Linear OPAMP Characterization: Common Mode Rejection Ratio

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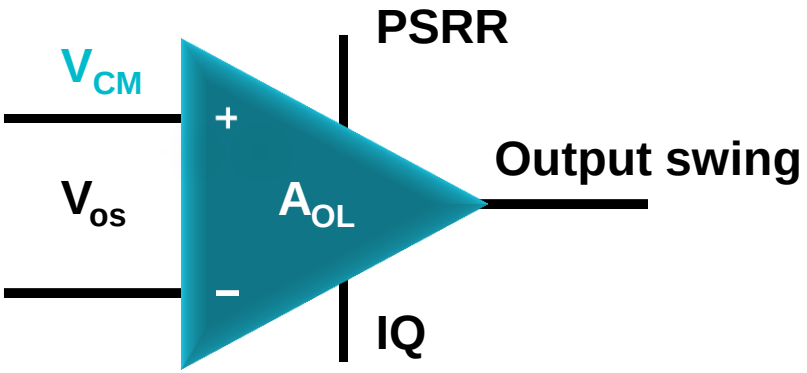
OPAMP verification

OPAMP electrical characterization:

- Characterizing the electrical behavior of an integrated circuit is critical during application troubleshooting
  - Non-conformances can be identified by comprehending device-level characteristics in addition to system performance
- OPAMP electrical characterization series will review the following topics:
  - Voltage offset (V_{OS})
  - **V_{CM} / Common Mode Rejection Ratio (CMRR)**
  - Power Supply Rejection ratio (PSRR)
  - Output swing
  - Quiescent current
  - Open loop gain (A_{OL})



Prerequisites

Electrical characterization: CMRR

- Common mode rejection ratio measurements methods are reviewed
- Following prerequisites are recommended prior to proceeding though the handbook

Prerequisites:

TI-Precision Labs (TIPL) courses:

CMRR: TIPL - Op Amps: Common Mode Rejection

ti.com/training-opamps-vos

Pocket reference:

Training: Analog Engineer's Pocket Reference

ti.com/analogrefguide

Application handbook:

A-B-A: Board Level Troubleshooting

ti.com/board-level-troubleshooting

Simulation tools:

Simulations are presented within the handbook. It is recommended to install TINA-TI

TINA-TI can be downloaded for free on ti.com: http://www.ti.com/tool/tina-ti

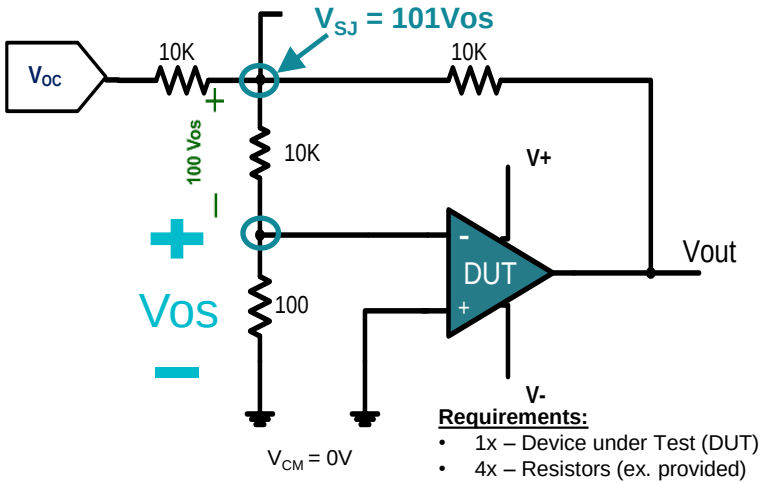
OPAMP test loops

Overview:

- Analyzing datasheet parameters may appear a daunting task!
- Multiple parameters can be derived easily from offset (V_{OS}).
  - PSRR, CMRR, and AOL can be calculated by monitoring shifts

False Summing Junction (FSJ):

- Accurate VOS measurements can be obtained through test loops
  - **Benefits:**
    - Simplistic
    - Stable
    - Small
  - **Disadvantages:**
    - Feedback resistor load in parallel with other added loads
    - Loop drive function of DUT V_{OS}
- Majority of **DC** parameters determined with 4 resistors!



Requirements:
- 1x – Device under Test (DUT)
- 4x – Resistors (ex. provided)
  - Resistor values can be varied depending on device

Measuring VOS:

- **VOS:** differential input voltage required to force output to mid-supply
  - best measured at the summing junction **(V_{SJ})**
- **Output control voltage (VOC):** Calibrate the out voltage to zero volts
  - Know as offset correction factor (derived from Kirchhoff's Voltage Law):

$$V_{OC} = -\left(V_{OUT} + VOS(302)\right) + 2VCM$$

Example:

- V+ = +10V
- V- = -10V
- V_{OUT} = 0V
- V_{OC} = 0V (ideal opamp)

Results:

- V_{SJ}= 1.01mV
- 1.01mV = (101)Vos = **V_{SJ}**
  10µV = Vos

Common mode rejection ratio - OPA192

Measurement preparation:

- **CMRR:** Change in V_{OS} divided by the V_{CM} change
- Review data sheet test conditions prior to evaluating **CMRR**
  - V_{CM} range of a complementary input AMP has three operation regions
    - **pMos** ,**nMos** ,and the **transition region**
  - Measuring CMRR in the **transition region** may impact the result

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
INPUT VOLTAGE							
V_{CM}	Common-mode voltage range			(V–) – 0.1		(V+) + 0.1	V
CMRR	Common-mode rejection ratio	(V–) – 0.1 V < V_{CM} < (V+) – 3 V		94	110		dB
			T_A = –40°C to +125°C	90	104		
		(V+) – 1.5 V < V_{CM} < (V+)		100	120		
			T_A = –40°C to +125°C	84	100		
		(V+) – 3 V < V_{CM} < (V+) – 1.5 V		See *Typical Characteristics*			

$$CMRR\left(\frac{V}{V}\right) = \left(\left|\frac{\Delta VOS}{\Delta V_{CM}}\right|\right)$$

$$CMRR(dB) = -20 \times LOG\left(CMRR\left(\frac{V}{V}\right)\right)$$

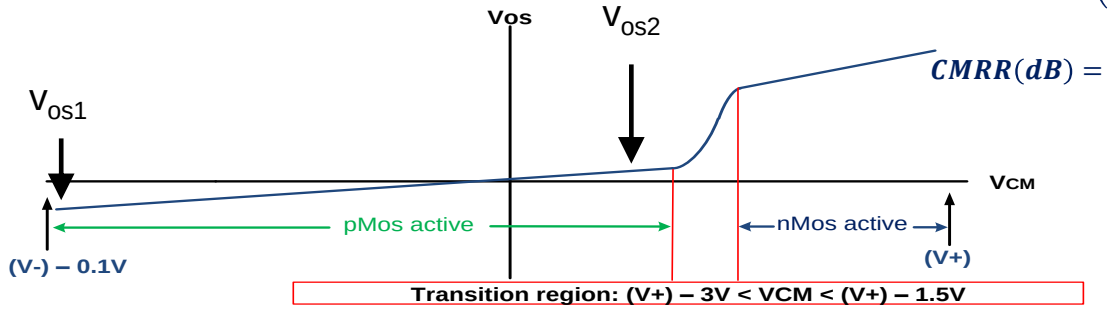


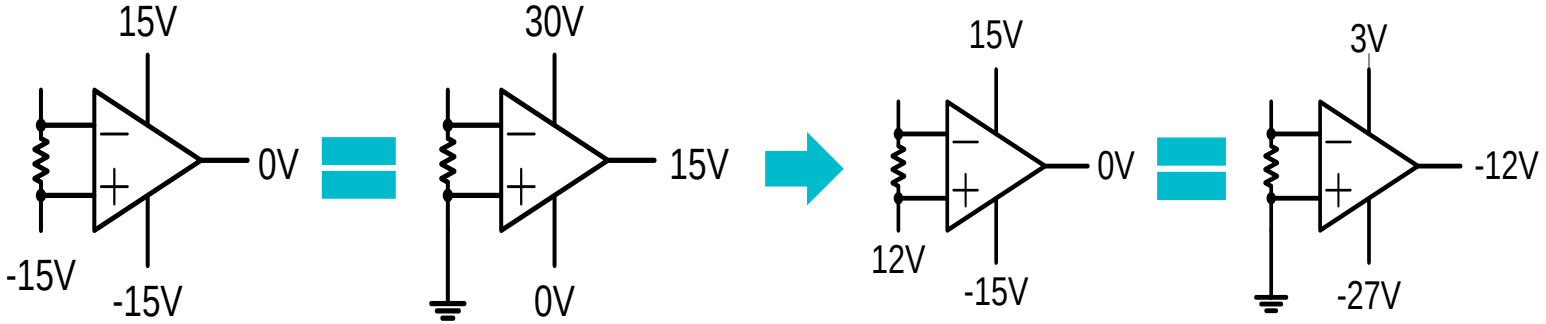
Figure 4: V_{CM} versus V_{OS} graph highlighting operating regions

*http://www.ti.com/lit/ds/symlink/opa192.pdf

Common mode rejection ratio

Bench setup and measurements:

- Shifting supplies & output is equivalent to moving V_{CM}



Offset voltage (1):

- **DUT:** OPA192IDGK
- V+ = +30V
- V- = 0V
- V_{OUT1} = 15V
- V_{CM1} = -15V

Offset voltage (2):

- **DUT:** OPA192IDGK
- V+ = +3V
- V- = -27V
- V_{OUT2} = -12V
- V_{CM2} = 12V

Use the offset correction factor equation to accurately set Vout