

# CMRR

TIPL 1231

TI Precision Labs – Op Amps

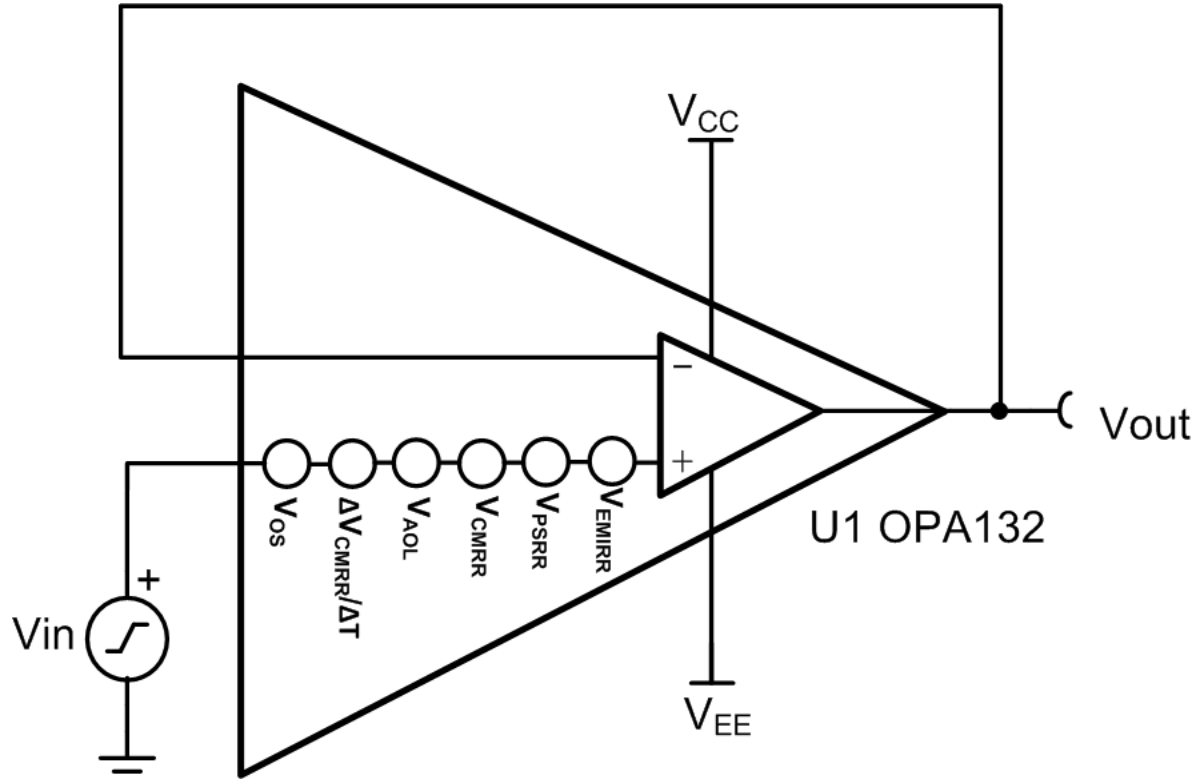
Presented by Collin Wells

Prepared by Collin Wells, Art Kay, Ian Williams, and Tim Green

Prerequisites: Op Amp Bandwidth 1 – 3

(TIPL1221 – TIPL1223)

# Referring Error to Input (RTI)



# CMRR and $A_{OL}$ Combined

	Typical	Unit
$A_{OL}$	136	dB
CMRR	134	dB

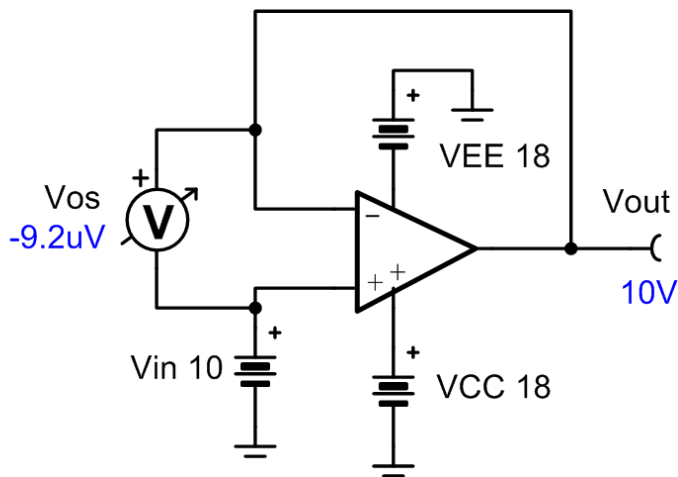
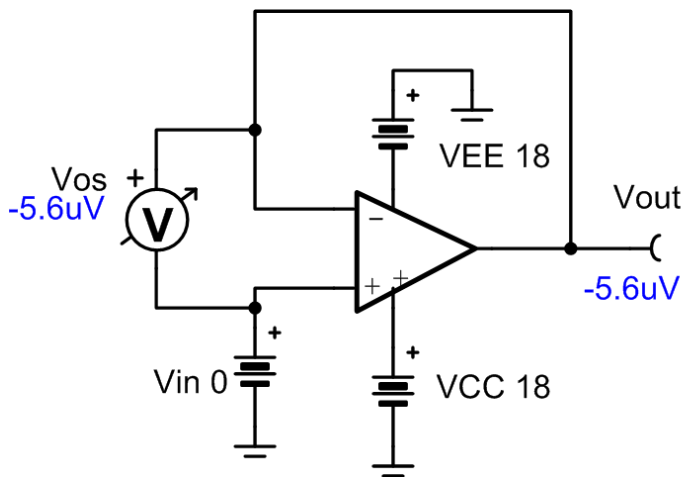
**Combined Effects of  $A_{OL}$  and CMRR**

$$V_{OS_{A_{OL}}} = \frac{\Delta V_{OUT}}{A_{OL}} = \frac{10V}{10^{\frac{136}{20}}} = 1.6\mu V$$

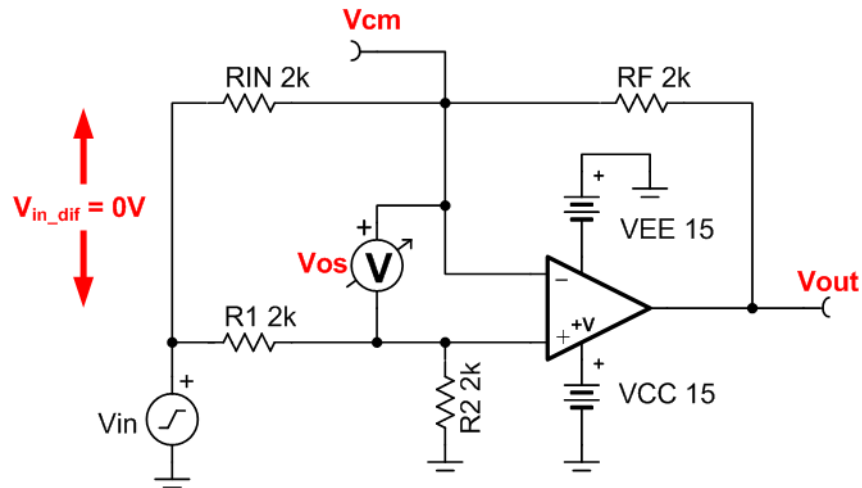
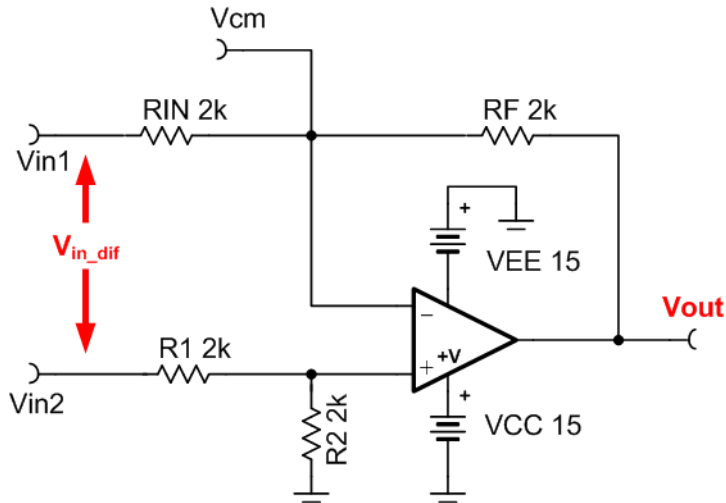
$$V_{OS_{CMRR}} = \frac{\Delta V_{OUT}}{CMRR} = \frac{10V}{10^{\frac{134}{20}}} = 2\mu V$$

$$\Delta V_{OS_{Total}} = V_{OS_{A_{OL}}} + V_{OS_{CMRR}} = 3.6\mu V$$

$$\Delta V_{OS_{Sim}} = V_{OS_{10V}} - V_{OS_{0V}} = 3.6\mu V$$



# Introducing the Dif Amp for testing CMRR



## Gain of a Dif-Amp

$$R_f = R_2 \text{ and } R_{in} = R_1$$

$$G_{\text{dif}} = \frac{R_F}{R_{IN}} = 1 \text{ V/V}$$

$$V_{\text{out}} = G_{\text{dif}} \cdot V_{\text{in\_dif}}$$

## CMRR of a Dif-Amp

$$V_{\text{out}} = (0\text{V}) \cdot (1 \text{ V/V}) = 0\text{V}$$

$$V_{\text{cm}} = V_{\text{in}} \cdot \left( \frac{R_2}{R_1 + R_2} \right) = \frac{V_{\text{in}}}{2}$$

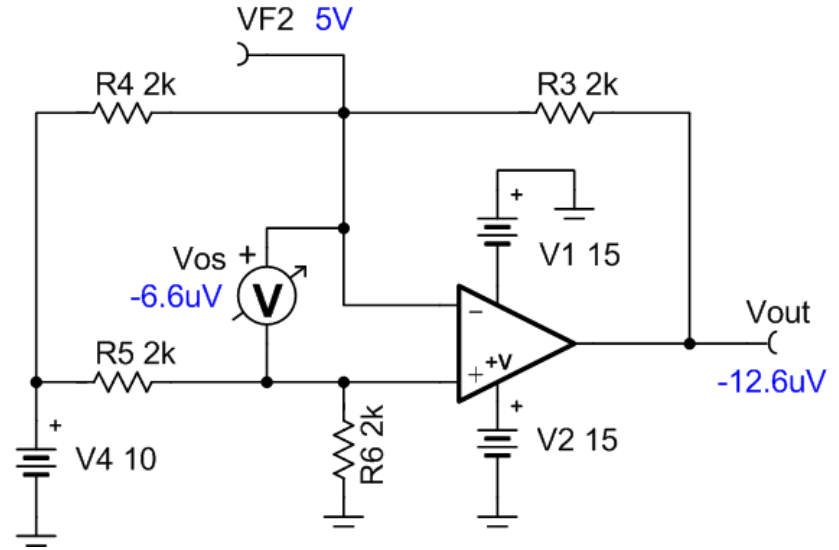
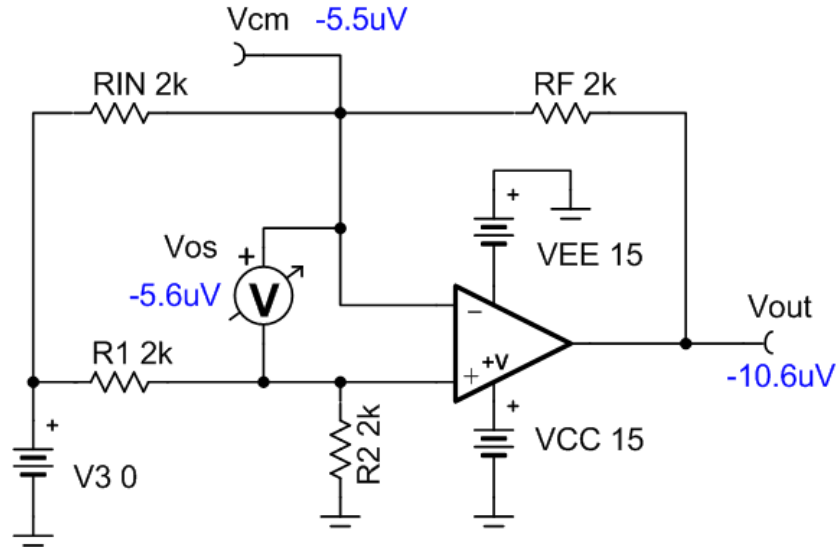
$$\text{CMRR}(\text{V/V}) = \frac{\Delta V_{\text{os}}}{\Delta V_{\text{cm}}}$$

Ideal output.

Common Mode Voltage

Common Mode Rejection

# DC CMRR Test

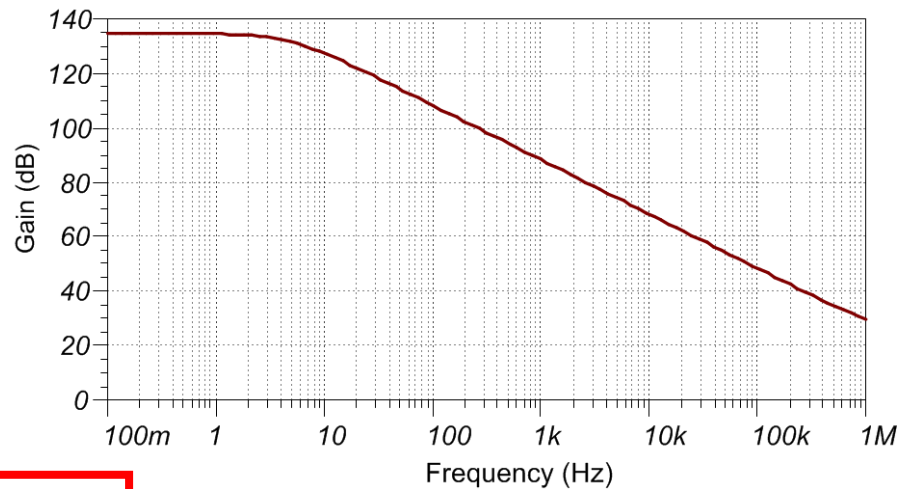
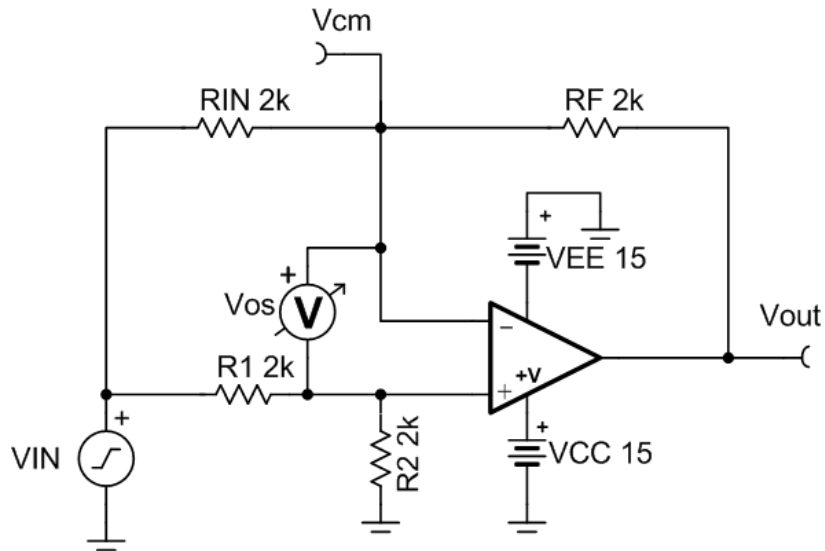


## CMRR of a Dif-Amp

$$\text{CMRR(V/V)} = \frac{\Delta V_{os}}{\Delta V_{cm}} = \frac{|-6.6\mu\text{V} - (-5.6\mu\text{V})|}{|5\text{V} - 0\text{V}|} = 0.2 \cdot 10^{-6} \text{ V/V}$$

$$\text{CMRR(dB)} = -20 \cdot \log[\text{CMRR(V/V)}] = 134\text{dB}$$

# AC CMRR Test



## CMRR of a Dif-Amp

$$\text{CMRR(V/V)} = \frac{\Delta V_{os}}{\Delta V_{cm}}$$

$$\text{CMRR(dB)} = -20 \cdot \log[\text{CMRR(V/V)}]$$

# Post Processor – Generating the Curve in Tina

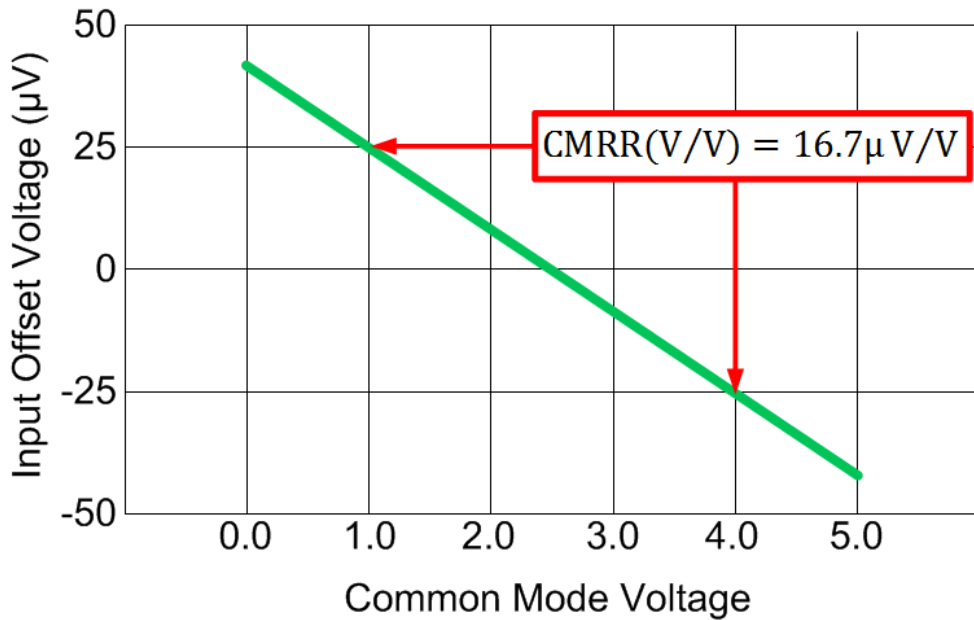
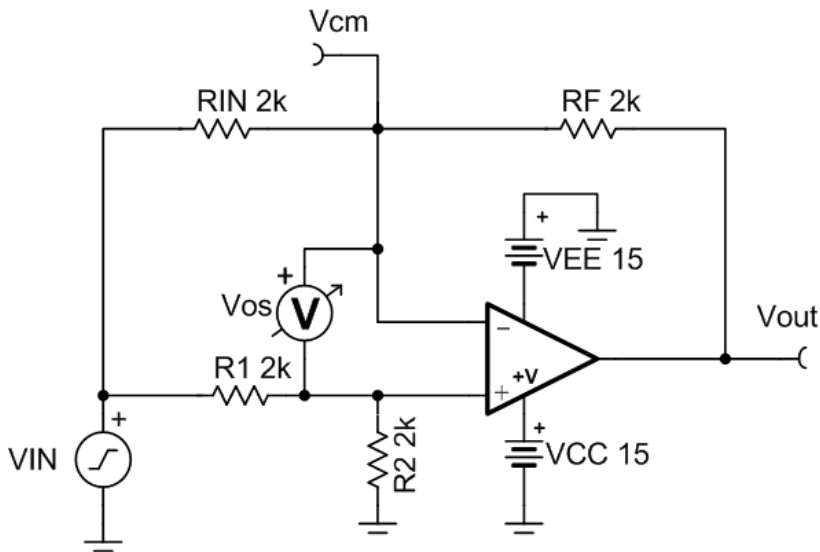
The screenshot shows the Schematic Editor interface for a circuit named 'cmr-opa188'. The 'Analysis' menu is open, and the path 'AC Analysis' > 'AC Transfer Characteristic...' is highlighted. The circuit diagram shows an OPA188 op-amp (U4) configured as a voltage follower. The non-inverting input (+V) is connected to a 2k resistor (R2) and the output (Vout). The inverting input (-) is connected to a 15V supply (VCC 15). The op-amp is powered by a 15V supply (VEE 15) and a 15V supply (VCC 15).

The Post-processor dialog box is shown with the following configuration:

- Available curves:** Vcm, Vos, Vout
- Curves to insert:** CMRR
- Show:**  Outputs,  Nodal Voltages,  Other Voltages,  Currents,  User defined,  Measurement
- User defined curves:** Built-in functions: +
- Line Edit:** Vcm (s) / Vos (s)
- Advanced Edit:** New function name: CMRR,  Advanced edit,  XY Plot

```
{This is a template}
{Don't modify the functionname}
Function F(s);
Begin
  {Your expressions here}
{The result value}
```

# Offset ( $V_{os}$ ) vs. Common Mode Voltage ( $V_{cm}$ )

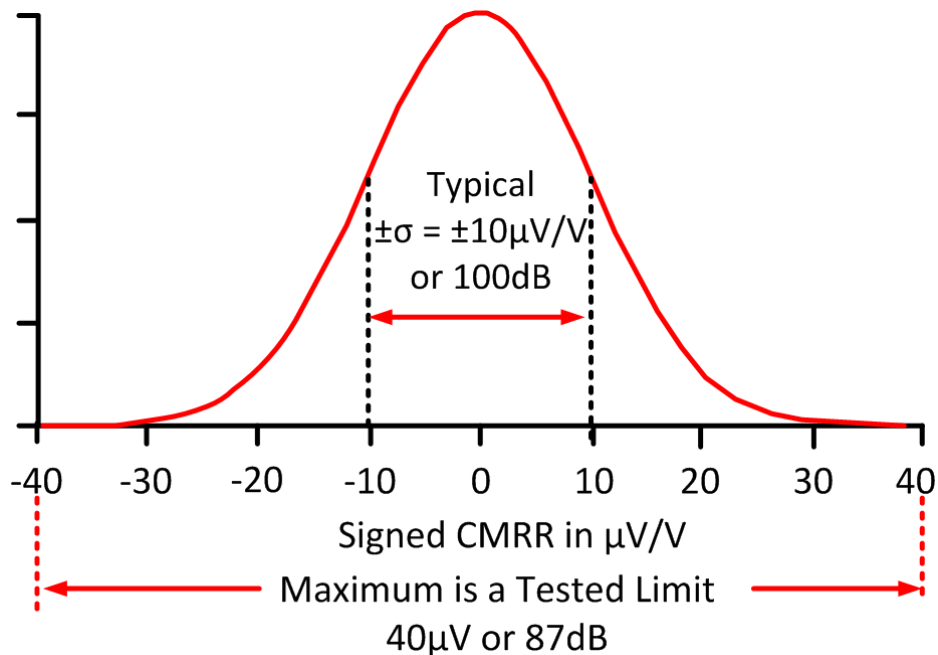


$$\text{CMRR}(\text{V/V}) = \frac{\Delta V_{os}}{\Delta V_{cm}} = \frac{|25 \mu\text{V} - (-25 \mu\text{V})|}{|1\text{V} - 4\text{V}|} = 16.7 \cdot 10^{-6} \text{ V/V}$$
$$\text{CMRR}(\text{dB}) = -20 \cdot \log[\text{CMRR}(\text{V/V})] = 96\text{dB}$$



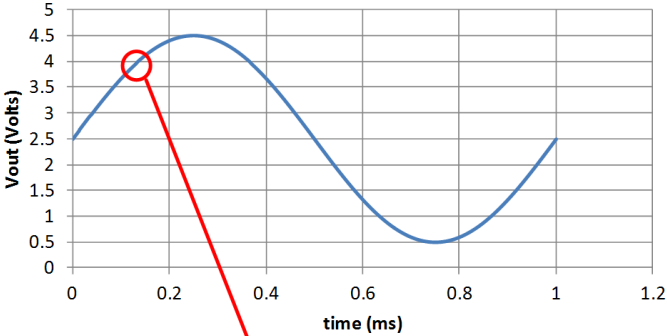
# Distribution of CMRR

PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
Common-Mode Rejection	$V_{CM} = -12.5V$ to $12.5V$	87	100		dB

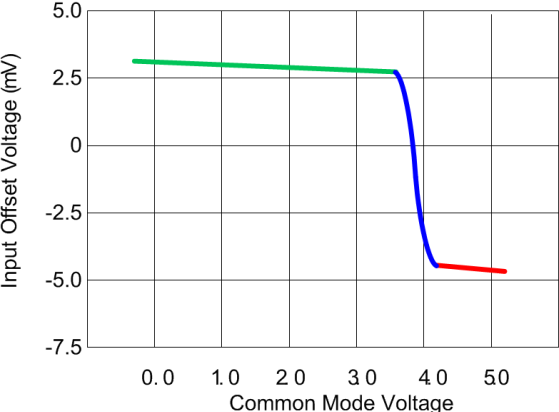
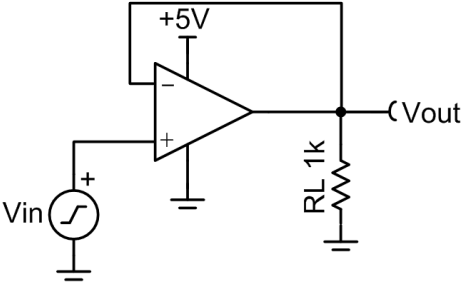
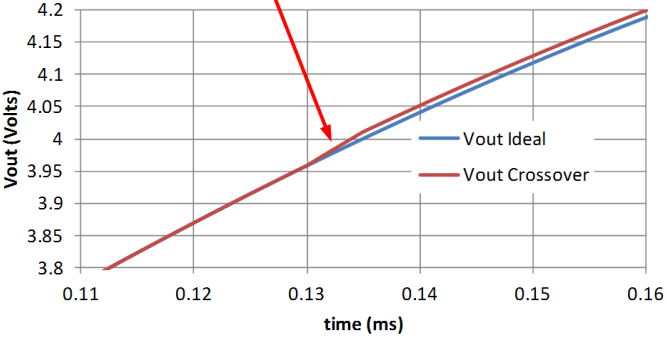


# Crossover Distortion Caused by CMRR

Vout vs. Time (Crossover Distortion)

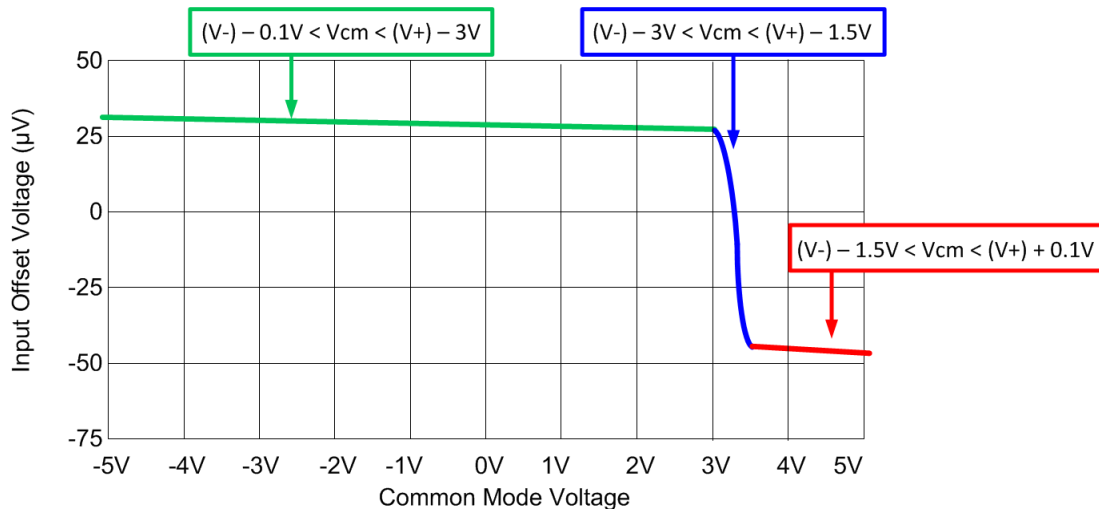
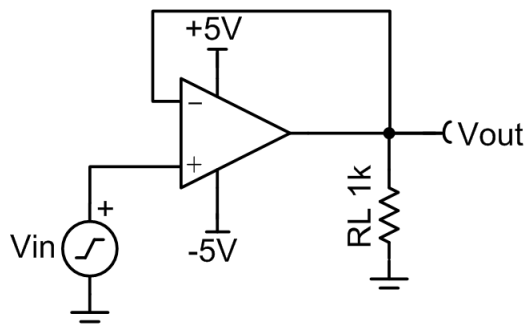


Zoom in on Crossover Distortion

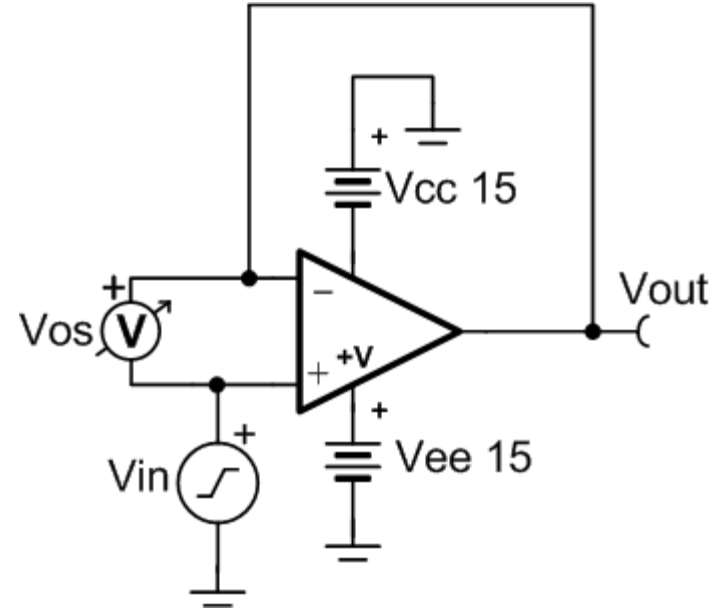
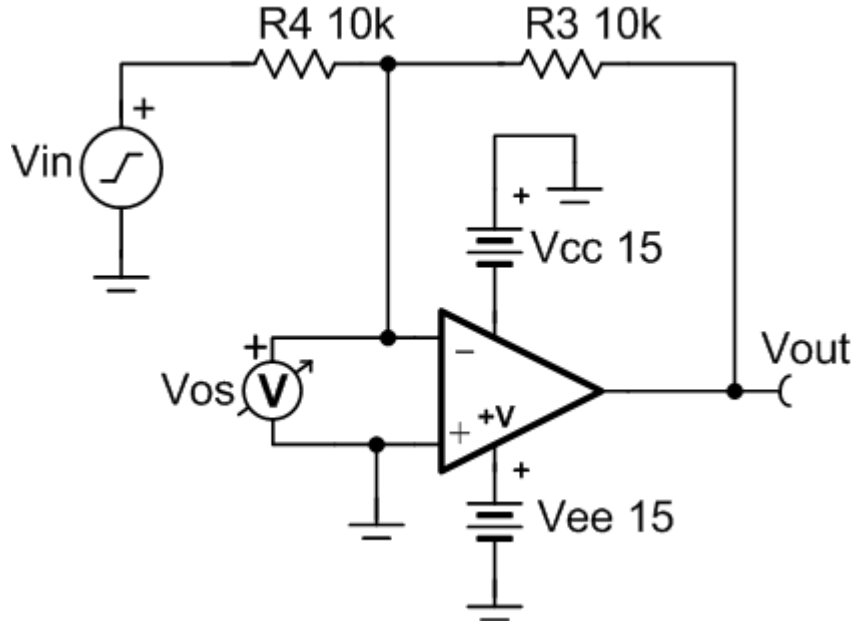


# CMRR for Amplifiers with Crossover Distortion

PARAMETER	TEST CONDITIONS	OPA192			UNIT
		MIN	TYP	MAX	
CMRR Common-mode rejection ratio	$(V-) - 0.1V < V_{CM} < (V+) - 3V$	120	140		dB
	$(V+) - 3V < V_{CM} < (V+) - 1.5V$	See <a href="#">Typical Characteristics</a>			
	$(V+) - 1.5V < V_{CM} < (V+) + 0.1V$	100	120		dB



# Inverting vs. Non-inverting (Impact on CMRR)



**Thanks for your time!  
Please try the quiz.**