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| **TOC** | **Title** |
| Fully-Differential Amplifier Circuits | Single-Ended Input to Differential Output using a Fully-Differential Amplifier |

**Design Goals**

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| **Input** | **Output** | **Supply** |
| Single-Ended | Differential | Vcc | Vee |
| 0V to 1V | 16Vpp | 10V | 0V |

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| **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 R4/R3, equal to R2/(R5||R6), 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 outputs’ ability 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**

1. Find the resistor divider with that produces a 0.5V, 1k$Ω$ reference from Vs=10V.

$$\frac{R6}{R5+R6}=F=\frac{0.5V}{10V} \frac{R5×R6}{R5+R6}=E=1kΩ$$

$$R\_{6}=FR\_{5}+FR\_{6}$$

$$R\_{6}(1-F)=FR\_{5}$$

$$R\_{5}=\frac{R\_{6}(1-F)}{F}$$

$$\frac{R\_{6}(1-F)/F×R6}{R\_{6}(1-F)/F+R6}=E$$

$$\frac{R\_{6}^{2}×(1-F)/F}{(R\_{6}/F-R\_{6})+R6}=E$$

$$\frac{R\_{6}^{2}×(1-F)/F}{R\_{6}/F}=E$$

$$R\_{6}×\left(1-F\right)=E$$

$$R\_{6}=\frac{E}{1-F}=\frac{1kΩ}{1-0.05}=1.05kΩ$$

$$R\_{5}=\frac{1.05Ω\left(1-0.05\right)}{0.05}=20kΩ$$

1. Verify that the minimum input of 0V and the maximum input of 1V result in an output within the $\pm $9.4V range available for Vocm=5V.
	1. Since the resistor divider acts like a 0.5V reference, the measured differential input for a 0V Vin is

$$Vin=0V-0.5V=-0.5V$$

And the output is.

$$-0.5V×\frac{16V}{V}=-8V>-9.8V$$

* 1. Likewise, for a 1V input,

$$Vin=1V-0.5V=0.5V$$

$$0.5V×\frac{16V}{V}=8V<9.8V$$

* 1. Note that with a reference voltage of 0V, a 1V input would result in an output voltage greater than the maximum output range of the amplifier.

**Design Simulations**

**AC Simulation Results:**

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**Transient Simulation Results:**

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**Design References**

See TIPD185, [www.ti.com/tool/tipd185](http://www.ti.com/tool/tipd185).

**Design Featured Op Amp:**

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| **THS4561** |
| **Vss** | 3V to 13.5V |
| **VinCM** | Vee-0.1V to Vcc-1.1V |
| **Vout** | Vee+0.2V to Vcc-0.2 |
| **Vos** | TBD |
| **Iq** | TBD |
| **Ib** | TBD |
| **UGBW** | 70MHz |
| **SR** | 4.4V/µs |
| **#Channels** | 1 |
| [**http://www.ti.com/product/THS4561**](http://www.ti.com/product/THS4561) |

**Design Alternate Op Amp:**

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| **THS4131** |
| **Vss** | 5V to 33V |
| **VinCM** | Vee+1.3V to Vcc-0.1V |
| **Vout** | Varies |
| **Vos** | 2mV |
| **Iq** | 14mA |
| **Ib** | 2uA |
| **UGBW** | 80MHz |
| **SR** | 52V/µs |
| **#Channels** | 1 |
| [**www.ti.com/product/THS4131**](http://www.ti.com/product/THS4131) |