

Simplifying Fully Differential Amplifier System Design with the DiffAmpCalc™

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INTRODUCTION

DiffAmpCalc™ is an interactive design and parametric simulation tool. It automates time consuming calculations required to determine optimal levels for gain, termination resistors, power dissipation, noise output, and input common-mode voltage. DiffAmpCalc reduces design risks by providing engineers with an effective and intuitive tool. The power of the DiffAmpCalc is in its design oriented features, ease of use, and built-in error detection.

This tool speeds the selection, evaluation, and troubleshooting of several Analog Devices, Inc., differential amplifiers by using

data sheet parameters to model mathematically the behavior of the amplifier. Any parameters not specified in the datasheet are extrapolated based on data sheet values and figures.

Three types of fully differential amplifiers (FDA) are modeled: FDA with user selectable gain, FDA with a preset gain, and fully differential funnel amplifiers. Figure 1 is the DiffAmpCalc graphical user interface (GUI). This application note describes the primary features of DiffAmpCalc.

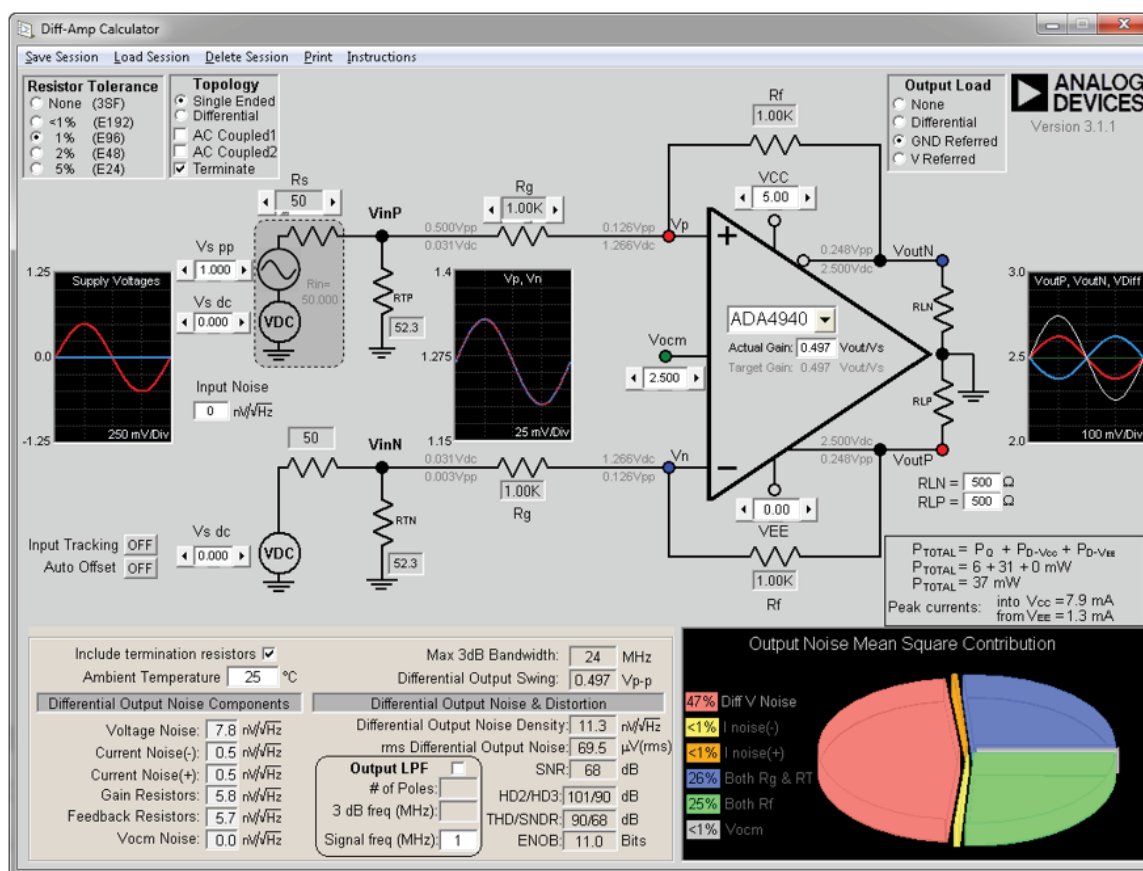


Figure 1. DiffAmpCalc GUI

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REVISION HISTORY

4/16—Revision 0: Initial Version

DIFFAMPCALC FEATURES

The design features of the DiffAmpCalc make it a powerful tool. Three key design features are circuit customization, optimization preferences, and the substantial amount of dynamic data available for a wide range of configurations. A user has several options for design customization. Figure 2 shows the user selectable options for input topology (**Single Ended** or **Differential**), input coupling (ac or dc), and input termination (**Terminate**). Figure 3 shows the output load choices: **None**, **Differential**, ground referred (**GND Referred**), or referenced to a voltage (**V Referred**).

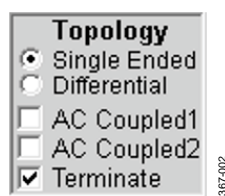


Figure 2. Input Topology, Input Coupling, and Input Termination Options

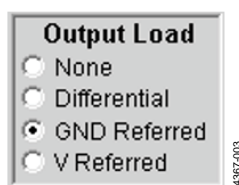


Figure 3. Output Load Options

For high differential gain requirements, cascading amplifier stages is an option. After the footprint of the design is set, several optimization features exist. Some of those features include automatic offset, input tracking, gain calculation, resistor tolerances, and thermal effects.

Automatic offset (**Auto Offset**), when turned on, automatically adjusts input offset voltages and **Vocm** to the center of the available input and output voltage ranges. This feature maximizes the dynamic ranges of the amplifier.

When trying to maintain balanced inputs, enabling **Input Tracking** is useful because the input amplitude and offset are automatically balanced. This is achieved by forcing the inverting and noninverting nodes to be equal. When **Auto Offset** is selected, **Input Tracking** is disabled. **Auto Offset** and **Input Tracking** option selections are shown in Figure 4.

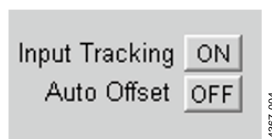


Figure 4. Input Tracking and Auto Offset

Setting the System Gain

DiffAmpCalc simplifies system gain calculations. Entering the desired gain into the **Actual Gain** text box (see the circled area in Figure 5), sets the system gain.

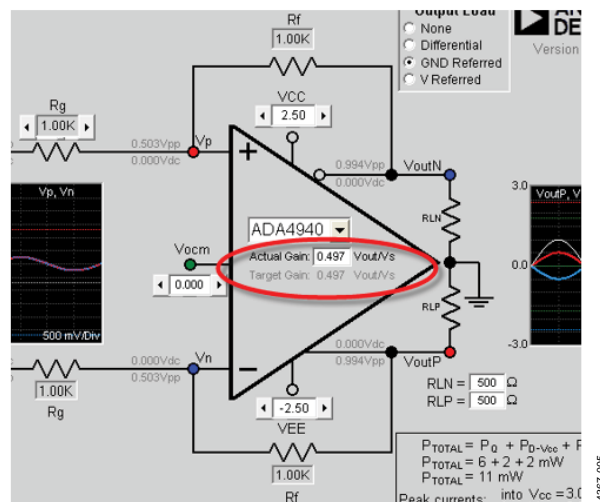


Figure 5. Setting the System Gain

All component values are provided and can be proportionally adjusted by using the scroll bar. A key feature of the DiffAmpCalc is the calculation of the component values when a user selects **Terminate** for **Topology** (**Terminate** is selected in Figure 2). Input termination is required for matching impedances. The option to match impedances allows the system designer flexibility in defining the input source. If using, for example, a signal generator as the input to the FDA, double termination is required.

Double termination requires termination resistors. These resistors affect the system gain. To maintain the same system gain for a double-terminated topology, the feedback and gain resistors are recalculated iteratively. This process is described in the [ADA4930-1](#) datasheet.

DiffAmpCalc simplifies iterative calculations by automatically calculating the component values when the topology, **Terminate**, is selected. This feature dynamically updates respective feedback and gain component values. The iterative calculations in DiffAmpCalc is, by default, hidden. The calculations can be made visible using the keyboard shortcut **Alt + V**. Hitting **Alt + V** again hides the calculations.

DiffAmpCalc easily assists the design optimization with error budgets and thermal resistor noise affects. The user is able to choose resistor tolerances from <1% to 5% by selecting one of the following options listed among the **Resistor Tolerance** buttons: **None**, <1% (E192), 1% (E96), 2% (E48), or 5% (E24), as shown in Figure 6.

Thermal impacts of resistor noise on performance is calculated when a user defines the ambient temperature. Resistor noise information is shown in Figure 7.

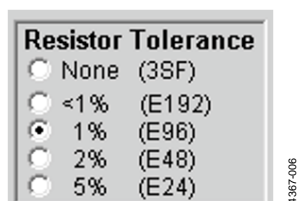


Figure 6. Resistor Tolerance Options

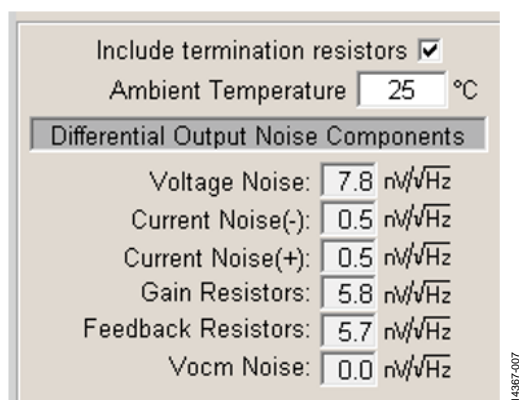


Figure 7. Noise Data and Input

Simulation Results

The immediate availability of simulation results at every node allows for real-time analysis. Nodal data and oscilloscope-like figures for the source voltage and the amplifier input and output voltage waveforms are beneficial for quickly understanding component and system trade-offs. Left-clicking on the oscilloscope-like displays enables 1×, 2×, 5×, 10×, 20×, 50×, and 100× magnification. Right-clicking on the displays reverts the magnification and zoom out.

The dc and ac peak-to-peak voltages are calculated at all nodes. The input voltages are specified as an ac voltage, with a peak-to-peak value superimposed on a dc offset. If peak currents are a concern, total power dissipation is separated into quiescent and dynamic powers. In Figure 8, nodal voltages are shown in the circled area of the circuit diagram and oscilloscope-like figures are shown in the boxed area to the right side of the circuit diagram. Power dissipation calculations are found beneath the boxed oscilloscope area.

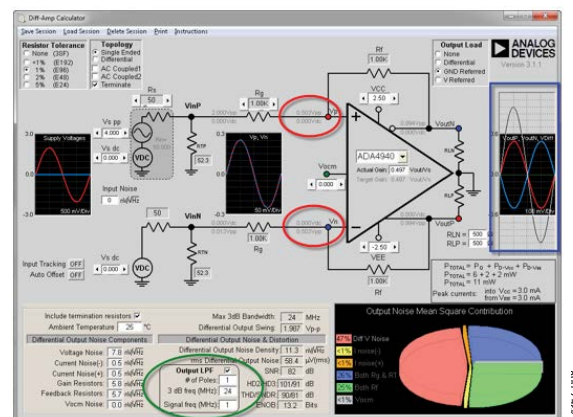


Figure 8. Screen Shot Highlighting Nodal Voltages and Oscilloscope-Like Displays

Time domain simulations are shown for the frequency at which the amplifier frequency response is flat. Frequency domain simulations include bandwidth of the amplifier and noise and distortion. Noise and distortion, by default, is calculated from the maximum bandwidth of the amplifier. If simulation results for noise and distortion at the output are required, selecting the output low-pass filter (**Output LPF** circled in Figure 8 at the bottom, center of the screen) specifies noise and distortion at the user defined frequency and peak-to-peak amplitude. This information is beneficial when using the DiffAmpCalc for selecting an ADC driver because ENOB and SINAD update automatically. If the system gain is greater than 4, N/A appears for HD2/HD3, THD/SNDR, and ENOB. The keyboard shortcut **Alt + N** makes these parameters visible.

Data Entry

The point and click method for entering user defined inputs in the DiffAmpCalc makes it an efficient tool. Entering data using the scroll bars and text boxes allows for dynamically updated simulation results. The default step size for the voltage scroll bars is 100 mV steps. To change the resolution, use the following keyboard combinations:

- For 1 V steps, **Shift** + left-click
- For 10 mV steps, **Ctrl** + left-click
- For 1 mV steps, **Alt** + left-click

Clicking inside a text box activates it. When activating a text box, the color of the text box changes from white to green. After activating a text box, the user can enter numbers, decimals, or negative signs.

Built-In Error Detection

DiffAmpCalc has several built-in error detection features that prevent common differential amplifier problems from infiltrating designs. When an entered value is out of specification, the text box changes to light red and a warning message shows either an automatic correction or the reason why no further adjustments in the current direction are allowed. Figure 9 is an example of a warning message and Figure 10 is an example of a recommended fix.

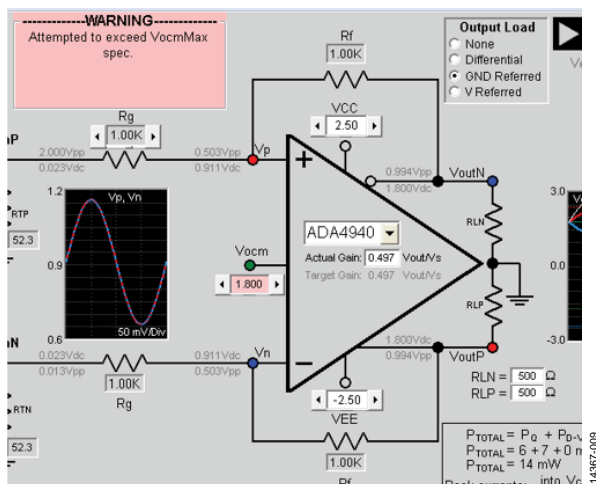


Figure 9. Warning Message

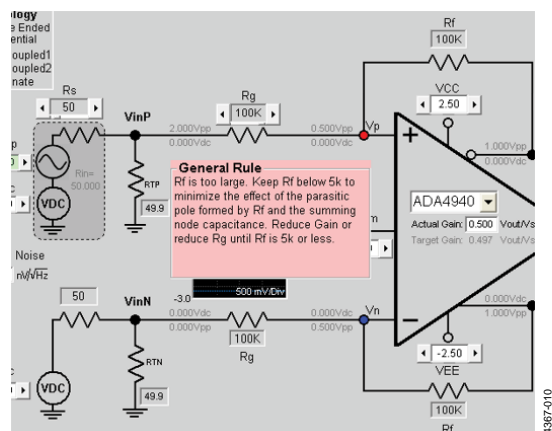


Figure 10. Recommended Fix

When adjustments and certain conditions coincide, a warning message alerts the user to these conflicting conditions. The warning message persists for as long as the erroneous condition exists. A quick solution for fixing clipped inputs and outputs is to enable the **AutoAlign** feature. This feature is a visible option when an input and/or output is clipped. The **AutoAlign** feature fixes the issue and sets the inputs and **Vcm** for maximum output dynamic range. See Figure 11 for an example of clipped

inputs with **AutoAlign** as an option and see Figure 12 for the **AutoAlign** fix.

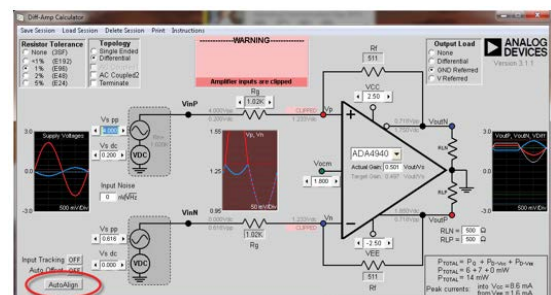


Figure 11. Clipped Input and Outputs with **AutoAlign** Option Visible

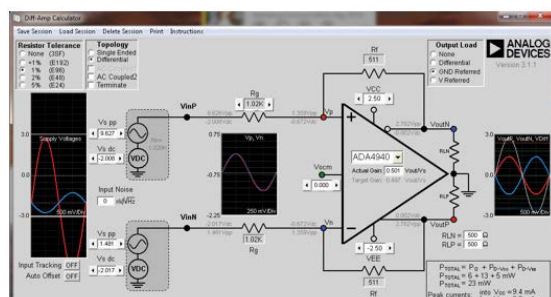


Figure 12. Results After Selecting **AutoAlign**

A subtle error prevention feature is built into the **Single-Ended Terminate** option. When using a single-ended to differential topology, the impedance of the unused input of the FDA must match the other input. See the circled area in Figure 13 for an example of an unused input with matched impedance.

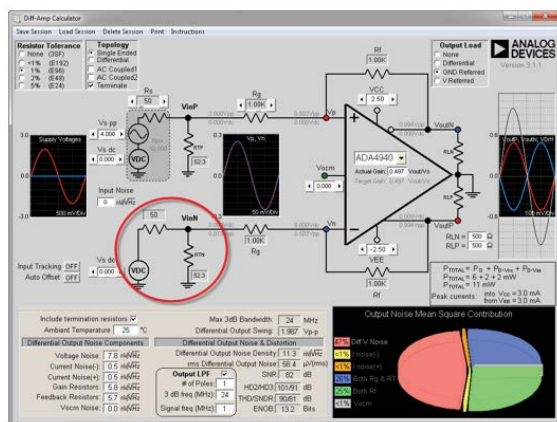


Figure 13. Impedance Matching a Single-Ended to Differential Topology

DiffAmpCalc gives the user a quick and efficient tool for dynamic design optimization. Detailed information for all of the features of DiffAmpCalc is in the **Help** file located in the menu bar of DiffAmpCalc. The DiffAmpCalc program is available for free download at <http://www.analog.com/en/design-center/interactive-design-tools/adi-DiffAmpCalc.html>.