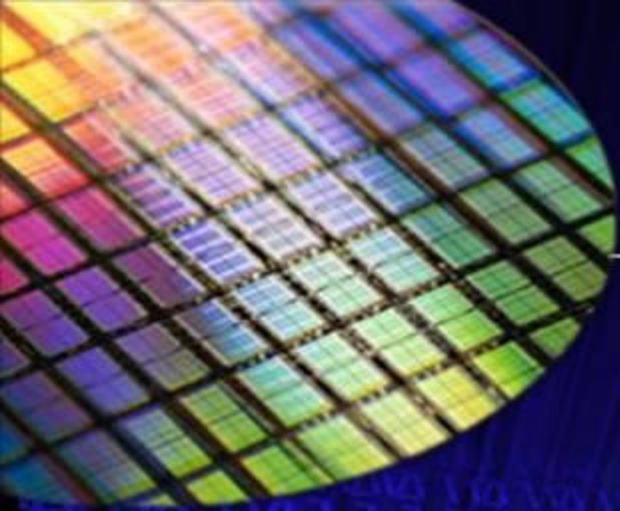


The World Leader in High Performance Signal Processing Solutions

差分放大器以及相关设计软件的基础知识

ANALOG DEVICES

Introduction to Differential Amplifiers

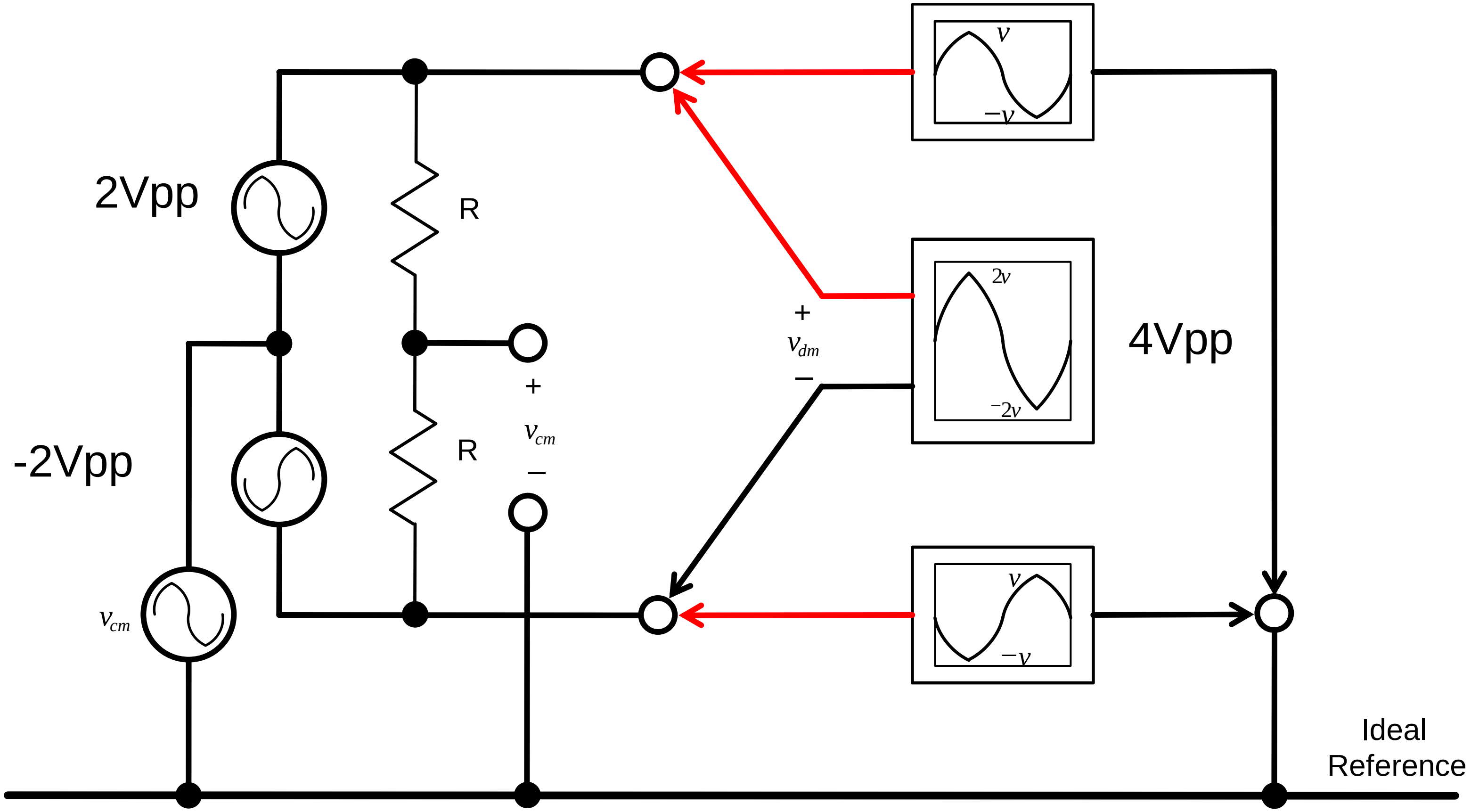
- **What is a Differential Amplifier?**
  - Op amp vs. differential amplifier
  - Discrete differential amplifier
  - Integrated differential amplifier
  - Advantages of differential amplifiers
- **Design Equations**
- **Design Example**
- **Demonstration of *NEW* Differential Amplifier Calculator**
- **Evaluation Boards**
- **Summary**

Differential Amplifiers

- Are also know as:
  - Diff Amps
  - ADC Drivers
  - Fully Differential Amplifiers

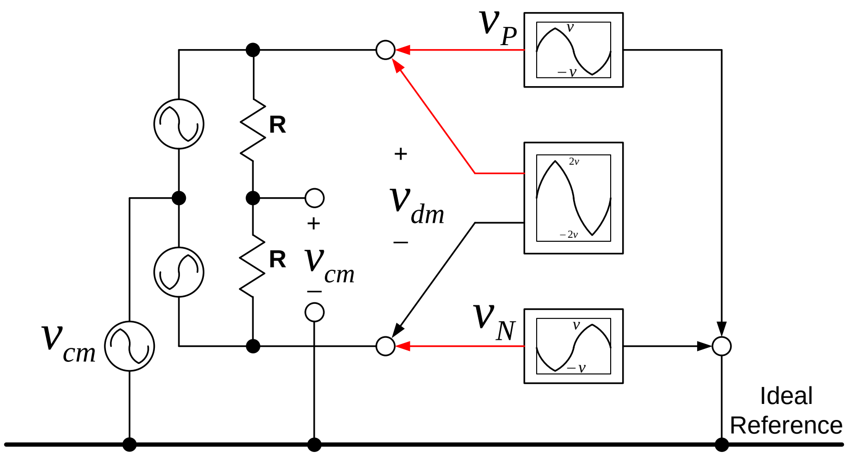
Differential Signals

What is a Differential Signal?



Key Points and Mathematical Definitions

- Differential Voltage is simply the potential *DIFFERENCE* between two conductors.
- *BALANCED* signaling uses two conductors that have signals of equal magnitude and opposite polarity with respect to a common reference.
- The terms *BALANCED* signaling and *DIFFERENTIAL* signaling are often used interchangeably.
- For any signal, balanced or otherwise, on two conductors, the signals can be defined as shown to the right with respect to a common reference, arbitrarily set = 0.



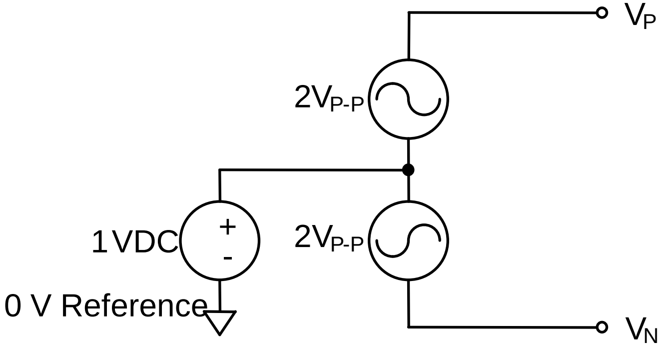
$$v_{dm} = v_P - v_N$$

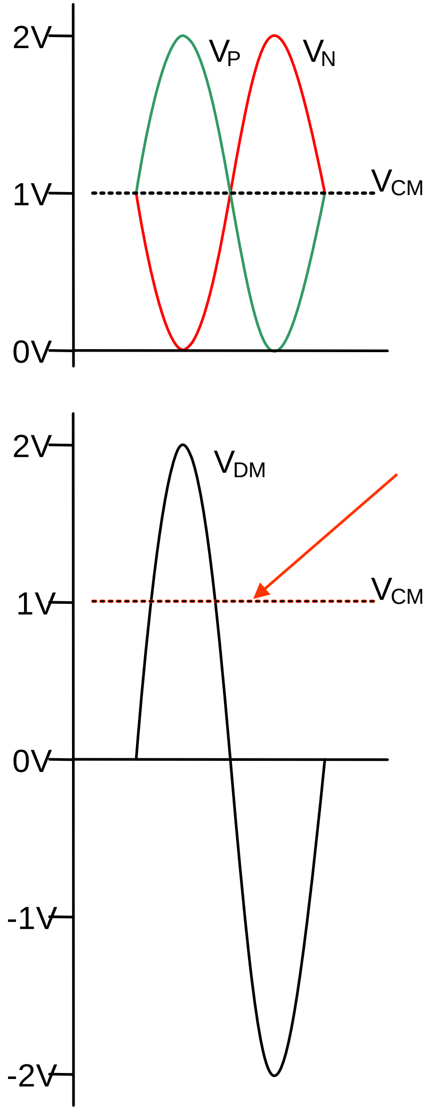
$$v_{cm} = \frac{v_P + v_N}{2}$$

$$v_P = v_{cm} + \frac{v_{dm}}{2} \qquad v_N = v_{cm} - \frac{v_{dm}}{2}$$

Example of Differential and Common-Mode Signals

Balanced Signal



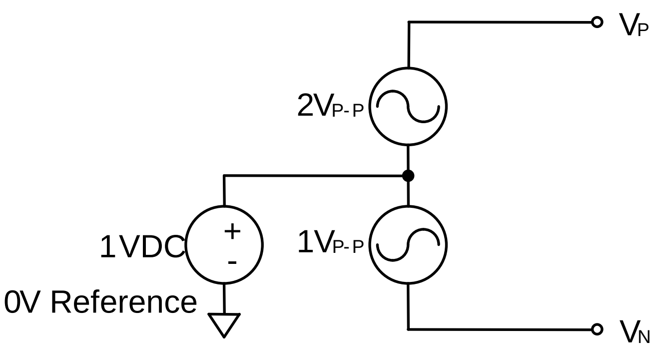


Essentially Constant
Common-Mode Voltage
Ensures Low EMI Radiation

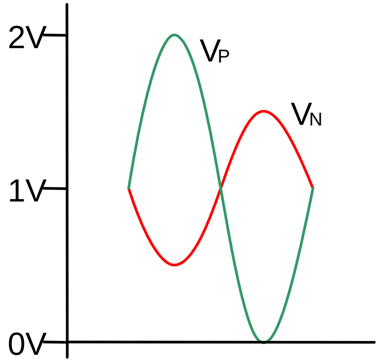
$$v_{cm} = \frac{v_P + v_N}{2}$$

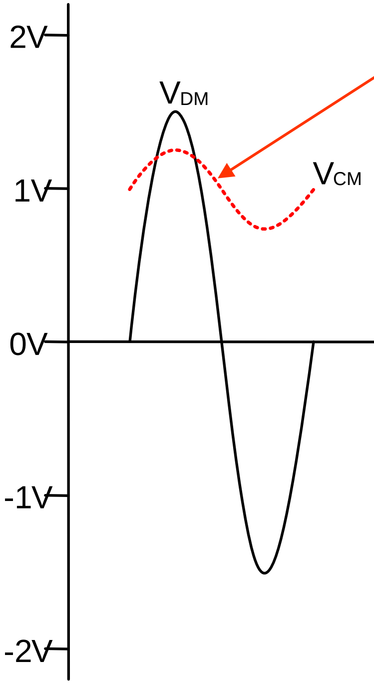
Example of Differential and Common-Mode Signals (cont'd)

Unbalanced Amplitude Signal



A common-mode signal is also generated for phase errors between V_P and V_N.



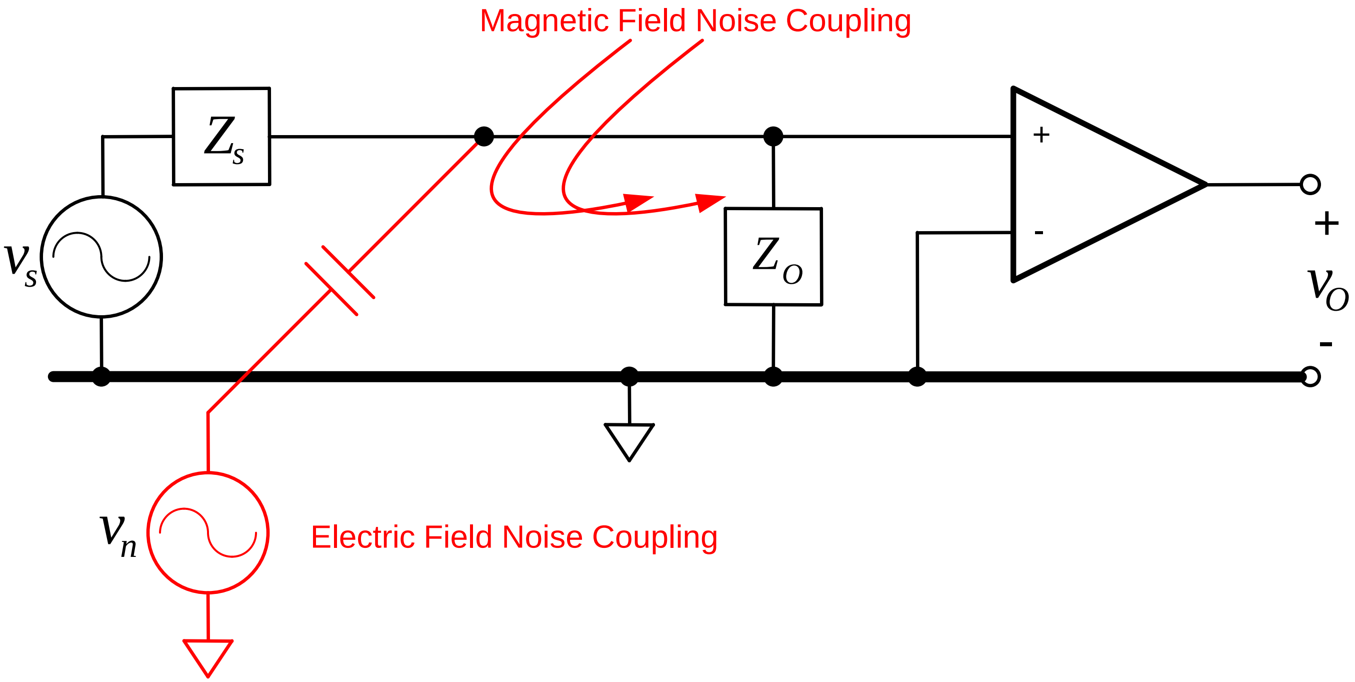


Common-Mode Signal Causes EMI Radiation

$$v_{cm} = \frac{v_P + v_N}{2}$$

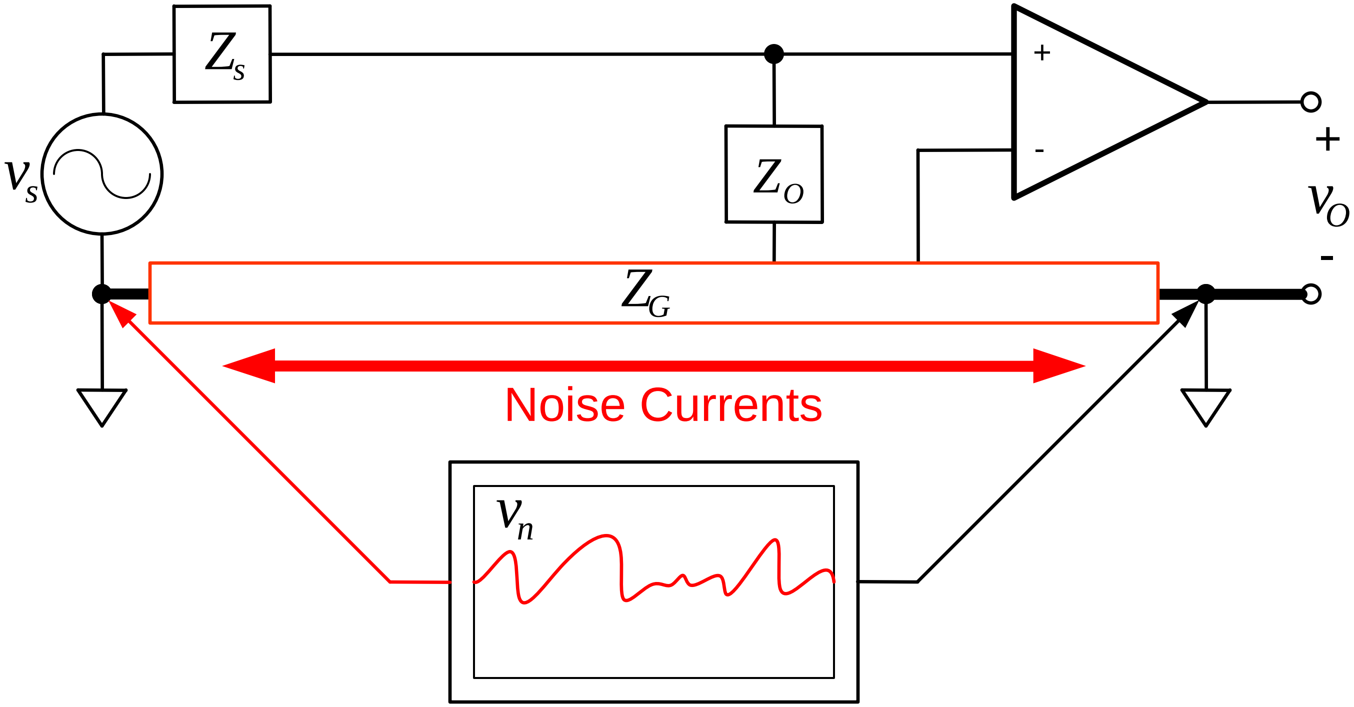
Comparison of Coupled Noise Behavior in Differential and Single-Ended Circuits (cont'd)

Noise Behavior In a Single-Ended Circuit



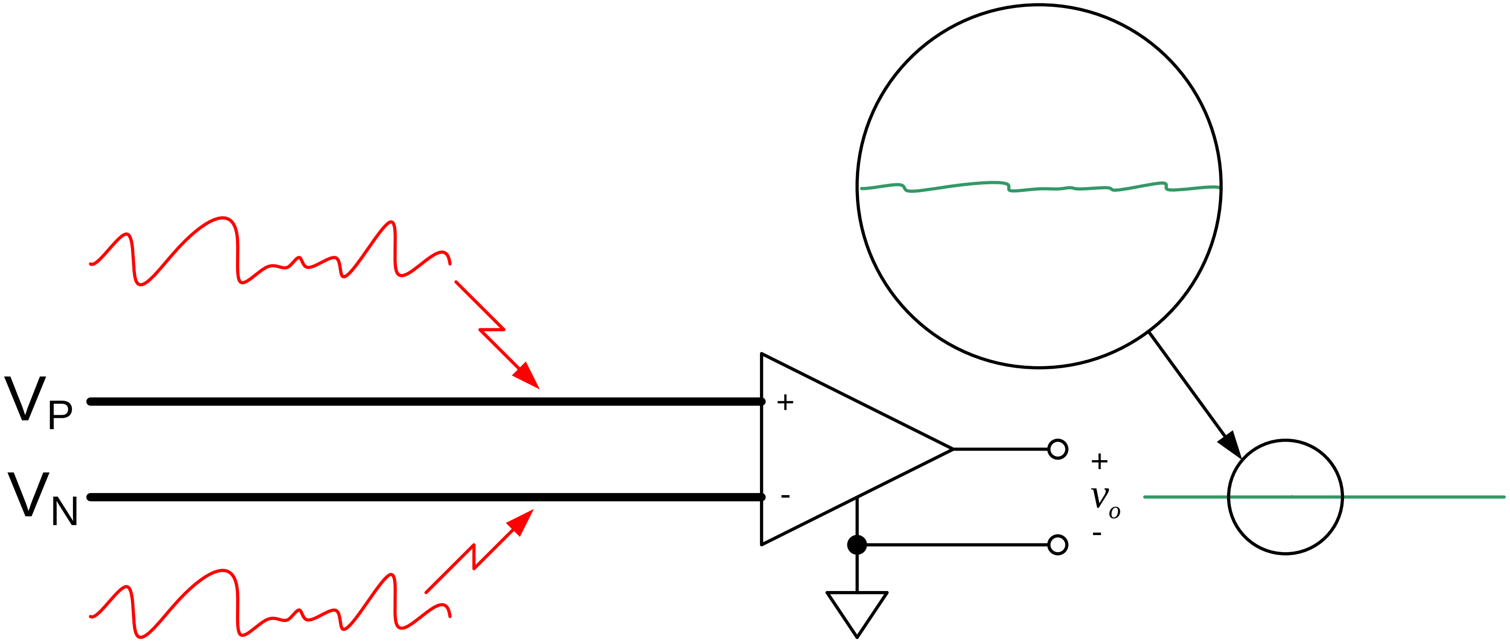
Comparison of Coupled Noise Behavior in Differential and Single-Ended Circuits (cont'd)

Noise Behavior In a Single-Ended Circuit (cont'd)



Comparison of Coupled Noise Behavior in Differential and Single-Ended Circuits

Noise Behavior In a Differential Circuit

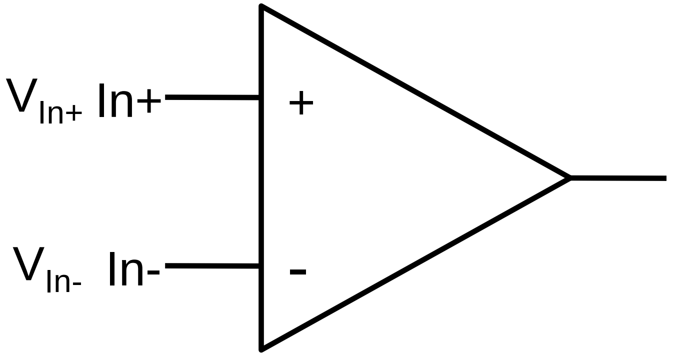


What is a Differential Amplifier?

Operational Amplifier vs. Differential Amplifier

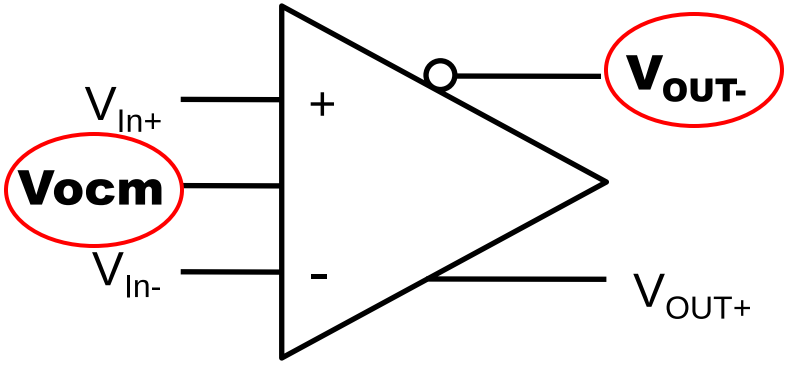
Operational Amplifier

- Differential input
  - Can be used single ended
- Single ended output
- Output common mode is set by signal
- Gain set by R_F & R_G

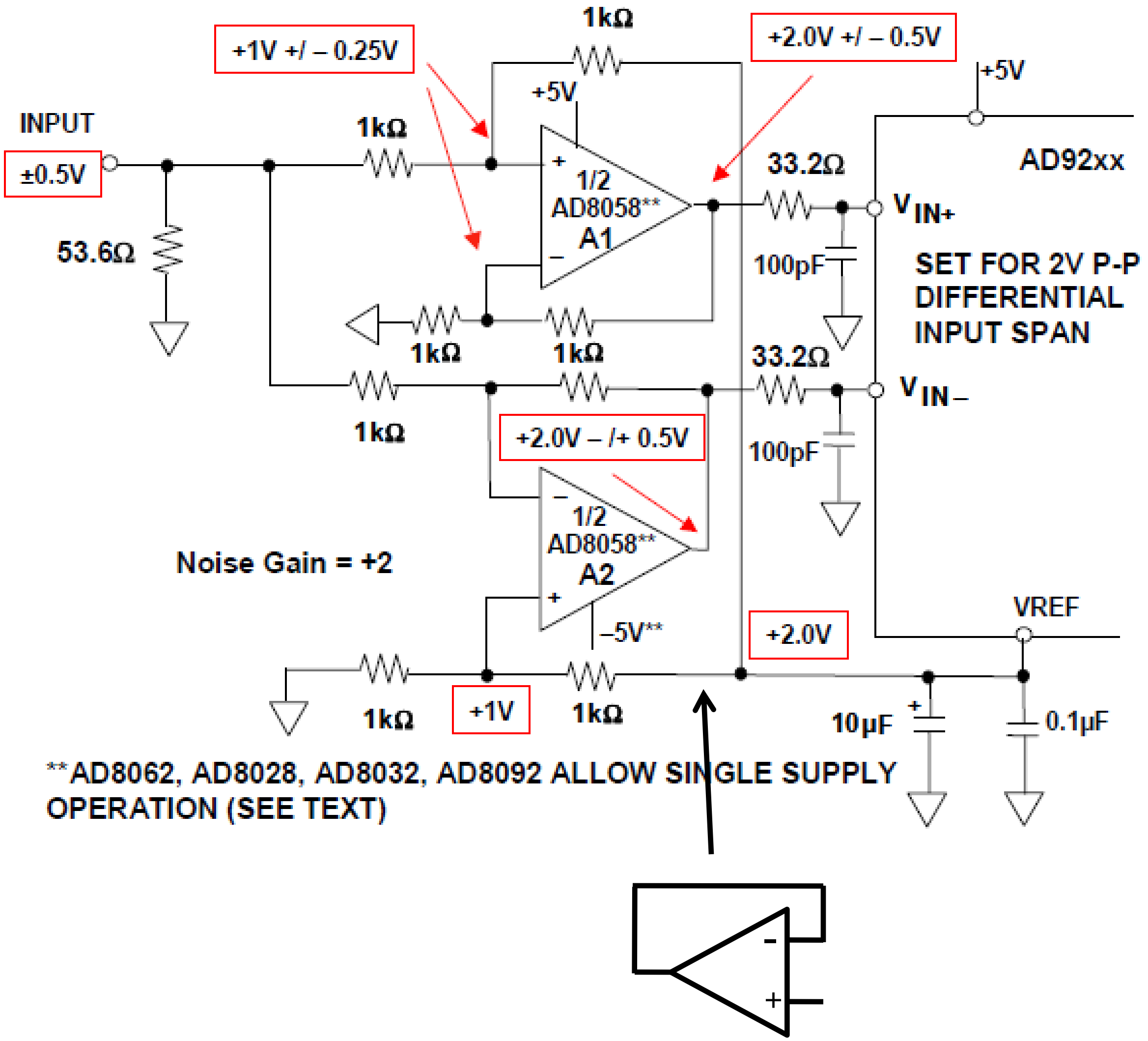


Differential Amplifier

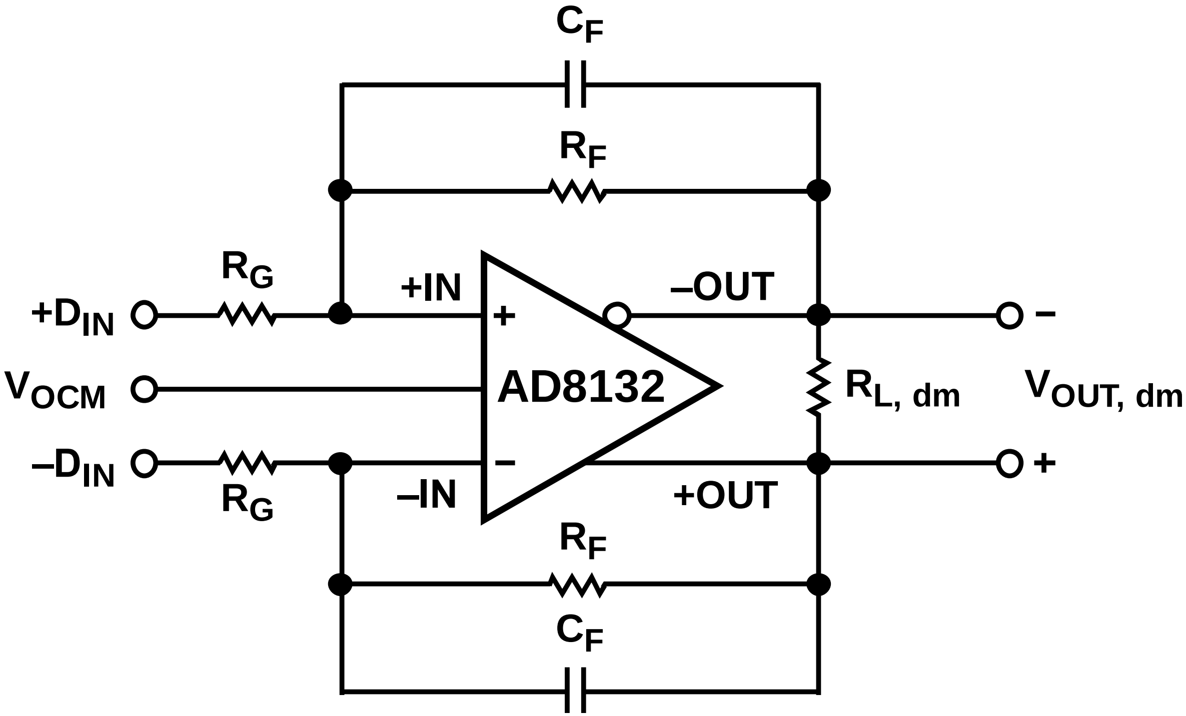
- Differential input
  - Can be used single ended
- Differential balanced output
- Output common mode set by Vocm input pin
- Gain set by two pairs of R_F & R_G



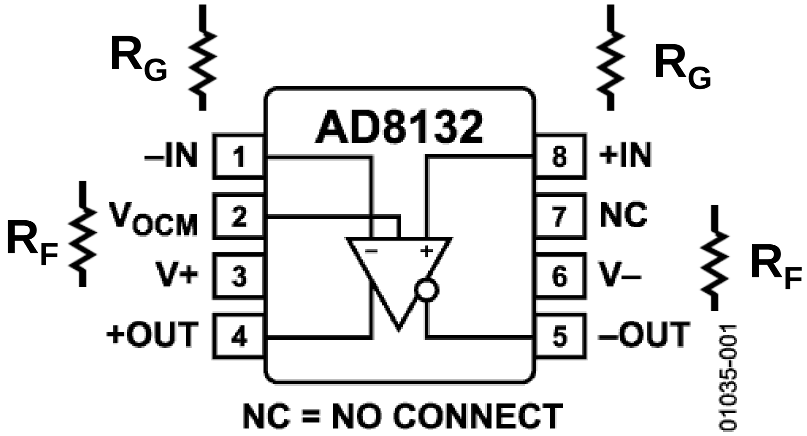
Discrete Differential Amplifier



Integrated Differential Amplifier Schematic



Integrated Differential Amplifier
Standard pinout vs. dedicated feedback



Pin Configuration Diagram for AD8132

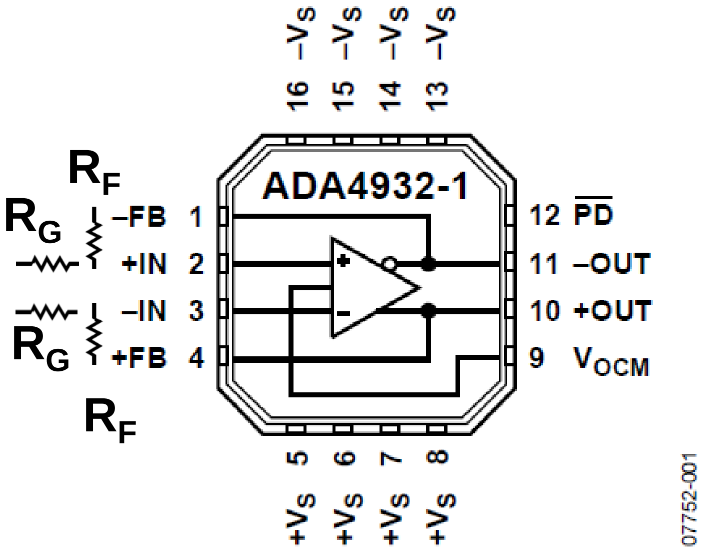
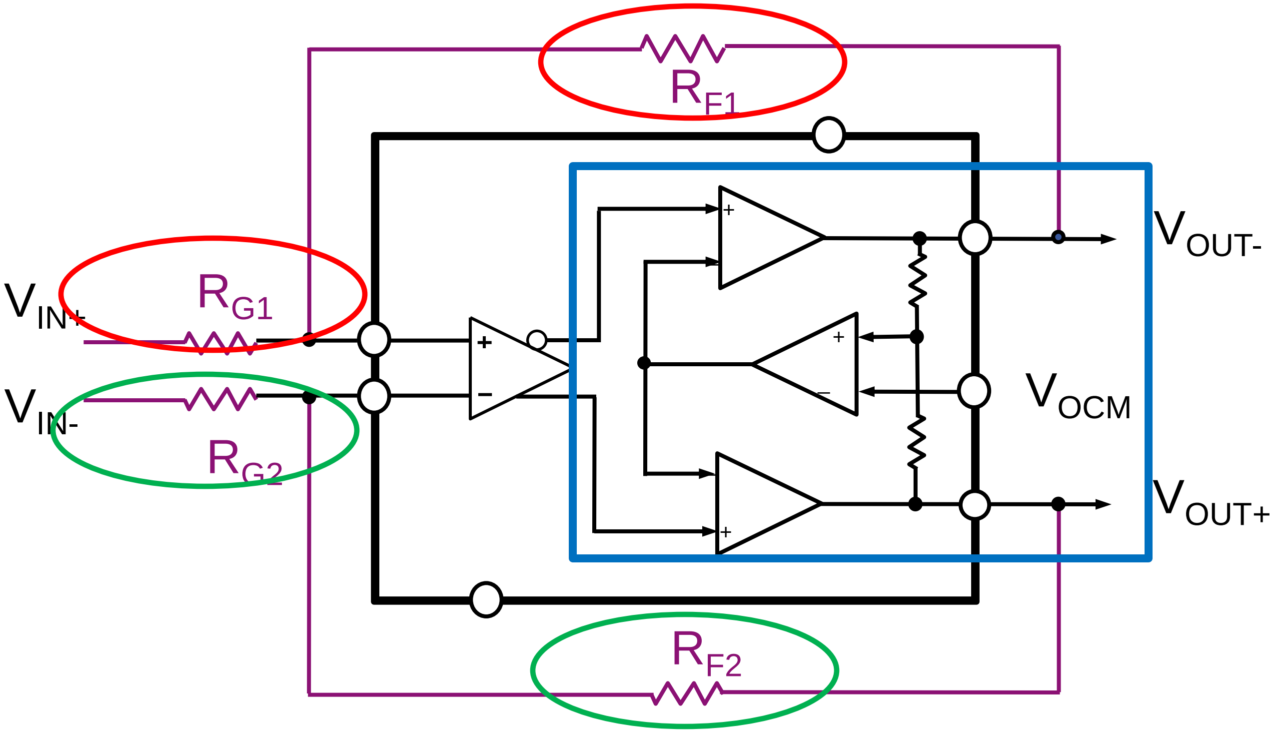


Figure 1. ADA4932-1

AD813x/ADA493x Series Internal Architecture

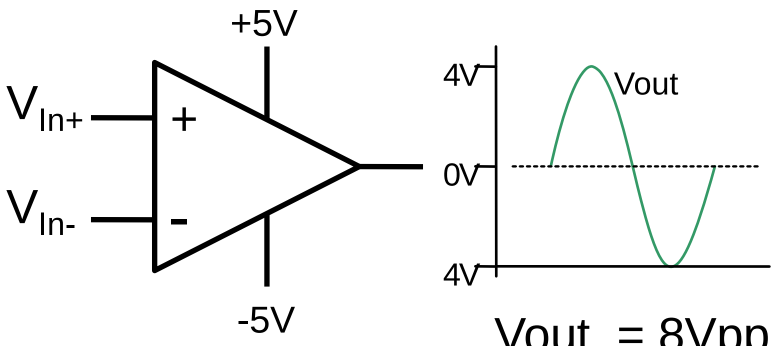


- Differential Amplifier Uses Two Separate Feedback Loops
- Negative Feedback Forces Output CM Voltage to Equal V_{OCM}
- Output Balance Controlled By Internal Feedback Loop, Not R_F/ R_G Ratios
- Internal Feedback Loop Allows Applications With Unequal R_F/ R_G Ratios

Advantages of Differential Amplifiers

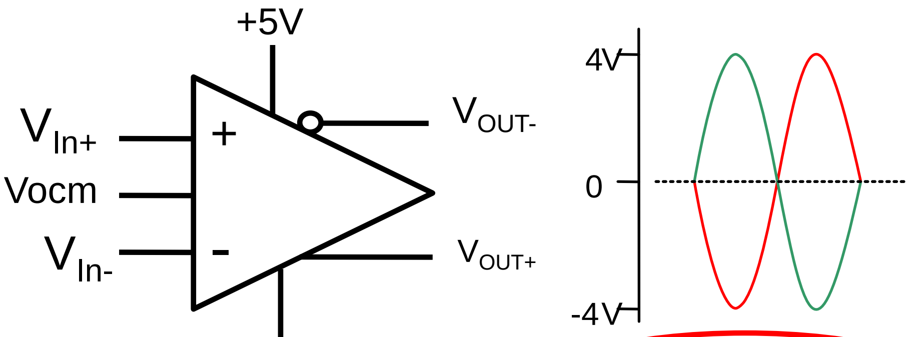
- **Integration**
- **Output balance**
- **Independent output Vocm adjustment**
- **Reduced second harmonic distortion**
- **High common mode rejection**
- **Wide output swing on single supply**

Op amp 1V headroom



Vout = 8Vpp

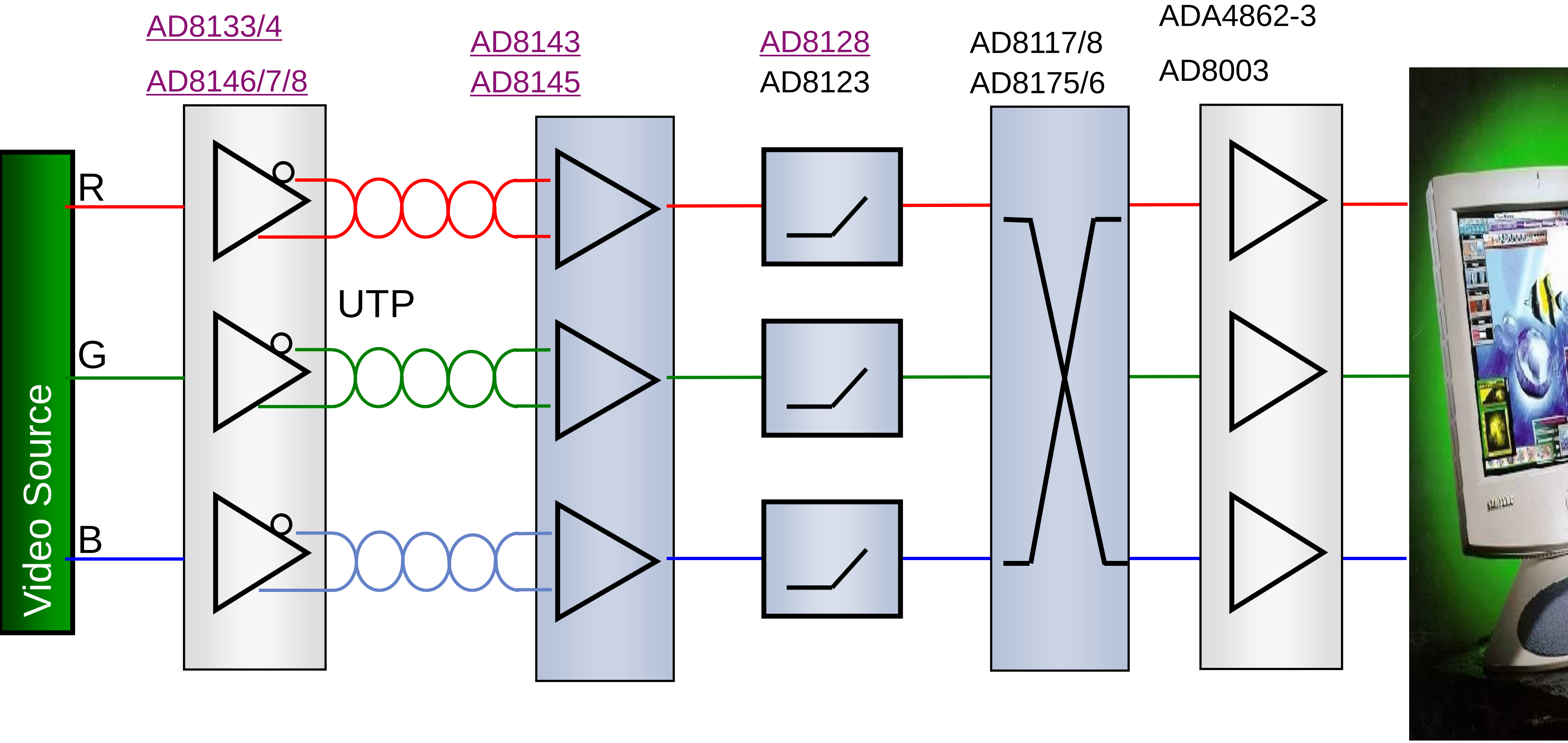
Diff amp 1V headroom



Vout = 16Vpp

Applications

ADI Complete Solution for Video over UTP
Utilize X-points and High Speed Amps



AD8133/4
AD8146/7/8

AD8143
AD8145

AD8128
AD8123

AD8117/8
AD8175/6

ADA4862-3
AD8003

DAC Output Buffer

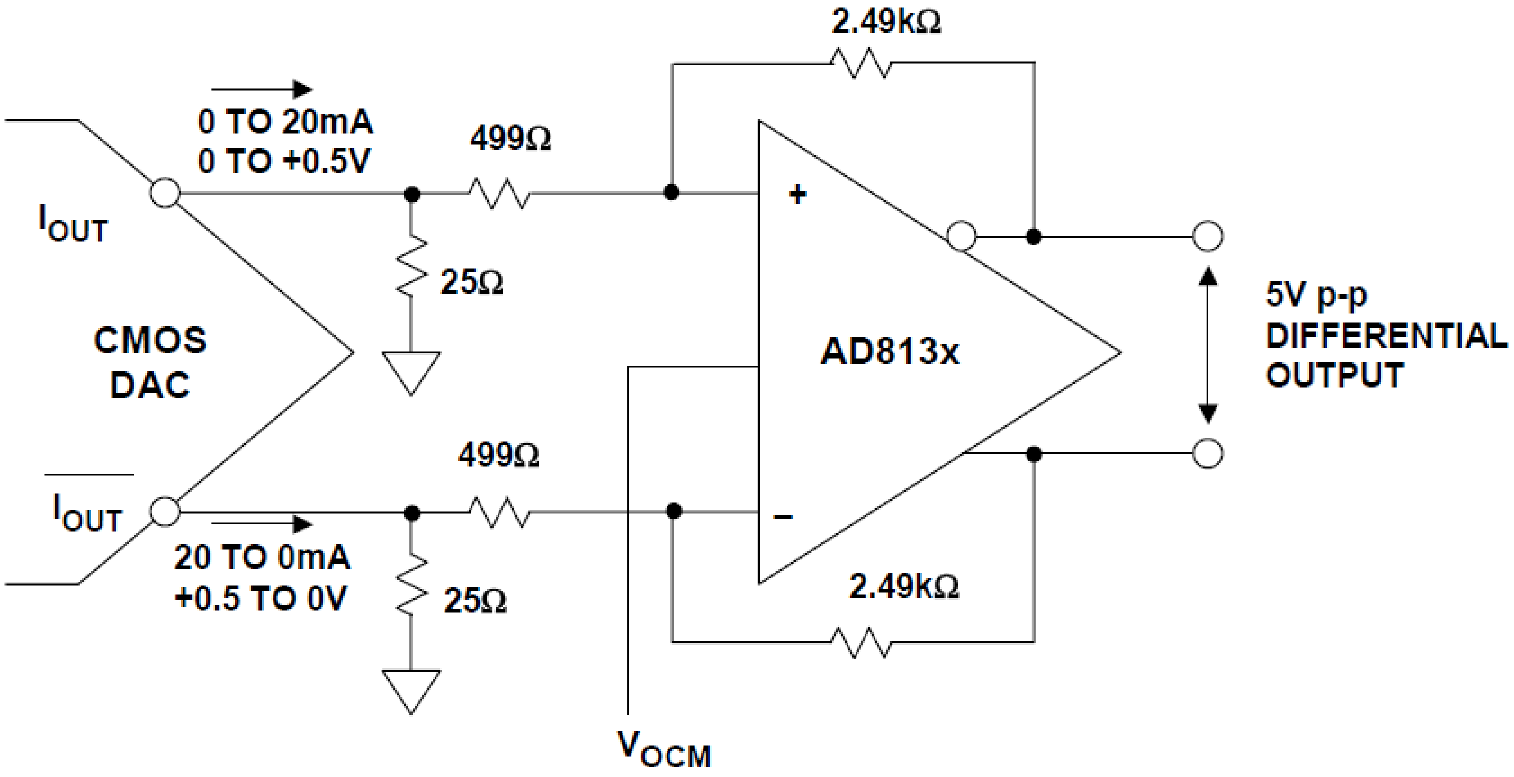
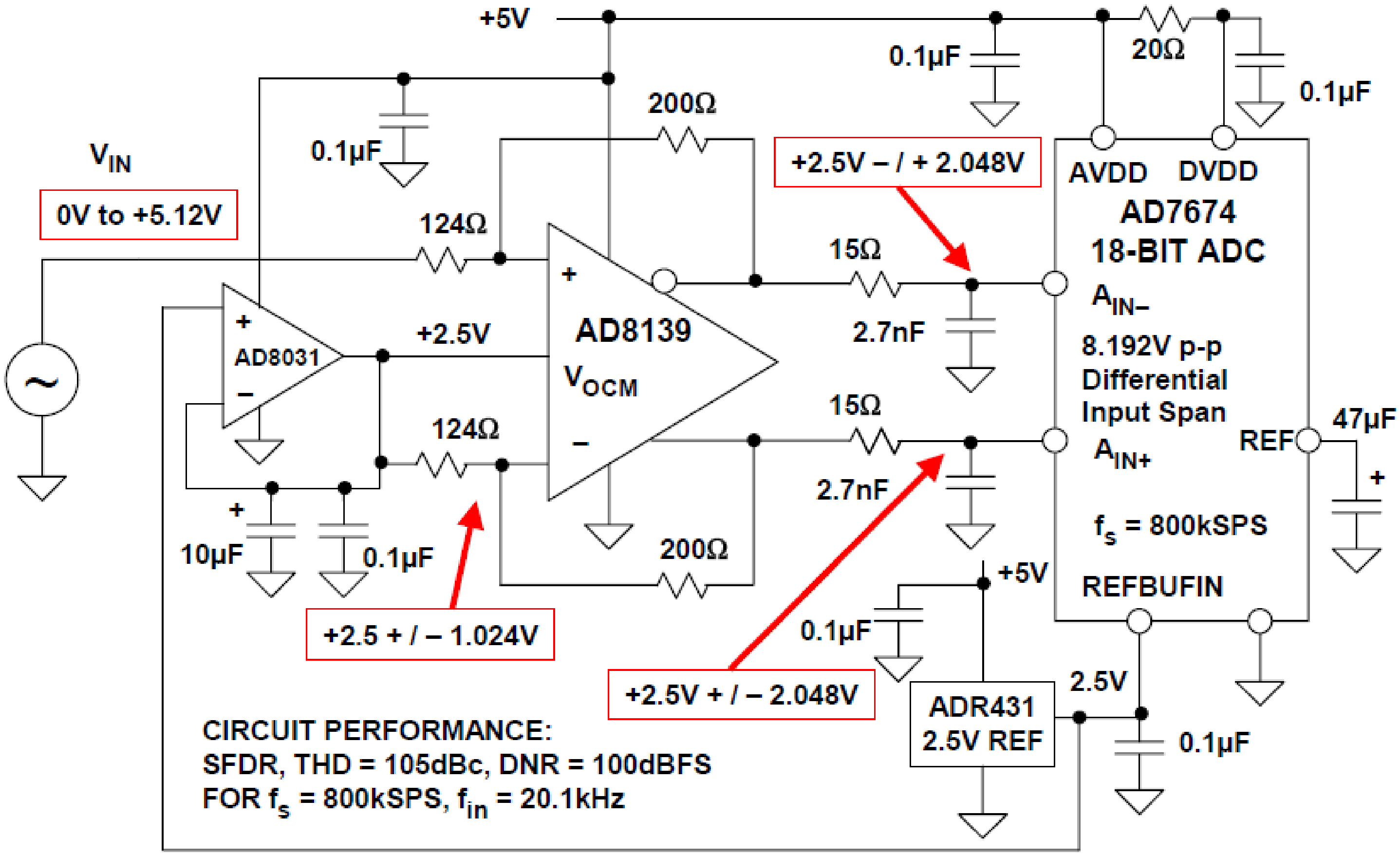


Figure 6.74: *Buffering High Speed DACs Using AD813X Differential Amplifier*

Differential Amplifier ADC Driver



0V to +5.12V

+2.5V – / + 2.048V

+2.5 + / – 1.024V

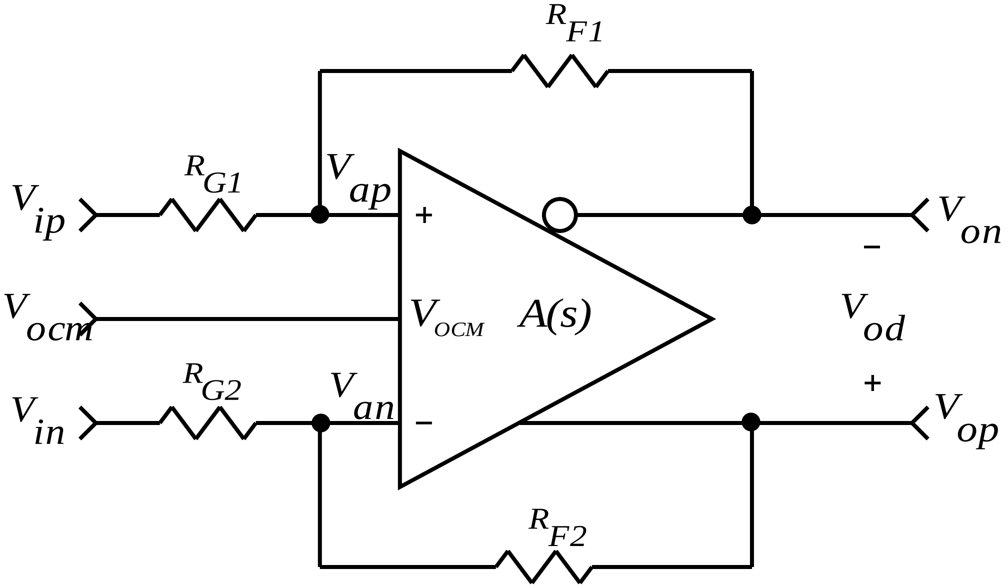
+2.5V + / – 2.048V

CIRCUIT PERFORMANCE:
SFDR, THD = 105dBc, DNR = 100dBFS
FOR f_s = 800kSPS, f_{in} = 20.1kHz

Figure 6.47: *AD8139 Low Noise Differential Driver in a 18-bit ADC Application*

Differential Amplifier Design Equations

General Gain Analysis - Differential Drivers



$$\beta_1 \equiv \frac{R_{G1}}{R_{F1} + R_{G1}}$$

$$\beta_2 \equiv \frac{R_{G2}}{R_{F2} + R_{G2}}$$

$$V_{od} = A(s)\left(V_{ap} - V_{an}\right)$$

$$V_{id} \equiv \left(V_{ip} - V_{in}\right)$$

$$V_{od} = \left[\frac{2}{\beta_1 + \beta_2}\right]\left[\frac{V_{ocm}\left(\beta_1 - \beta_2\right) + V_{ip}\left(1 - \beta_1\right) - V_{in}\left(1 - \beta_2\right)}{1 + \frac{2}{A(s)\left(\beta_1 + \beta_2\right)}}\right]$$

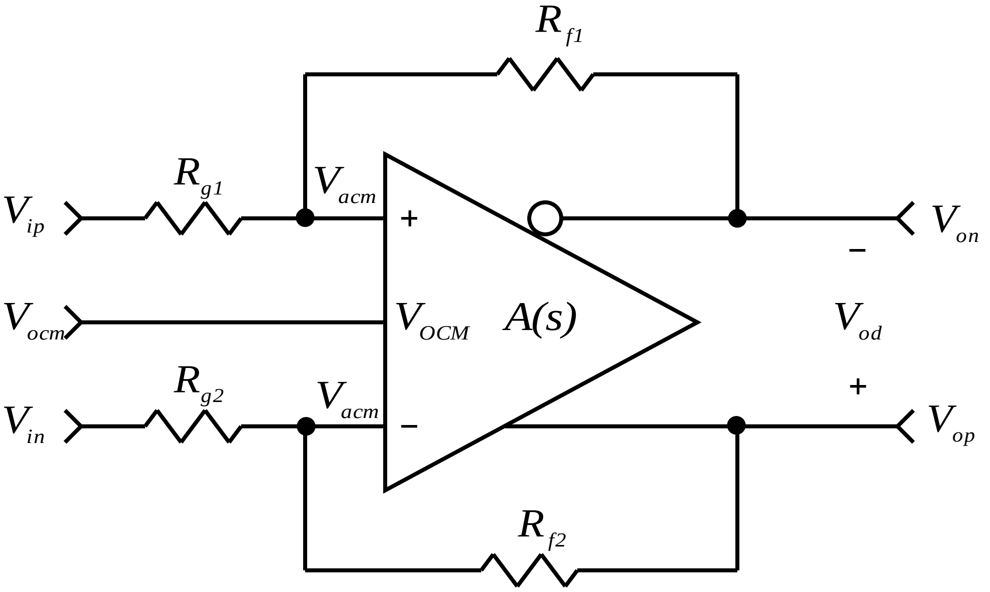
General Case, $\beta_1 \neq \beta_2$

For $\beta_1 = \beta_2 \equiv \beta$:

$$\boxed{\frac{V_{od}}{V_{id}} = \left[\frac{R_F}{R_G}\right]\left[\frac{1}{1 + \cancelto{0}{\frac{1}{A(s)\beta}}}\right]}$$

$$\frac{V_{od}}{V_{id}} = \left[\frac{R_F}{R_G}\right]$$

General Common Mode Voltage Analysis – Differential Drivers



$$\beta_1 \equiv \frac{R_{g1}}{R_{f1} + R_{g1}}$$

$$\beta_2 \equiv \frac{R_{g2}}{R_{f2} + R_{g2}}$$

$$A(s) \rightarrow \infty$$

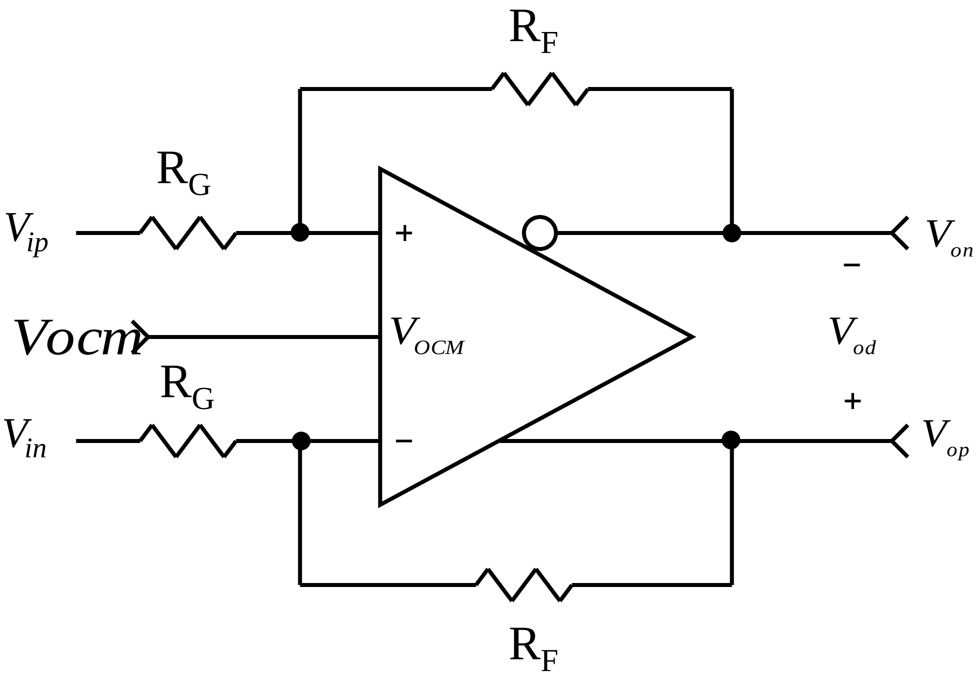
$$V_{acm} = \frac{2\beta_1\beta_2 V_{ocm} + V_{ip}\beta_2(1-\beta_1) + V_{in}\beta_1(1-\beta_2)}{\beta_1 + \beta_2}$$

$$\beta_1 = \beta_2 \equiv \beta$$

$$\boxed{\begin{gathered} V_{acm} = \beta V_{ocm} + (1-\beta)V_{icm} \\ or \\ V_{acm} = V_{icm} + \beta(V_{ocm} - V_{icm}) \end{gathered}}$$

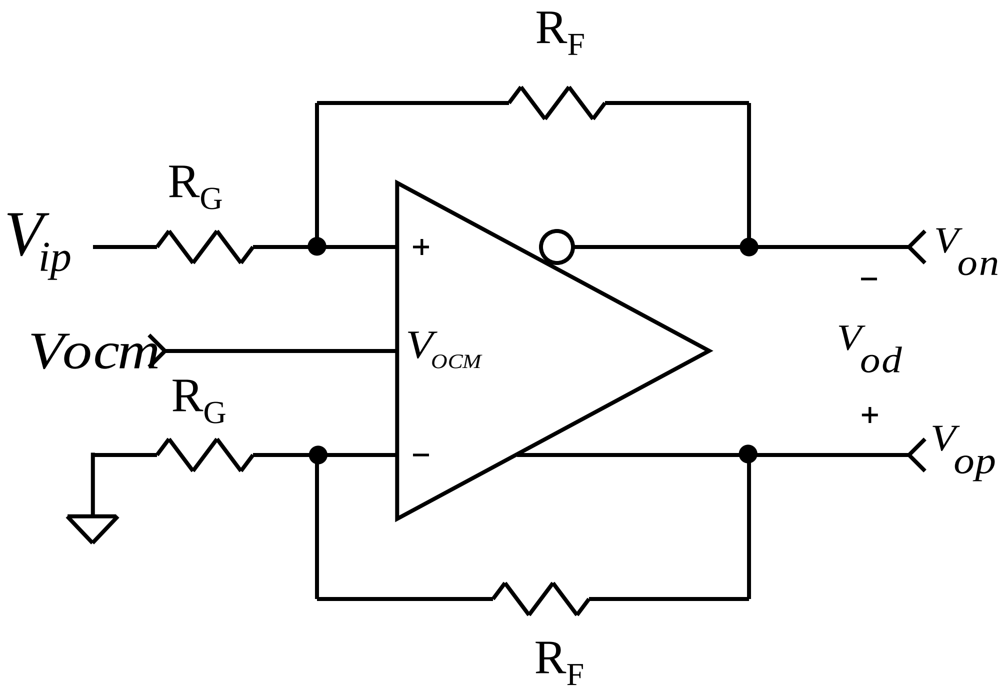
$$V_{icm} \equiv \frac{V_{ip} + V_{in}}{2}$$

Differential Input Impedance



$R_{IN,dm} = 2xR_G$

Single Ended Input Impedance

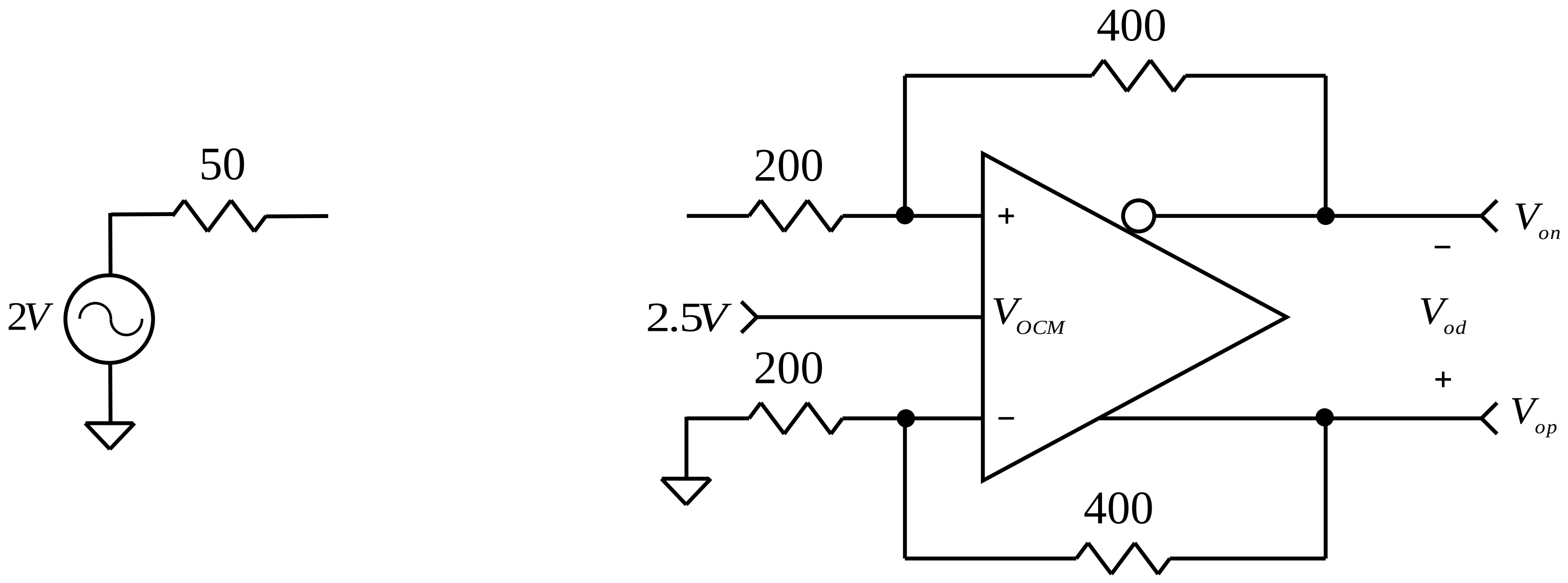


$$R_{IN} = \left\{ \frac{R_G}{1 - \frac{R_F}{2 * (R_G + R_F)}} \right\}$$

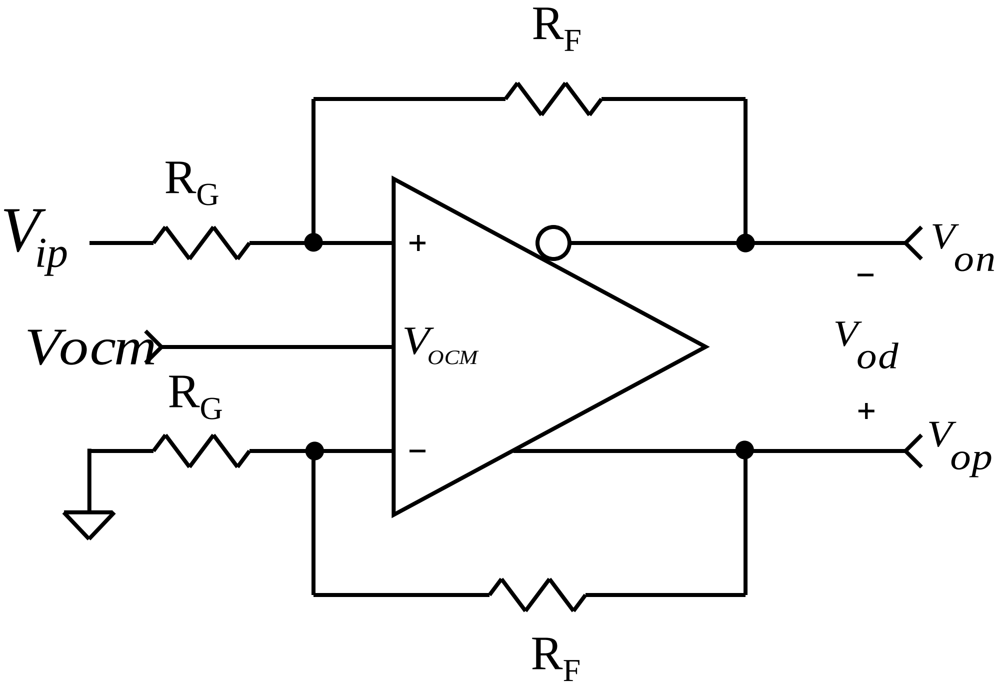
Single Ended to Differential Design Example

Terminate a Single-Ended Input and Calculate the Noise

Requirements: Differential Gain = 1, 50Ω Termination, Resistors ~200/400Ω



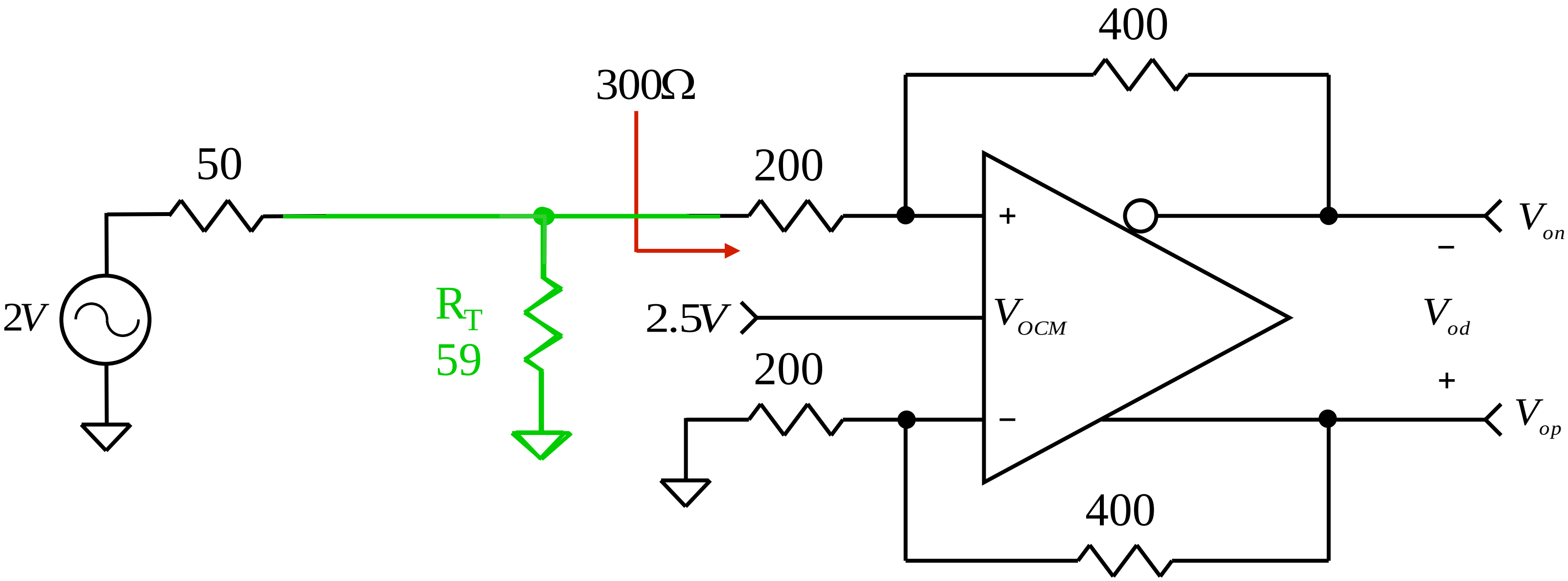
Single Ended Input Impedance



$$R_{IN} = \left\{ \frac{R_G}{1 - \frac{R_F}{2*(R_G + R_F)}} \right\}$$

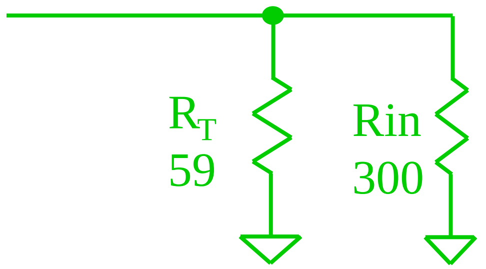
Terminating a Single-Ended Input

Requirements: Differential Gain = 1, 50Ω Termination, Resistors ~200Ω

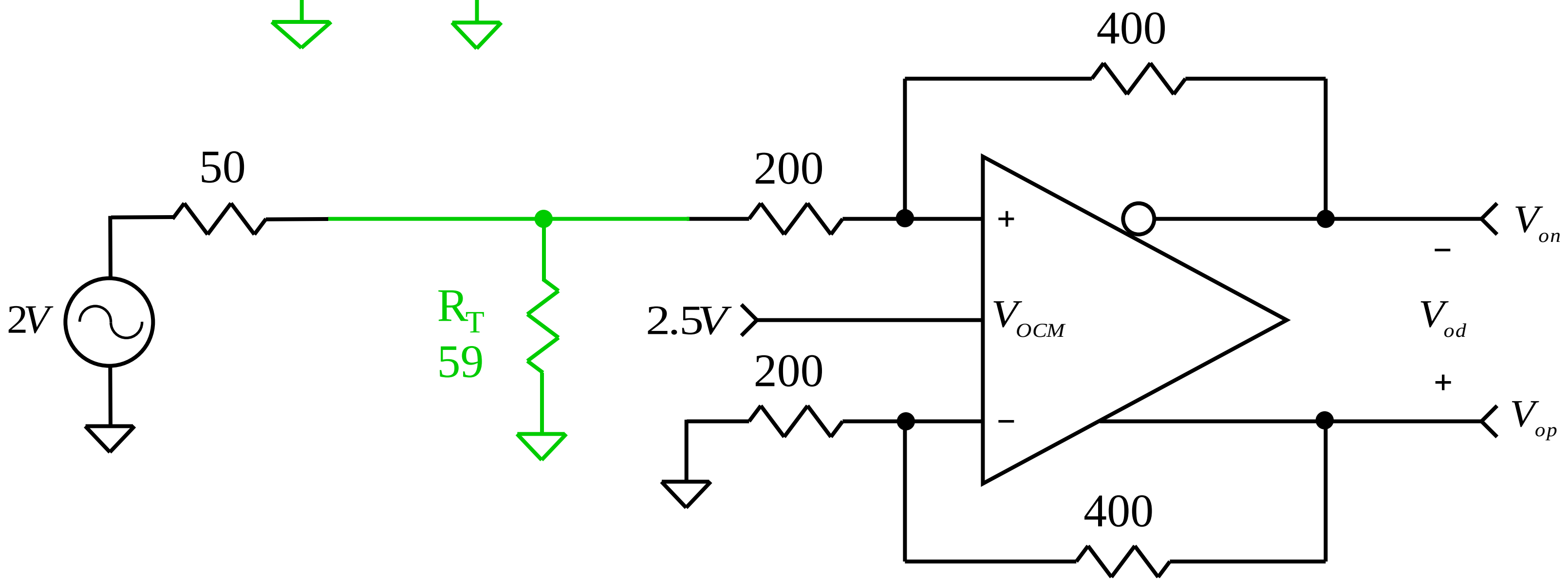


Terminating a Single-Ended Input

Requirements: Differential Gain = 1, 50Ω Termination, Resistors ~200Ω

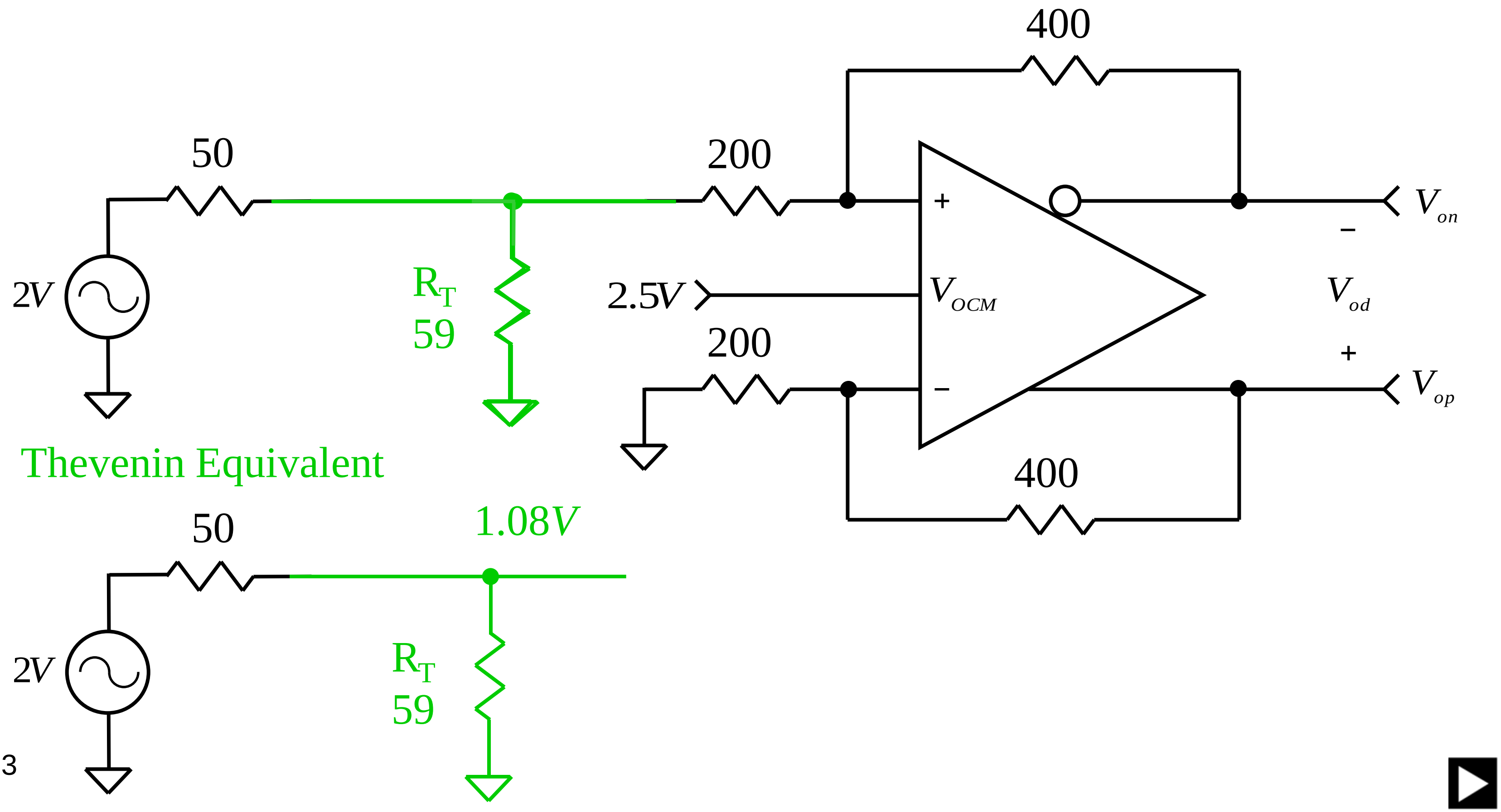


59||300 = 50



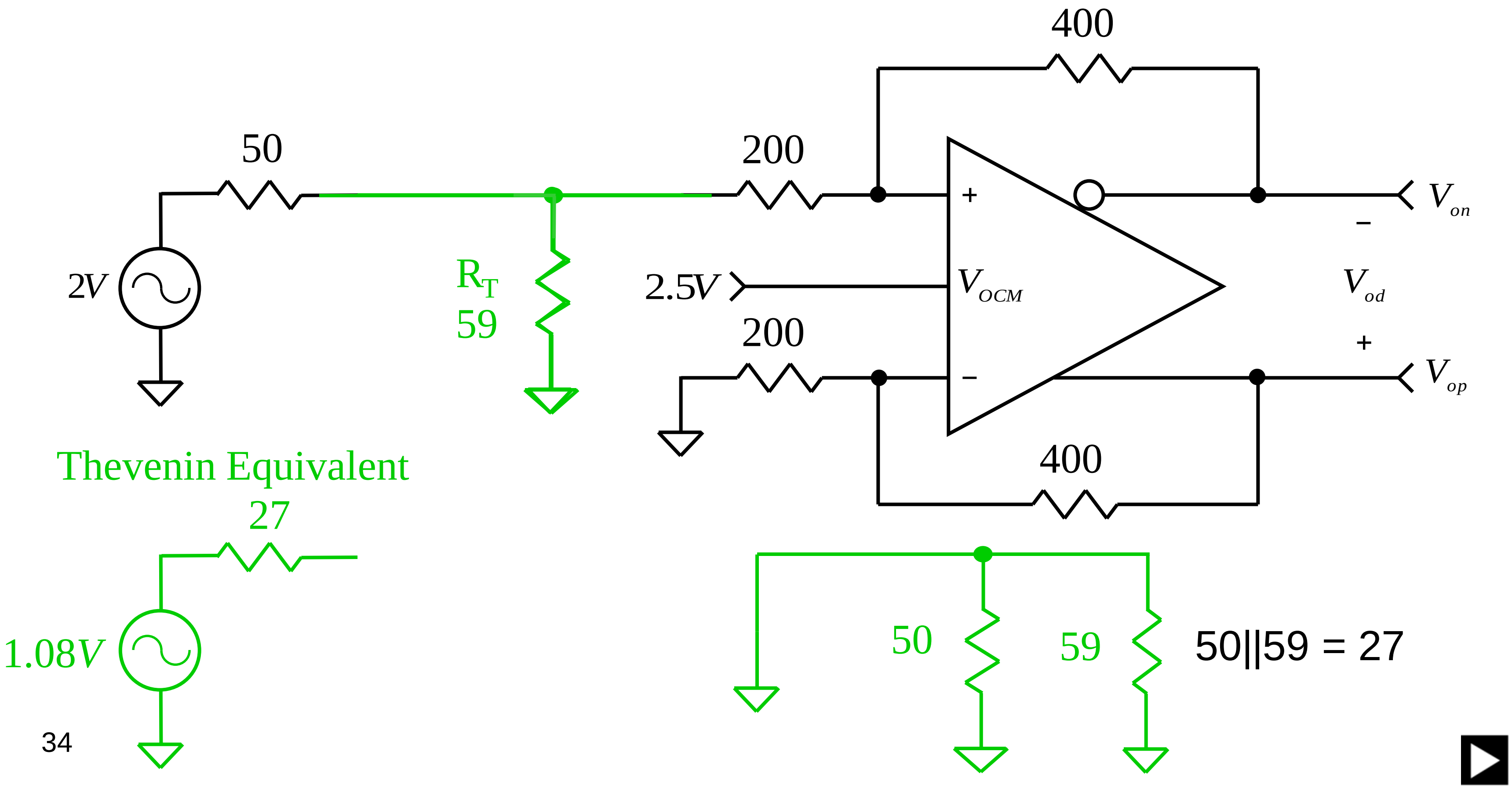
Terminating a Single-Ended Input

Requirements: Differential Gain = 1, 50Ω Termination, Resistors ~200Ω



Terminating a Single-Ended Input

Requirements: Differential Gain = 1, 50Ω Termination, Resistors ~200Ω



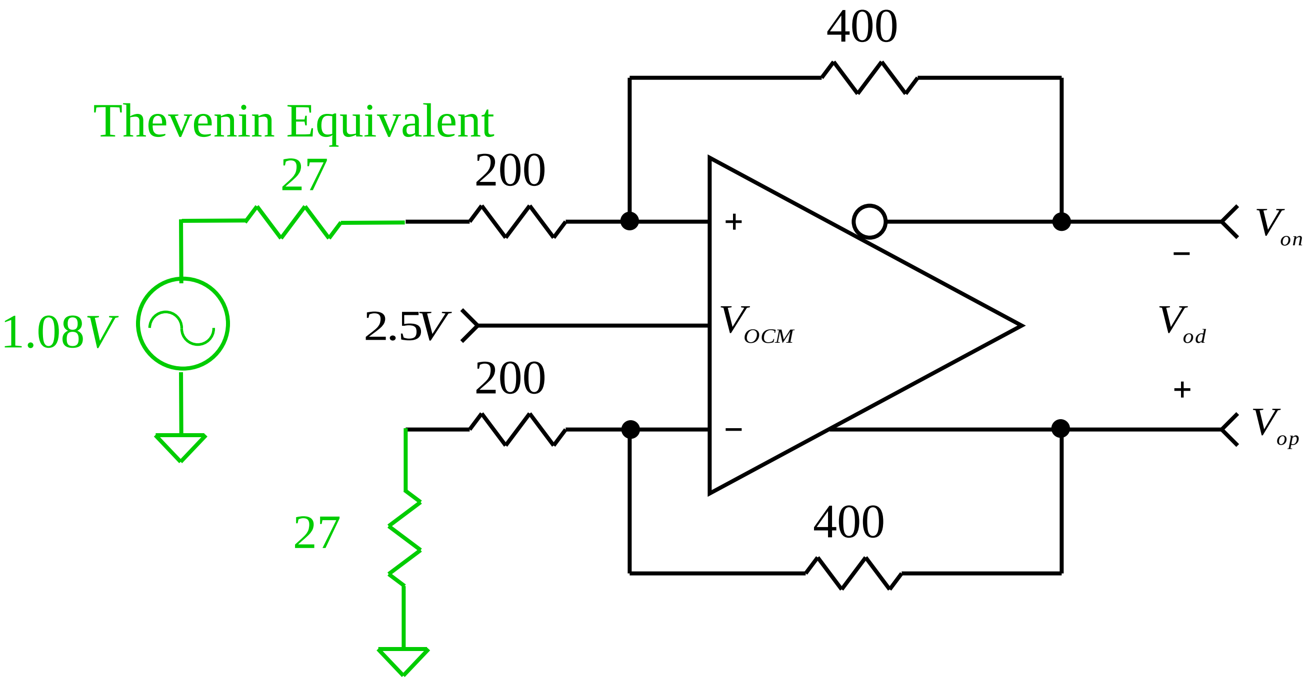
50||59 = 27

Terminating a Single-Ended Input

Requirements: Differential Gain = 1, 50Ω Termination, Resistors ~200Ω

$$\frac{V_{od}}{V_{id}} = \left[\frac{R_F}{R_G}\right]$$

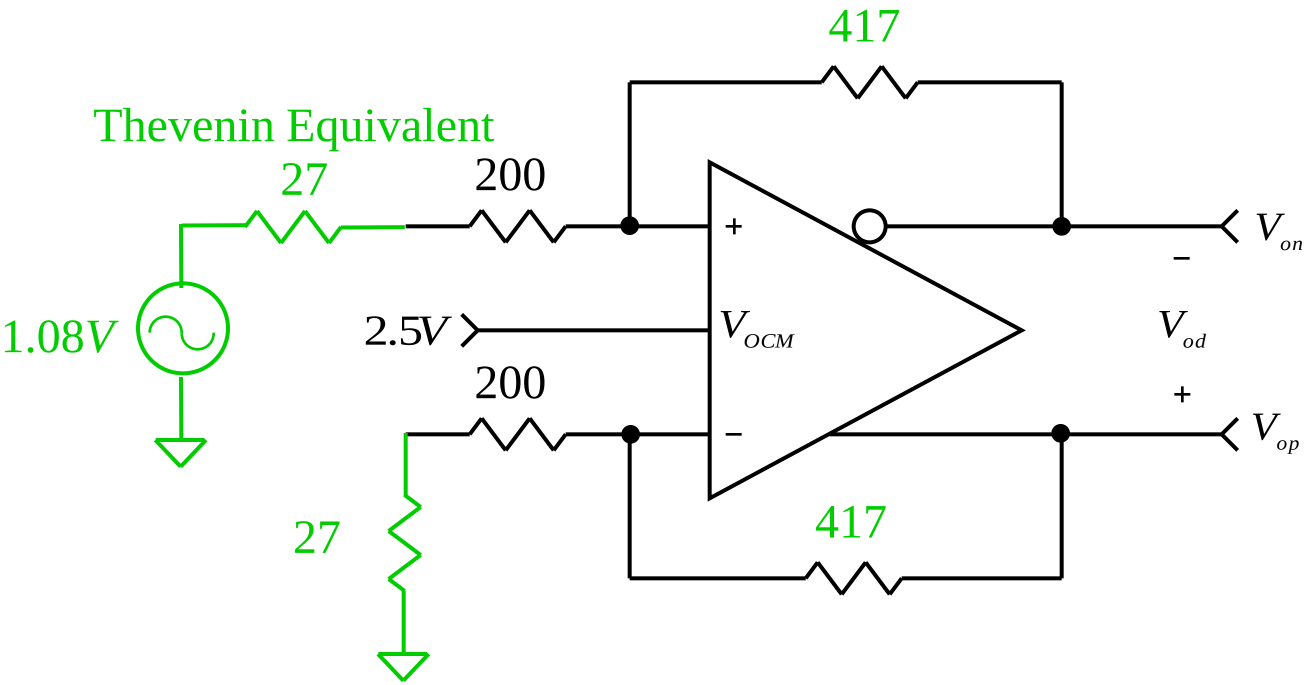
$$\frac{\mathrm{V_{od}}}{\mathrm{V_{id}}} = \left[\frac{400}{227}\right] = 1.76 * 1.08\mathrm{V} = 1.9\mathrm{V}$$



Terminating a Single-Ended Input

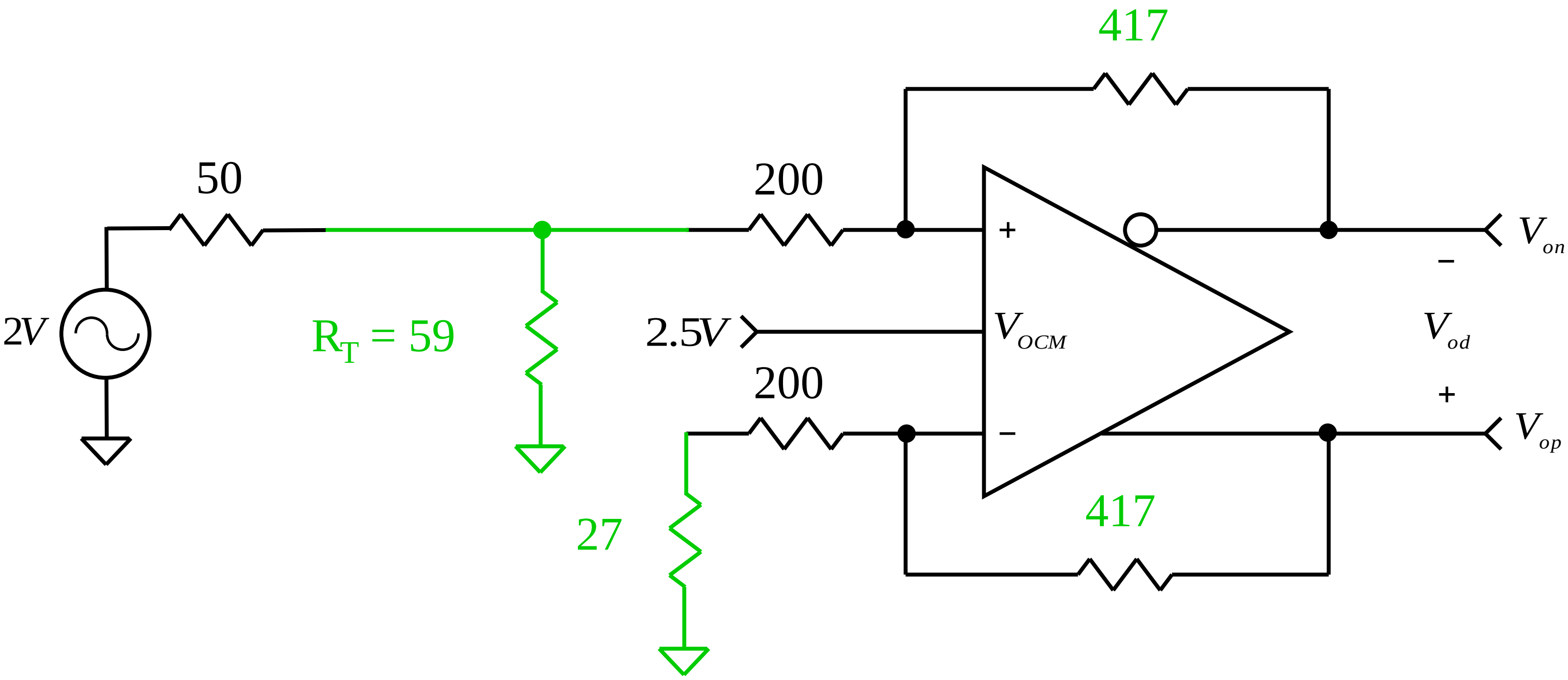
Requirements: Differential Gain = 1, 50Ω Termination, Resistors ~200Ω

$$\frac{V_{od}}{V_{id}} = \left[\frac{R_F}{R_G}\right] = \frac{417}{227} = 1.84 * 1.08V = 1.99V$$

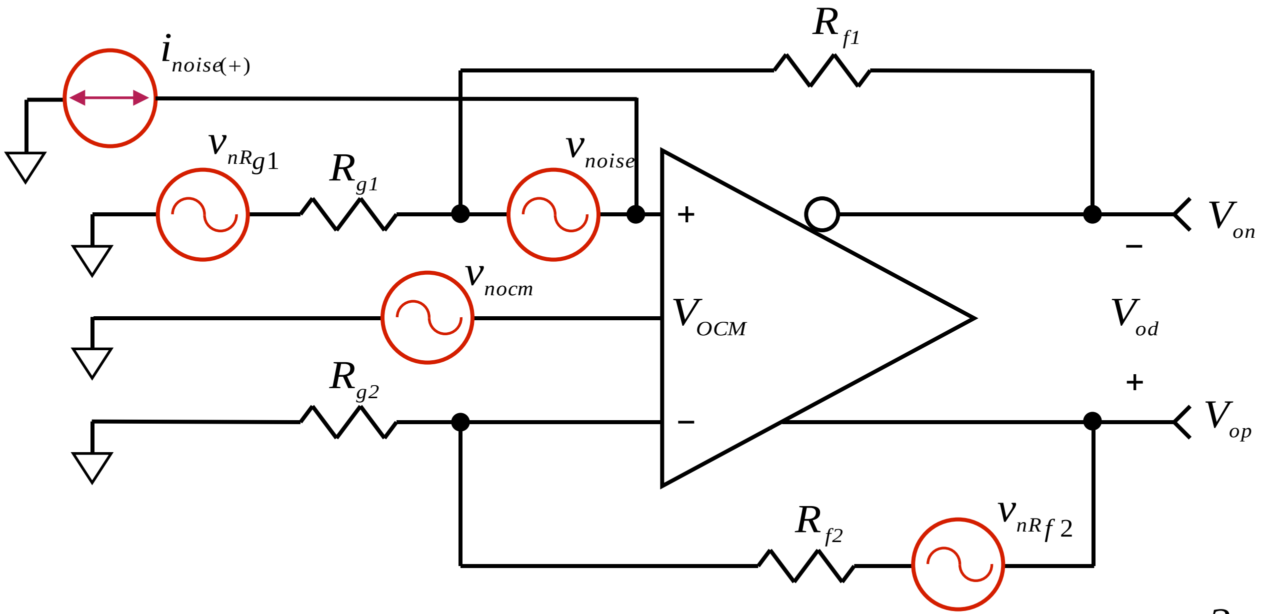


Terminating a Single-Ended Input

Requirements: Differential Gain = 1, 50Ω Termination, Resistors ~200Ω



General Differential Driver Noise Analysis



$$\beta_1 \equiv \frac{R_{g1}}{R_{f1}+R_{g1}}$$

$$\beta_2 \equiv \frac{R_{g2}}{R_{f2}+R_{g2}}$$

$$A(s) \rightarrow \infty$$

$$\text{Differential output noise due to Input} - \text{Referred Voltage Noise} = \frac{2v_{noise}}{\beta_1+\beta_2} = \frac{v_{noise}}{\beta} \text{ for } \beta_1 = \beta_2 \equiv \beta$$

$$\text{Differential output noise due to } V_{OCM} \text{ Input} - \text{Referred Noise} = \frac{2v_{nocm}(\beta_1-\beta_2)}{\beta_1+\beta_2} = 0 \text{ for } \beta_1 = \beta_2$$

$$\text{Differential output noise due to } i_{noise(+)} = \frac{(2i_{noise(+)})R_{g1}(1-\beta_1)}{\beta_1+\beta_2} = i_{noise(+)}R_{f1} \text{ for } \beta_1 = \beta_2 \text{ ; similar for } i_{noise(-)}$$

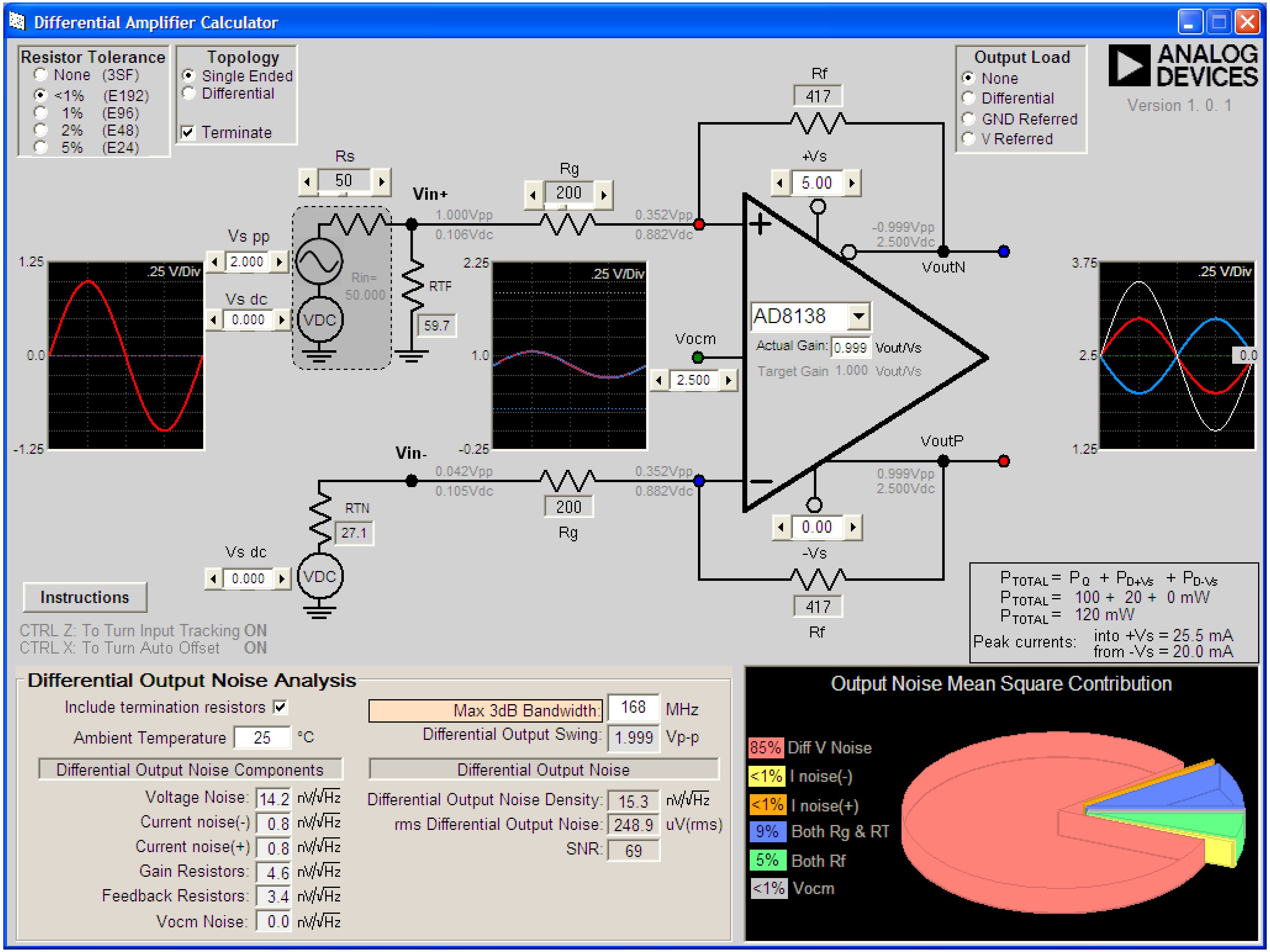
$$\text{Differential output noise due to } R_{g1} = \frac{\left(2\sqrt{4kTR_{g1}}\right)(1-\beta_1)}{\beta_1+\beta_2} = \sqrt{4kTR_{g1}}\left(\frac{R_f}{R_g}\right) \text{ for } \beta_1 = \beta_2 \text{ ; similar for } R_{g2}$$

$$\text{Differential output noise due to } R_{f2} = \frac{2\beta_2\sqrt{4kTR_{f2}}}{\beta_1+\beta_2} = \sqrt{4kTR_{f2}} \text{ for } \beta_1 = \beta_2 \text{ ; similar for } R_{f1}$$

Single Ended to Differential Design Example Using

New Differential Amplifier Calculator

Differential Amplifier Calculator



Differential Amplifier Calculator

Resistor Tolerance
- ○ None (3SF)
- ● <1% (E192)
- ○ 1% (E96)
- ○ 2% (E48)
- ○ 5% (E24)

Topology
- ● Single Ended
- ○ Differential
- ☑ Terminate

Output Load
- ● None
- ○ Differential
- ○ GND Referred
- ○ V Referred

ANALOG DEVICES
Version 1. 0. 1

Rs: 50
Vs pp: 2.000
Vs dc: 0.000
Rin= 50.000
RTF: 59.7
Rg: 200
Rf: 417
+Vs: 5.00
AD8138
Actual Gain: 0.999 Vout/Vs
Target Gain 1.000 Vout/Vs
Vocm: 2.500
RTN: 27.1
Vs dc: 0.000
-Vs: 0.00
Rg: 200
Rf: 417

Instructions

CTRL Z: To Turn Input Tracking ON
CTRL X: To Turn Auto Offset ON

$P_{TOTAL} = P_Q + P_{D+Vs} + P_{D-Vs}$
$P_{TOTAL} =$ 100 + 20 + 0 mW
$P_{TOTAL} =$ 120 mW
Peak currents: into +Vs = 25.5 mA
from -Vs = 20.0 mA

Differential Output Noise Analysis

Include termination resistors ☑
Ambient Temperature: 25 °C

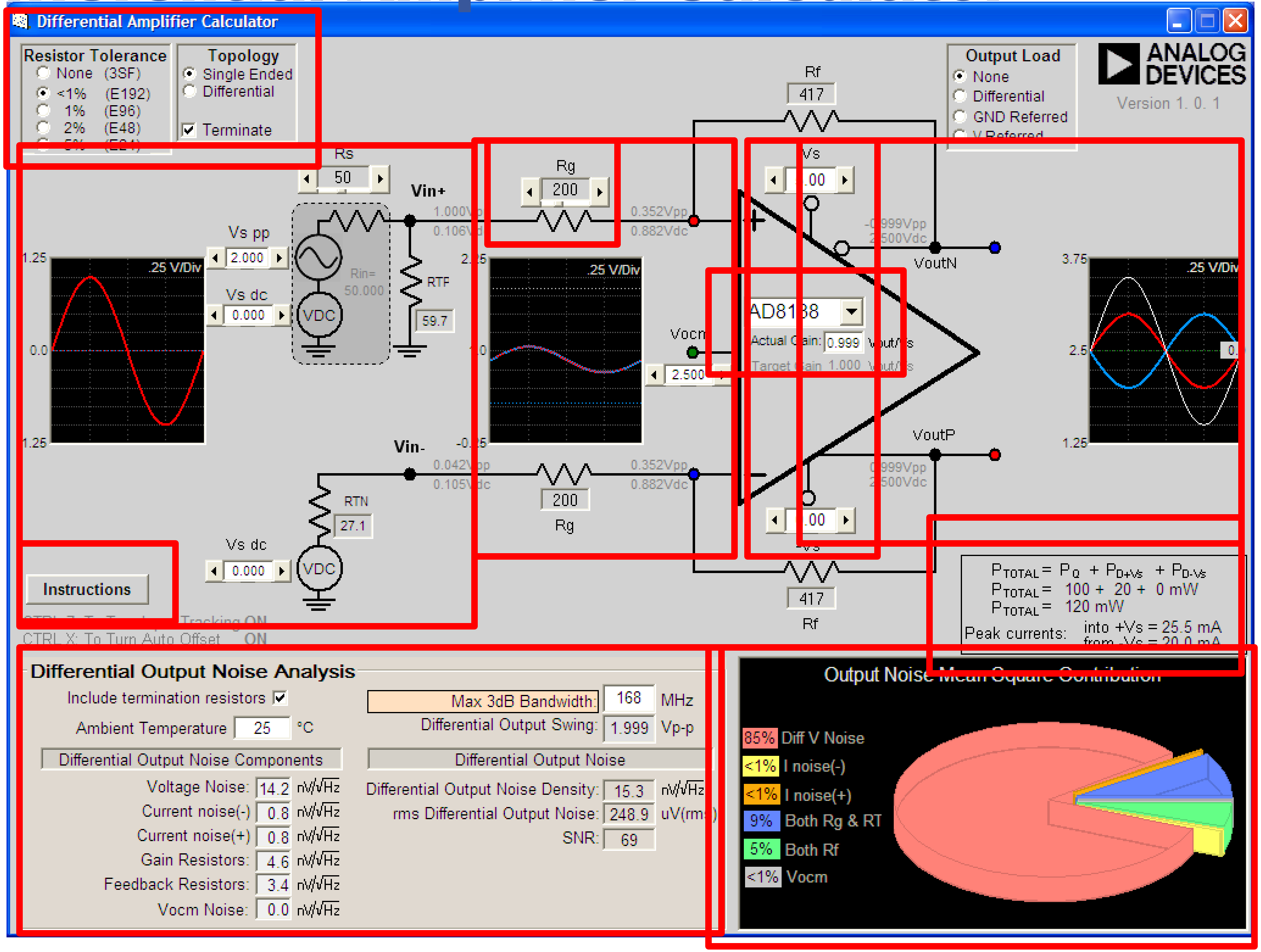
Max 3dB Bandwidth: 168 MHz
Differential Output Swing: 1.999 Vp-p

Differential Output Noise Components
- Voltage Noise: 14.2 nV/√Hz
- Current noise(-): 0.8 nV/√Hz
- Current noise(+): 0.8 nV/√Hz
- Gain Resistors: 4.6 nV/√Hz
- Feedback Resistors: 3.4 nV/√Hz
- Vocm Noise: 0.0 nV/√Hz

Differential Output Noise
- Differential Output Noise Density: 15.3 nV/√Hz
- rms Differential Output Noise: 248.9 uV(rms)
- SNR: 69

Output Noise Mean Square Contribution
- 85% Diff V Noise
- <1% I noise(-)
- <1% I noise(+)
- 9% Both Rg & RT
- 5% Both Rf
- <1% Vocm

Differential Amplifier Calculator



Differential Amplifier Calculator

Resistor Tolerance
○ None (3SF)
● <1% (E192)
○ 1% (E96)
○ 2% (E48)

Topology
● Single Ended
○ Differential
☑ Terminate

Output Load
● None
○ Differential
○ GND Referred

Version 1. 0. 1

Rs: 50
Vs pp: 2.000
Vs dc: 0.000
Rin= 50.000
RTF: 59.7
Rg: 200
Rf: 417
Vs: .00
RTN: 27.1
Vs dc: 0.000
Rg: 200
Rf: 417
-Vs: .00
Vocm: 2.500
AD81[illegible]8
Actual Gain: 0.999 Vout/Vs
Target Gain 1.000 Vout/Vs

$P_{TOTAL} = P_Q + P_{D+Vs} + P_{D-Vs}$
$P_{TOTAL} = 100 + 20 + 0$ mW
$P_{TOTAL} = 120$ mW
Peak currents: into +Vs = 25.5 mA
from -Vs = 20.0 mA

Instructions

CTRL Z: To T... Tracking ON
CTRL X: To Turn Auto Offset ON

Differential Output Noise Analysis

Include termination resistors ☑
Ambient Temperature: 25 °C

Max 3dB Bandwidth: 168 MHz
Differential Output Swing: 1.999 Vp-p

Differential Output Noise Components

Voltage Noise:	14.2	nV/√Hz
Current noise(-):	0.8	nV/√Hz
Current noise(+):	0.8	nV/√Hz
Gain Resistors:	4.6	nV/√Hz
Feedback Resistors:	3.4	nV/√Hz
Vocm Noise:	0.0	nV/√Hz

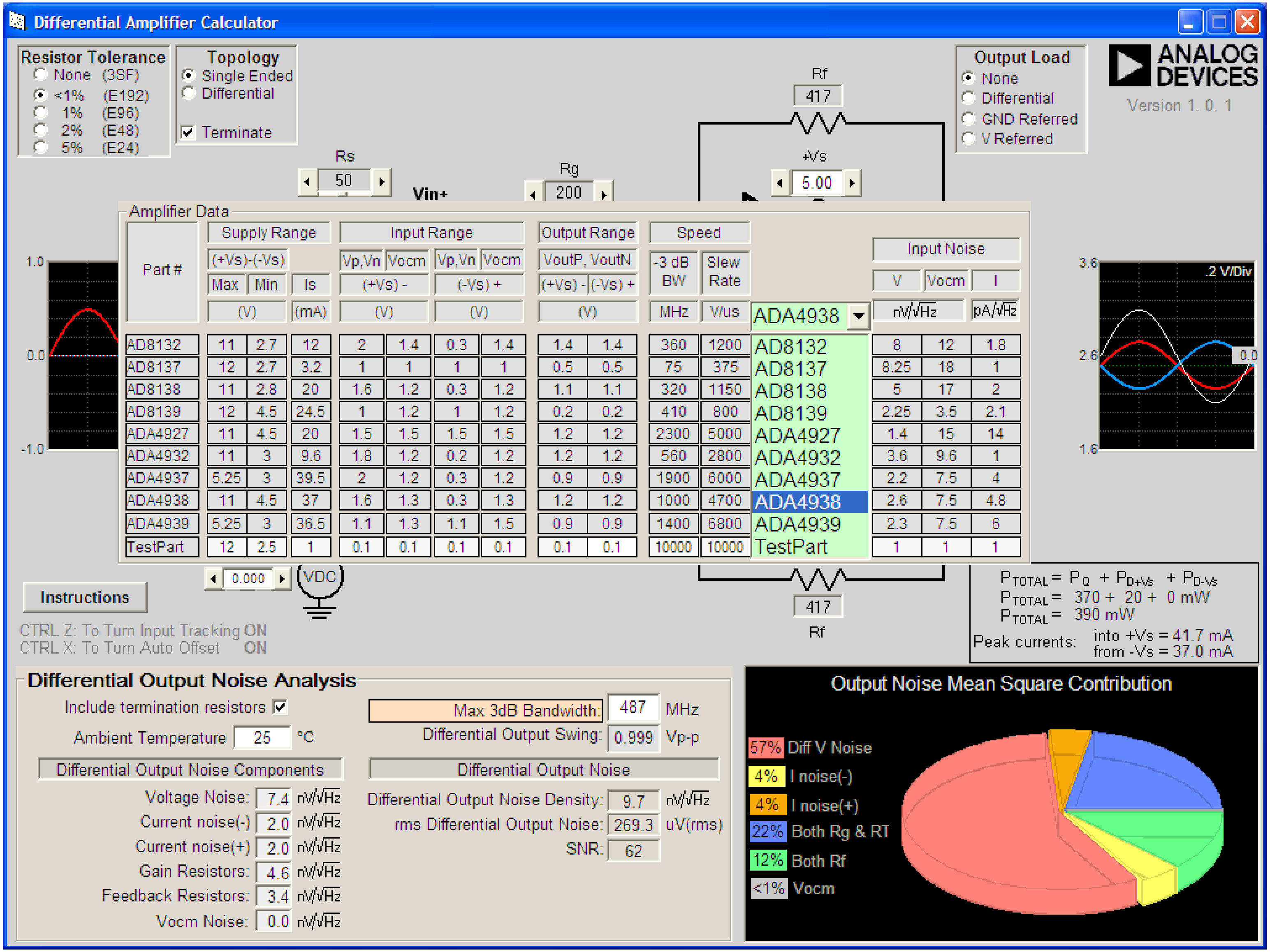
Differential Output Noise

Differential Output Noise Density:	15.3	nV/√Hz
rms Differential Output Noise:	248.9	uV(rms)
SNR:	69	

Output Noise Mean Square Contribution

85%	Diff V Noise
<1%	I noise(-)
<1%	I noise(+)
9%	Both Rg & RT
5%	Both Rf
<1%	Vocm

Differential Amplifier Calculator



Version 1. 0. 1

Resistor Tolerance
- ○ None (3SF)
- ● <1% (E192)
- ○ 1% (E96)
- ○ 2% (E48)
- ○ 5% (E24)

Topology
- ● Single Ended
- ○ Differential
- ☑ Terminate

Output Load
- ● None
- ○ Differential
- ○ GND Referred
- ○ V Referred

Rf: 417
Rs: 50
Rg: 200
+Vs: 5.00
VDC: 0.000
Rf: 417

Amplifier Data

Part #	Supply Range (+Vs)-(-Vs) Max (V)	Supply Range (+Vs)-(-Vs) Min (V)	Is (mA)	Input Range (+Vs) - Vp,Vn (V)	Input Range (+Vs) - Vocm (V)	Input Range (-Vs) + Vp,Vn (V)	Input Range (-Vs) + Vocm (V)	Output Range VoutP, VoutN (+Vs) - (V)	Output Range VoutP, VoutN (-Vs) + (V)	Speed -3 dB BW MHz	Speed Slew Rate V/us	ADA4938	Input Noise V nV/√Hz	Input Noise Vocm nV/√Hz	Input Noise I pA/√Hz
AD8132	11	2.7	12	2	1.4	0.3	1.4	1.4	1.4	360	1200	AD8132	8	12	1.8
AD8137	12	2.7	3.2	1	1	1	1	0.5	0.5	75	375	AD8137	8.25	18	1
AD8138	11	2.8	20	1.6	1.2	0.3	1.2	1.1	1.1	320	1150	AD8138	5	17	2
AD8139	12	4.5	24.5	1	1.2	1	1.2	0.2	0.2	410	800	AD8139	2.25	3.5	2.1
ADA4927	11	4.5	20	1.5	1.5	1.5	1.5	1.2	1.2	2300	5000	ADA4927	1.4	15	14
ADA4932	11	3	9.6	1.8	1.2	0.2	1.2	1.2	1.2	560	2800	ADA4932	3.6	9.6	1
ADA4937	5.25	3	39.5	2	1.2	0.3	1.2	0.9	0.9	1900	6000	ADA4937	2.2	7.5	4
ADA4938	11	4.5	37	1.6	1.3	0.3	1.3	1.2	1.2	1000	4700	ADA4938	2.6	7.5	4.8
ADA4939	5.25	3	36.5	1.1	1.3	1.1	1.5	0.9	0.9	1400	6800	ADA4939	2.3	7.5	6
TestPart	12	2.5	1	0.1	0.1	0.1	0.1	0.1	0.1	10000	10000	TestPart	1	1	1

$P_{TOTAL} = P_Q + P_{D+Vs} + P_{D-Vs}$
$P_{TOTAL} = 370 + 20 + 0$ mW
$P_{TOTAL} = 390$ mW

Peak currents: into +Vs = 41.7 mA
from -Vs = 37.0 mA

CTRL Z: To Turn Input Tracking ON
CTRL X: To Turn Auto Offset ON

Differential Output Noise Analysis

Include termination resistors ☑
Ambient Temperature: 25 °C

Max 3dB Bandwidth: 487 MHz
Differential Output Swing: 0.999 Vp-p

Differential Output Noise Components

Voltage Noise:	7.4	nV/√Hz
Current noise(-)	2.0	nV/√Hz
Current noise(+)	2.0	nV/√Hz
Gain Resistors:	4.6	nV/√Hz
Feedback Resistors:	3.4	nV/√Hz
Vocm Noise:	0.0	nV/√Hz

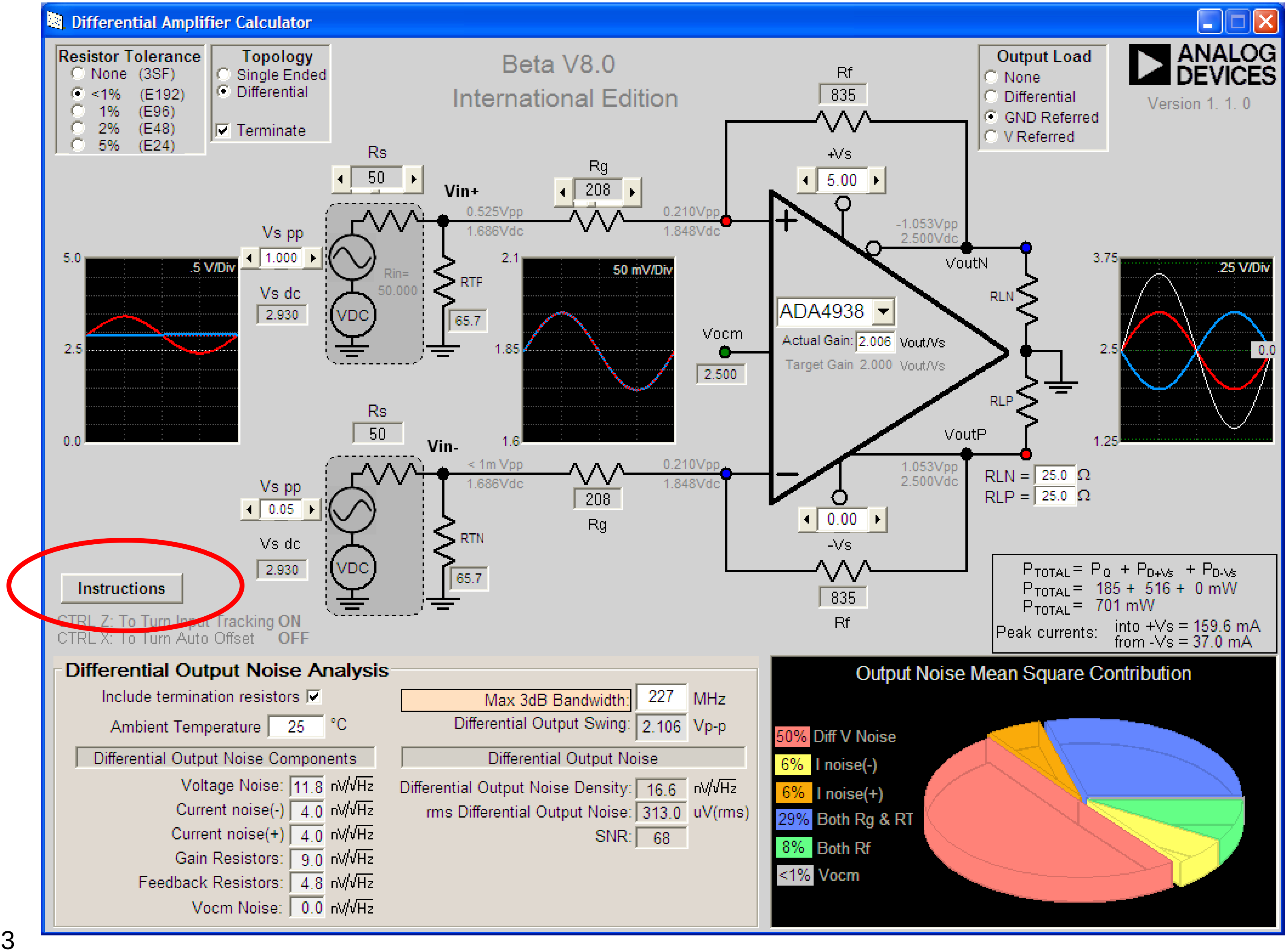
Differential Output Noise

Differential Output Noise Density:	9.7	nV/√Hz
rms Differential Output Noise:	269.3	uV(rms)
SNR:	62	

Output Noise Mean Square Contribution

57%	Diff V Noise
4%	I noise(-)
4%	I noise(+)
22%	Both Rg & RT
12%	Both Rf
<1%	Vocm

Differential Amplifier Calculator



Resistor Tolerance
○ None (3SF)
● <1% (E192)
○ 1% (E96)
○ 2% (E48)
○ 5% (E24)

Topology
○ Single Ended
● Differential
☑ Terminate

Beta V8.0
International Edition

Output Load
○ None
○ Differential
● GND Referred
○ V Referred

ANALOG DEVICES
Version 1. 1. 0

Rf: 835
Rs: 50
Rg: 208
+Vs: 5.00
Vs pp: 1.000
Vs dc: 2.930
Rin= 50.000
RTF: 65.7
Vocm: 2.500
ADA4938
Actual Gain: 2.006 Vout/Vs
Target Gain 2.000 Vout/Vs
Rs: 50
Vs pp: 0.05
Vs dc: 2.930
RTN: 65.7
Rg: 208
-Vs: 0.00
Rf: 835
RLN = 25.0 Ω
RLP = 25.0 Ω

PTOTAL = PQ + PD+Vs + PD-Vs
PTOTAL = 185 + 516 + 0 mW
PTOTAL = 701 mW
Peak currents: into +Vs = 159.6 mA
from -Vs = 37.0 mA

Instructions

CTRL Z: To Turn Input Tracking ON
CTRL X: To Turn Auto Offset OFF

Differential Output Noise Analysis

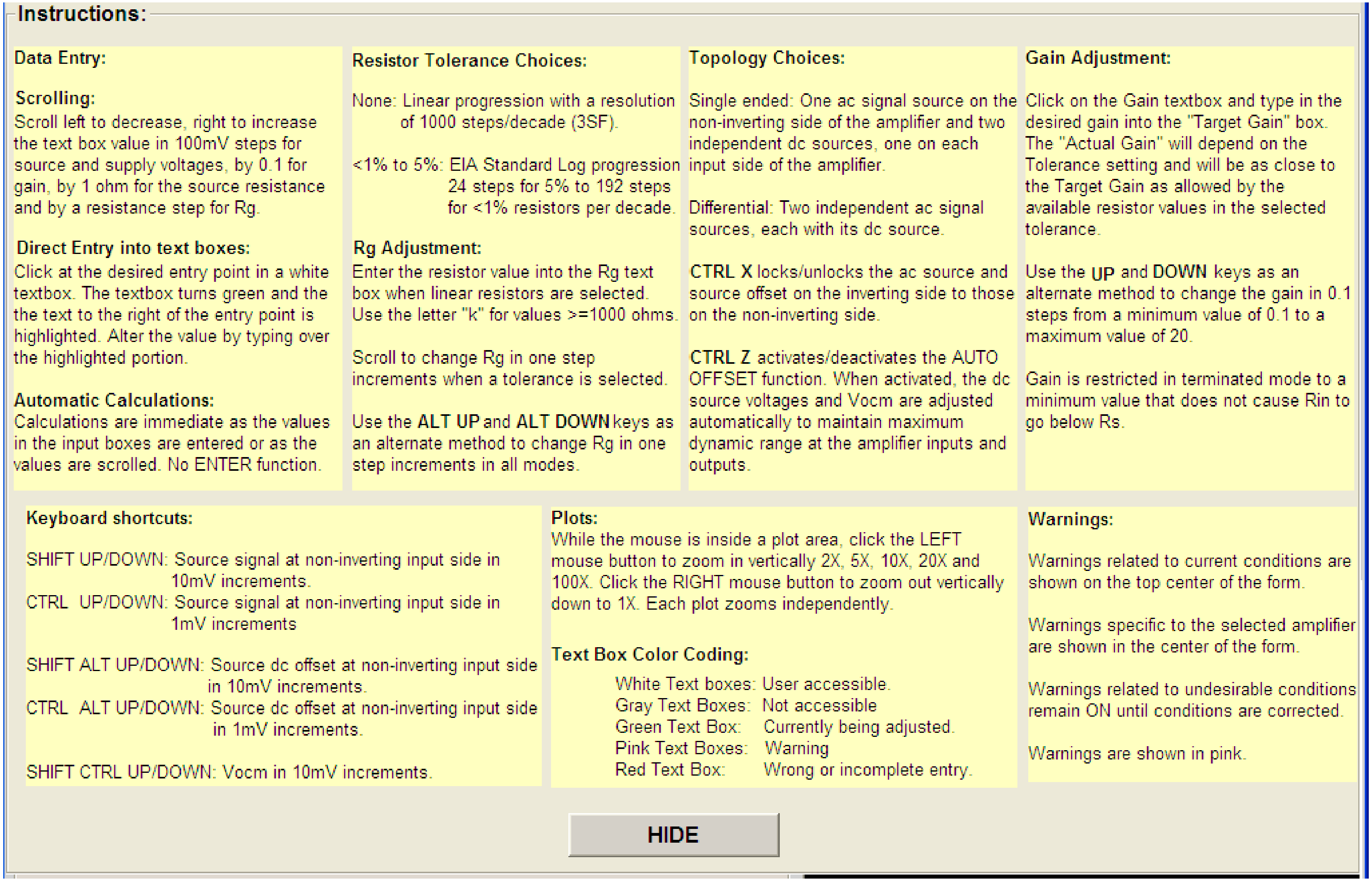
Include termination resistors ☑
Ambient Temperature 25 °C
Max 3dB Bandwidth: 227 MHz
Differential Output Swing: 2.106 Vp-p

Differential Output Noise Components
Voltage Noise: 11.8 nV/√Hz
Current noise(-): 4.0 nV/√Hz
Current noise(+): 4.0 nV/√Hz
Gain Resistors: 9.0 nV/√Hz
Feedback Resistors: 4.8 nV/√Hz
Vocm Noise: 0.0 nV/√Hz

Differential Output Noise
Differential Output Noise Density: 16.6 nV/√Hz
rms Differential Output Noise: 313.0 uV(rms)
SNR: 68

Output Noise Mean Square Contribution
50% Diff V Noise
6% I noise(-)
6% I noise(+)
29% Both Rg & RT
8% Both Rf
<1% Vocm

New Differential Amplifier Calculator (cont)



Instructions:

Data Entry:

Scrolling:
Scroll left to decrease, right to increase the text box value in 100mV steps for source and supply voltages, by 0.1 for gain, by 1 ohm for the source resistance and by a resistance step for Rg.

Direct Entry into text boxes:
Click at the desired entry point in a white textbox. The textbox turns green and the the text to the right of the entry point is highlighted. Alter the value by typing over the highlighted portion.

Automatic Calculations:
Calculations are immediate as the values in the input boxes are entered or as the values are scrolled. No ENTER function.

Resistor Tolerance Choices:

None: Linear progression with a resolution of 1000 steps/decade (3SF).

<1% to 5%: EIA Standard Log progression 24 steps for 5% to 192 steps for <1% resistors per decade.

Rg Adjustment:
Enter the resistor value into the Rg text box when linear resistors are selected. Use the letter "k" for values >=1000 ohms.

Scroll to change Rg in one step increments when a tolerance is selected.

Use the **ALT UP** and **ALT DOWN** keys as an alternate method to change Rg in one step increments in all modes.

Topology Choices:

Single ended: One ac signal source on the non-inverting side of the amplifier and two independent dc sources, one on each input side of the amplifier.

Differential: Two independent ac signal sources, each with its dc source.

CTRL X locks/unlocks the ac source and source offset on the inverting side to those on the non-inverting side.

CTRL Z activates/deactivates the AUTO OFFSET function. When activated, the dc source voltages and Vocm are adjusted automatically to maintain maximum dynamic range at the amplifier inputs and outputs.

Gain Adjustment:

Click on the Gain textbox and type in the desired gain into the "Target Gain" box. The "Actual Gain" will depend on the Tolerance setting and will be as close to the Target Gain as allowed by the available resistor values in the selected tolerance.

Use the **UP** and **DOWN** keys as an alternate method to change the gain in 0.1 steps from a minimum value of 0.1 to a maximum value of 20.

Gain is restricted in terminated mode to a minimum value that does not cause Rin to go below Rs.

Keyboard shortcuts:

SHIFT UP/DOWN: Source signal at non-inverting input side in 10mV increments.
CTRL UP/DOWN: Source signal at non-inverting input side in 1mV increments

SHIFT ALT UP/DOWN: Source dc offset at non-inverting input side in 10mV increments.
CTRL ALT UP/DOWN: Source dc offset at non-inverting input side in 1mV increments.

SHIFT CTRL UP/DOWN: Vocm in 10mV increments.

Plots:
While the mouse is inside a plot area, click the LEFT mouse button to zoom in vertically 2X, 5X, 10X, 20X and 100X. Click the RIGHT mouse button to zoom out vertically down to 1X. Each plot zooms independently.

Text Box Color Coding:

White Text boxes: User accessible.
Gray Text Boxes: Not accessible
Green Text Box: Currently being adjusted.
Pink Text Boxes: Warning
Red Text Box: Wrong or incomplete entry.

Warnings:

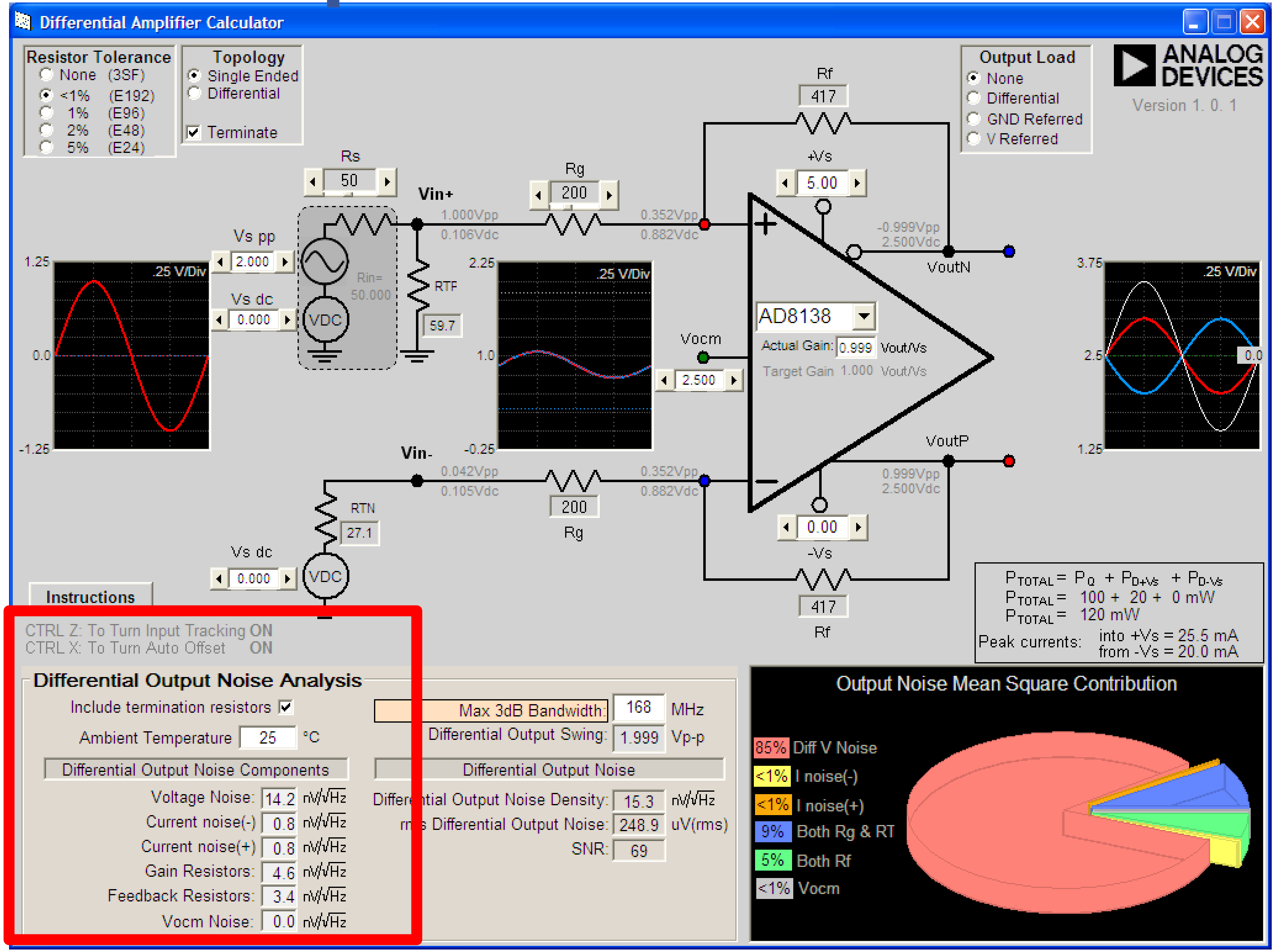
Warnings related to current conditions are shown on the top center of the form.

Warnings specific to the selected amplifier are shown in the center of the form.

Warnings related to undesirable conditions remain ON until conditions are corrected.

Warnings are shown in pink.

ADI DiffAmpCalc™



Differential Amplifier Calculator

Resistor Tolerance
○ None (3SF)
● <1% (E192)
○ 1% (E96)
○ 2% (E48)
○ 5% (E24)

Topology
● Single Ended
○ Differential
☑ Terminate

Output Load
● None
○ Differential
○ GND Referred
○ V Referred

Version 1. 0. 1

Rs: 50
Vs pp: 2.000
Vs dc: 0.000
RTF: 59.7
RTN: 27.1
Vs dc: 0.000
Rg: 200
Rg: 200
Rf: 417
Rf: 417
+Vs: 5.00
-Vs: 0.00
Vocm: 2.500
AD8138
Actual Gain: 0.999 Vout/Vs
Target Gain 1.000 Vout/Vs

PTOTAL = PQ + PD+Vs + PD-Vs
PTOTAL = 100 + 20 + 0 mW
PTOTAL = 120 mW
Peak currents: into +Vs = 25.5 mA
from -Vs = 20.0 mA

Instructions

CTRL Z: To Turn Input Tracking ON
CTRL X: To Turn Auto Offset ON

Differential Output Noise Analysis

Include termination resistors ☑
Ambient Temperature 25 °C

Differential Output Noise Components

Voltage Noise: 14.2 nV/√Hz
Current noise(-) 0.8 nV/√Hz
Current noise(+) 0.8 nV/√Hz
Gain Resistors: 4.6 nV/√Hz
Feedback Resistors: 3.4 nV/√Hz
Vocm Noise: 0.0 nV/√Hz

Max 3dB Bandwidth: 168 MHz
Differential Output Swing: 1.999 Vp-p

Differential Output Noise

Differential Output Noise Density: 15.3 nV/√Hz
rms Differential Output Noise: 248.9 uV(rms)
SNR: 69

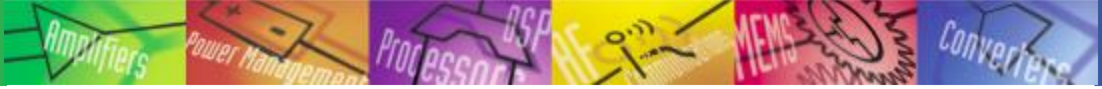
Output Noise Mean Square Contribution

85% Diff V Noise
<1% I noise(-)
<1% I noise(+)
9% Both Rg & RT
5% Both Rf
<1% Vocm

www.analog.com/diffampcalc

Differential Amplifier Calculator

- Downloadable
- Easy to use
- Fast and intuitive
- Various configurations
- Calculate: Gain, noise, power dissipation, input common mode range, output swing and more
- Test part
- What if scenarios



FREE Universal Evaluation Boards

KEY BENEFITS

- **Boards are blank, maximizing design flexibility**
  - Amplifiers must be ordered separately
- **Optimized for high speed amplifiers**
- **User defined circuit configurations**
- **EVAL-ADOPAMP-1CPEZ and -1REZ feature INV and NINV configurations on the same board**
- **SMA connectors for easy interface to test equipment or other circuits**
- **RoHS Compliant**
- **Available on ADI web site!**
  - **Free to customers**
  - **Order from ADI web site www.analog.com**

Order Number	Description
EVAL-ADOPAMP-1CPZ	Single CSP
EVAL-ADOPAMP-1KSZ	Single SC70
EVAL-ADOPAMP-1RINZ	Single SO AD8099
EVAL-ADOPAMP-1RNIZ	Single SO AD8099
EVAL-ADOPAMP-1CPZ	LFCSP AD8099
EVAL-ADOPAMP-1CPNZ	LFCSP AD8099
EVAL-ADOPAMP-1CPEZ	LFCSP INV and NINV
EVAL-ADOPAMP-1REZ	SOIC INV and NINV
EVAL-ADOPAMP-1RZ	Single SO
EVAL-ADOPAMP-1RTZ	Single SOT23
EVAL-ADOPAMP-2RZ	Dual SO
EVAL-ADOPAMP-2RJZ	Dual SOT23
EVAL-ADOPAMP-2RM	Dual µSO
EVAL-ADOPAMP- 3CPZ	LFCSP
EVAL-ADOPAMP- 3RUZ	Triple TSSOP
EVAL-ADOPAMP-4RUZ	Quad TSSOP
EVAL-ADDIFFAMP-1RZ	Single SO
EVAL-ADDIFFAMP-1RMZ	Single MSOP (µSOIC)
EVAL-ADDIFAMP-1CPZ	Single LFCSP (ADA4937/38-1)
EVAL-ADDIFFAMP-CPZ	Single LFCSP
EVAL-ADDIFAMP-2CPZ	Dual LFCSP (ADA4937/38-2)
EVAL-ADDIFFRX-1RZ	Single SO
EVAL-ADDIFFRX-1RM	Single MSOP (µSOIC)

Note:

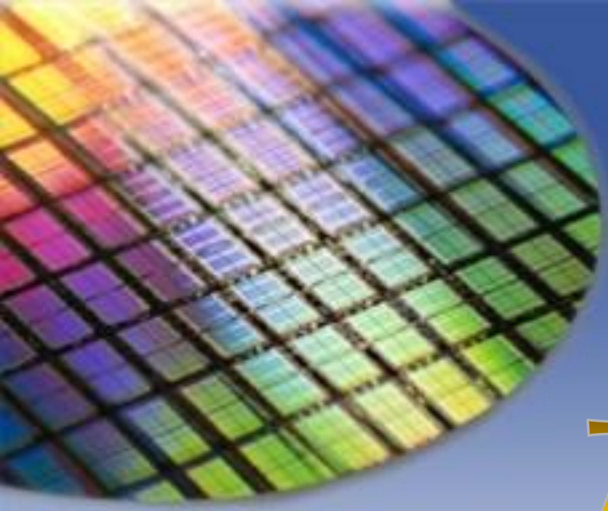
Z Indicates lead free

Support Collateral
High-Speed Amplifiers

- Selection Guides
  - “High-Speed Amplifiers” Order code: ST06702-2-10/09(L)
- Design Tutorials
  - http://www.analog.com/static/imported-files/tutorials/MT-0XX.pdf
  - MT-032: Ideal Voltage Feedback
  - MT-033: Voltage Feedback Op Amp Gain and Bandwidth
  - MT-049: Op Amp Total Output Noise Calculations for Single-Pole System
  - MT-056: High Speed Voltage Feedback Op Amps
  - MT-060: Choosing Between Voltage Feedback and Current Feedback Op Amps
- Circuits From The Lab
  - http://www.analog.com/en/verifiedcircuits/index.html
- Sites of Interest
  - Differential Amplifiers: www.analog.com/diffamp
  - Active Filter Evaluation Boards: www.analog.com/active-fltr
  - Solutions Bulletins: www.analog.com/bulletins

Summary of Differential Amplifiers

- Integration
- Output balance
- Independent output Vocm adjustment
- Reduced second harmonic distortion
- Wide output swing on single supply
- High common mode rejection
- Differential Amplifier Calculator
  - Simplifies design time
  - Lowers risk
  - What if scenario’s
- Evaluation Boards



谢谢！

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ADI样片申请网址：http://www.analog.com/zh/sample

MAKEADIFFERENCE