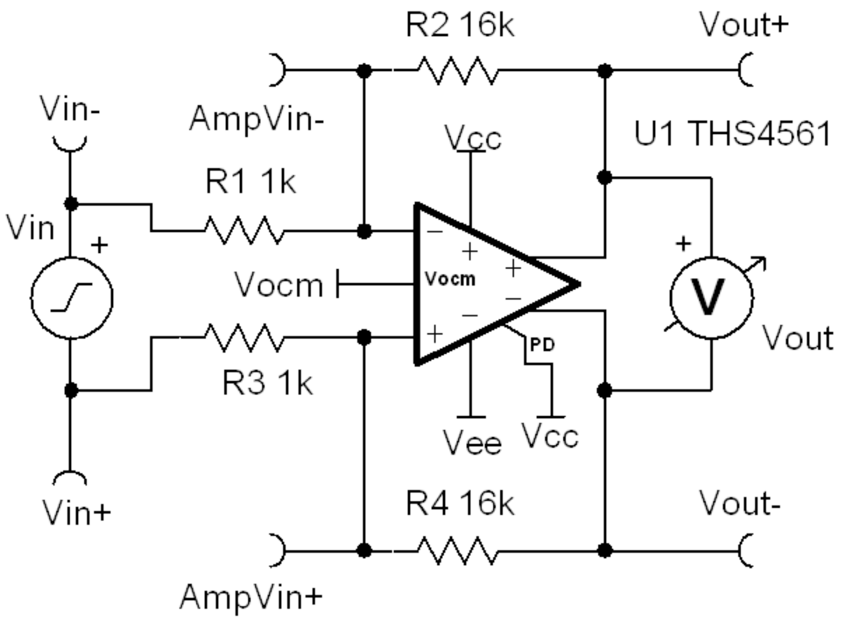
Design Goals

Input	Output	Supply	
Differential	Differential	V_{cc}	V_{ee}
1Vpp	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 differential input to differential output amplifier.



Design Notes

1. The ratio R2/R1, equal to R4/R3, sets the gain of the amplifier.
2. For a given supply, the output swing for and FDA is twice that of a single ended amplifier. This is because a fully differential amplifier swings both terminals of the output, instead of swinging one and fixing the other to either ground or a Vref. The minimum voltage of an FDA is therefore achieved when Vout+ is held at the negative rail and Vout- is held at the positive rail, and the maximum is achieved when Vout+ is held at the positive rail and Vout- is held at the negative rail.
3. FDAs are useful for noise sensitive signals, since noise coupling equally into both inputs will not be amplified, as is the case in a single ended signal referenced to ground.
4. The output voltages will be centered about the output common-mode voltage set by Vocm.
5. Both feedback paths should be kept symmetrical in layout.

Design Steps

- Set the ratio R2/ R1 to select the AC voltage gain. To keep the feedback paths balanced,

$$R_1 = R_3 = 1k\Omega \text{ (Standard Value)}$$

$$R_2 = R_4 = R_1 \bullet (G_{AC}) = 1k\Omega \bullet \left(16\frac{V}{V}\right) = 16k\Omega \text{ (Standard Value)}$$

- Given the output rails of 9.8V and 0.2V for Vs = 10V, verify that 16Vpp falls within the output range available for V_{ocm} = 5V.

  In normal operation:

$$AmpV_{IN+} = AmpV_{IN-}$$

$$V_{OUT+} - V_{ocm} = V_{ocm} - V_{OUT-}$$

$$V_{OUT} = V_{OUT+} - V_{OUT-}$$

- Rearrange to solve for each output voltage in edge conditions

$$V_{OUT-} = 2V_{ocm} - V_{OUT+}$$

$$V_{OUT-} = V_{OUT+} - V_{OUT}$$

$$2V_{OUT+} = 2V_{ocm} + V_{OUT}$$

$$V_{OUT+} = V_{ocm} + \frac{V_{OUT}}{2}$$

$$V_{OUT-} = V_{ocm} - \frac{V_{OUT}}{2}$$

- Verifying for Vout = +8V and Vocm = +5V,

$$V_{OUT+} = 5 + \frac{8}{2} = 9V < 9.8V$$

$$V_{OUT-} = 5 - \frac{8}{2} = 1V > 0.2V$$

- Verifying for Vout = -8V and Vocm = +5V,

$$V_{OUT+} = 5 + \frac{-8}{2} = 1V > 0.2V$$

$$V_{OUT-} = 5 - \frac{-8}{2} = 9V > 9.8V$$

Note that the maximum swing possible is:

$$(9.8V - 0.2V) - (0.2V - 9.8V) = 18.4V_{pp}, \text{ or } \pm 9.4V$$

- Use the input common mode voltage range of the amplifier and the feedback resistor divider to find the signal input range when the output range is 1V to 9V. Due to symmetry, calculation of one side is sufficient.

$$\mathrm{Min}(\mathrm{AmpV}_{IN+}) = \mathrm{Min}(\mathrm{AmpV}_{IN-}) = \mathrm{Vee} - 0.1V = -0.1V$$

$$\mathrm{Max}(\mathrm{AmpV}_{IN+}) = \mathrm{Max}(\mathrm{AmpV}_{IN-}) = \mathrm{Vcc} - 1.1V = 8.9V$$

$$\frac{\mathrm{AmpV}_{IN-} - V_{IN-}}{R_1} = \frac{V_{OUT+} - \mathrm{AmpV}_{IN-}}{R_2}$$

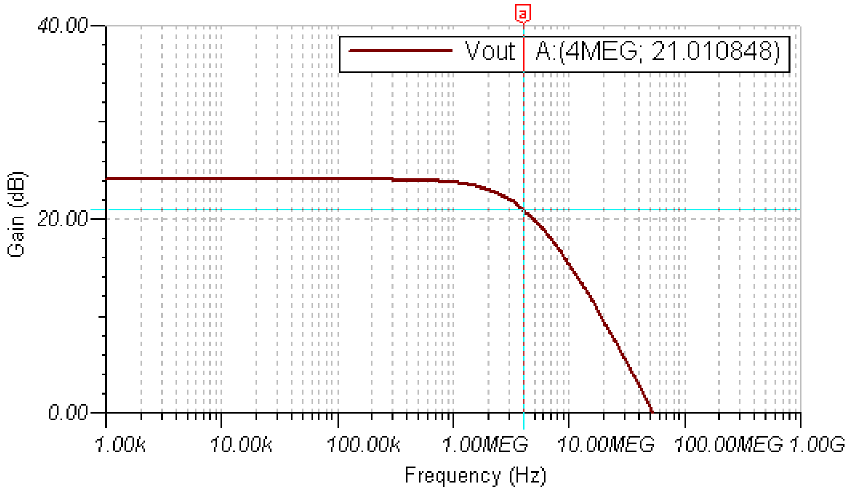
$$V_{IN-} = \mathrm{AmpV}_{IN-} - \frac{V_{OUT+} - \mathrm{AmpV}_{IN-}}{\frac{R_2}{R_1}}$$

$$\mathrm{Min}(V_{IN-}) = -0.1V - \frac{9V - (-0.1V)}{16\,\frac{V}{V}} = -0.65V$$

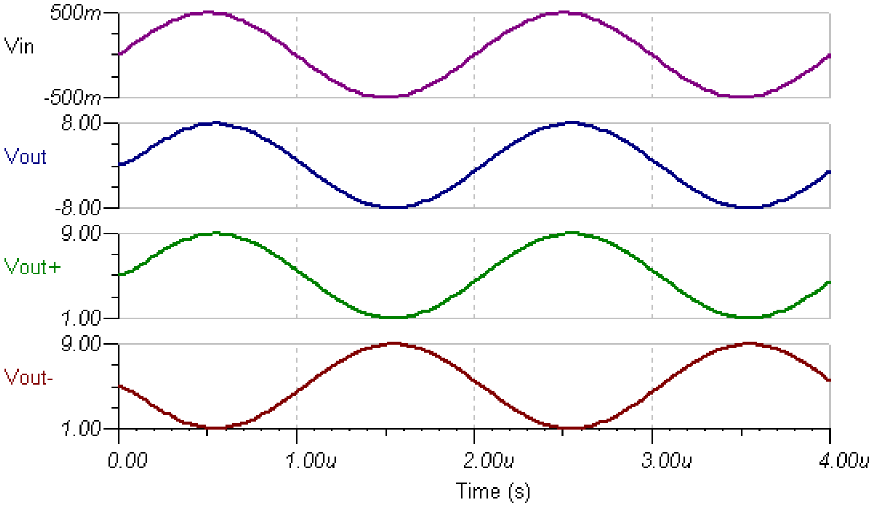
$$\mathrm{Max}(V_{IN-}) = 8.9V + \frac{8.9V - 1V}{16\,\frac{V}{V}} = 9.4V$$

Design Simulations

AC Simulation Results



Transient Simulation Results



Design References

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

See the TIDA-01036 tool folder 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	

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