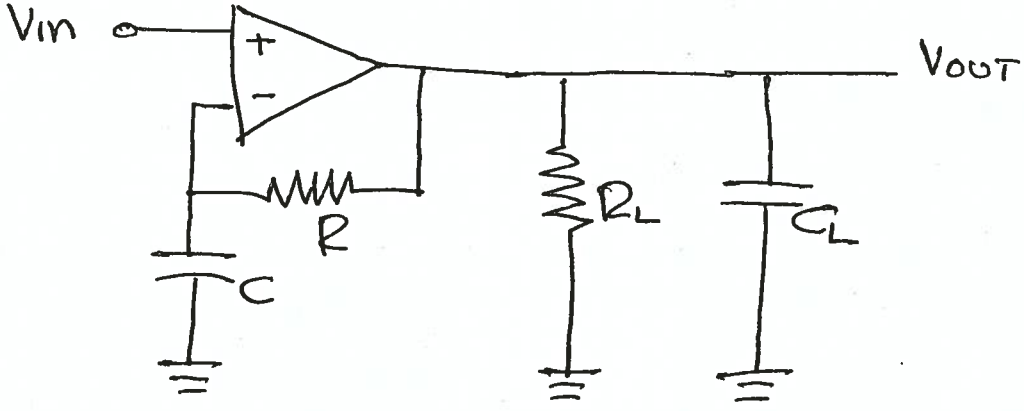
# SIMULATION AND MEASUREMENTS OF OP AMP.

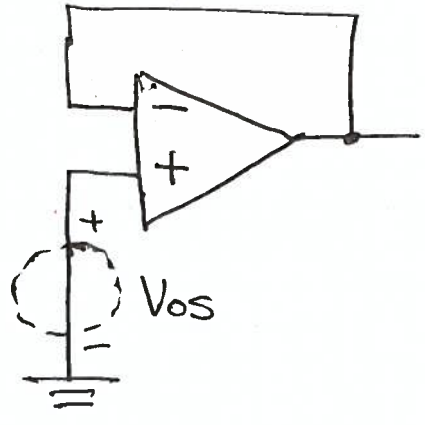
- OPEN LOOP GAIN




DETERMINE

$$RC < \frac{1}{GB}$$

- MEASURING THE INPUT OFFSET VOLTAGE $V_{OS}$




IF $V_{OS}$ IS VERY SMALL USE A FEEDBACK CIRCUIT TO INCREASE THE OUTPUT i.e. $V_{OUT,OS} = \left(1 + \frac{R_F}{R_1}\right) V_{OS}$

- PSRR USING PREVIOUS CIRCUIT

FIRST

$$\left.\begin{array}{l} V_{DD} \rightarrow V_{DD}+1V \\ -V_{OUT} \rightarrow -V_{OUT}=0 \end{array}\right\} V_{OS3}$$

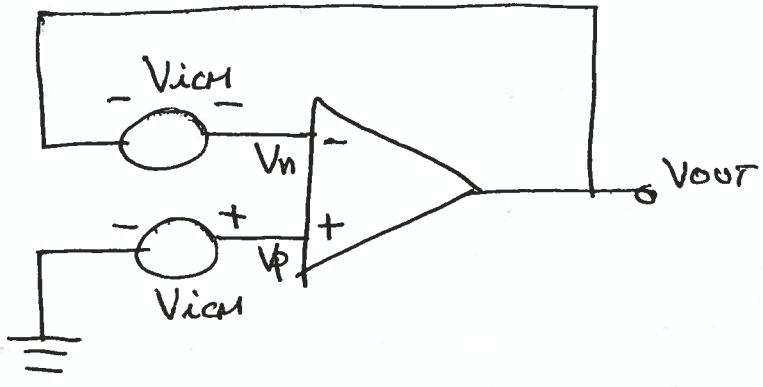
$$PSRR^{+} = \frac{2000}{|V_{OS3} - V_{OS4}|}$$

SECOND

$$\left.\begin{array}{l} V_{DD} \rightarrow V_{DD}-1 \\ V_{OUT}=0 \rightarrow -V_{OUT}=0 \end{array}\right\} V_{OS4}=V_{OFF}$$

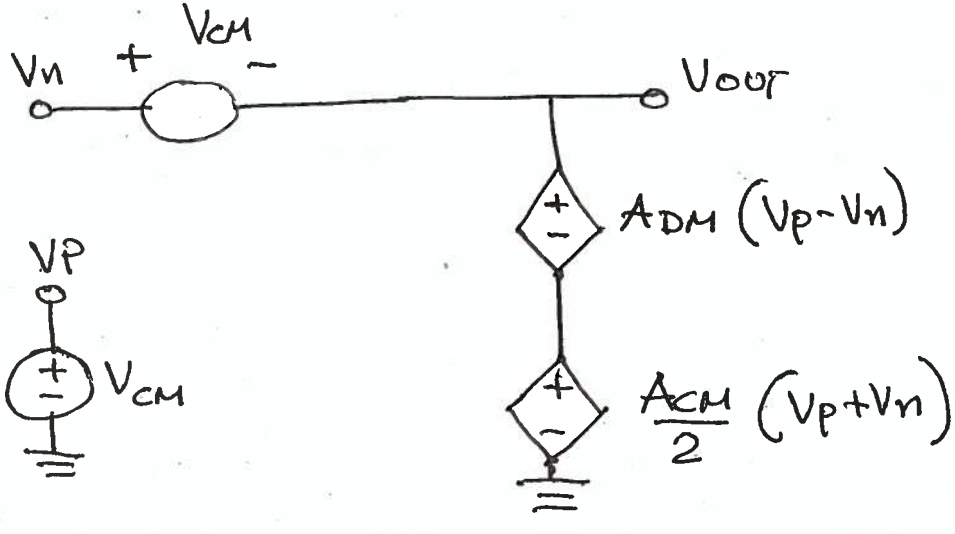
FOR $PSRR^{-}$ FIX $V_{DD}$ AND CHANGE $V_{SS}$ WHILE $V_{OUT}=0$

## – MEASURING CMRR (SIMULATING)




$$\frac{V_{OUT}}{V_{CM}} = \frac{\pm A_{CM}}{1 + A_{DM} - \left(\pm \frac{A_{CM}}{2}\right)}$$

$$\frac{V_{OUT}}{V_{CM}} \cong \frac{|A_{CM}|}{A_{DM}} = \frac{1}{CMRR}$$

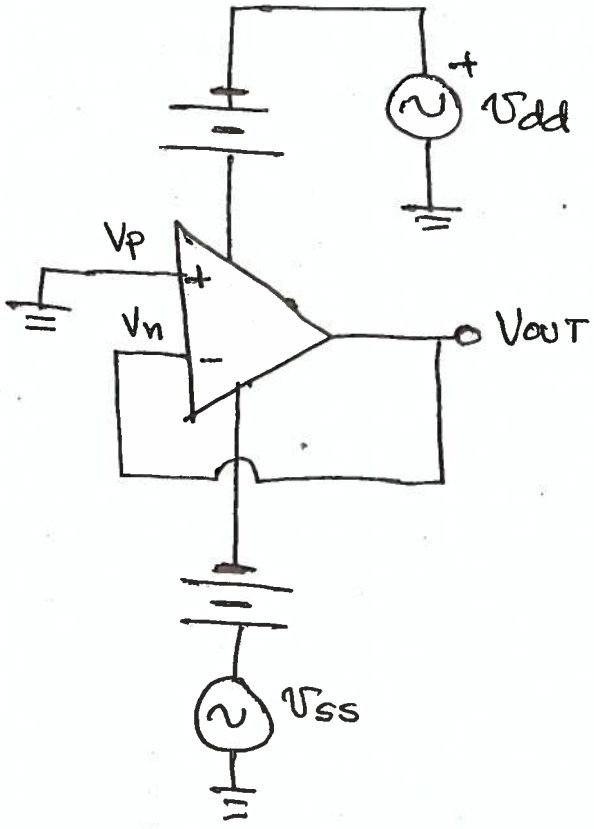


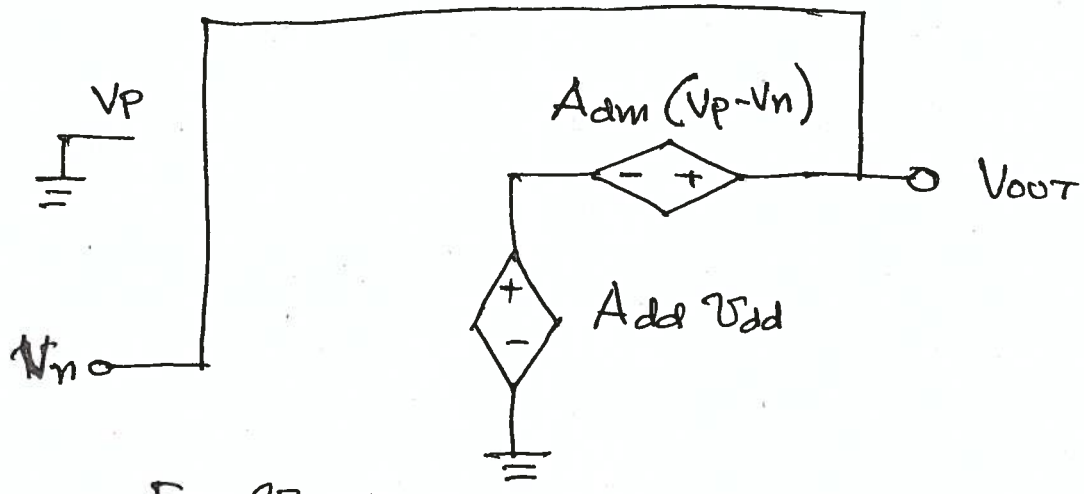

NOTE THAT

$$V_{OUT} = A_{DM}(V_{CM} - V_n) + \frac{A_{CM}}{2}(V_{CM} + V_n)$$

$$V_n = V_{CM} + V_{OUT}.$$

## – MEASURING DIRECTLY PSRR




. FOR $V_{ss}=0$

$$V_{OUT} = A_{dm}(0 - V_n) + A_{dd} V_{dd}$$

$$V_n = V_{OUT}$$

THEN

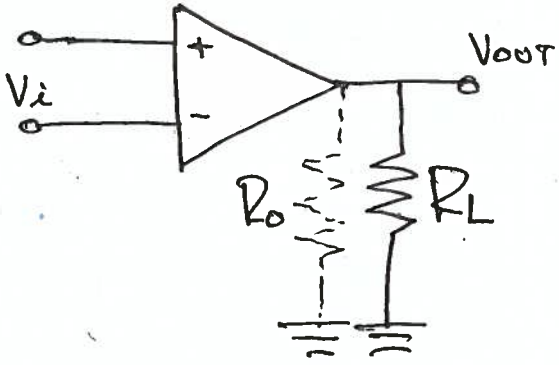
$$V_{OUT} = -A_{dm} V_{OUT} + A_{dd} V_{dd}$$

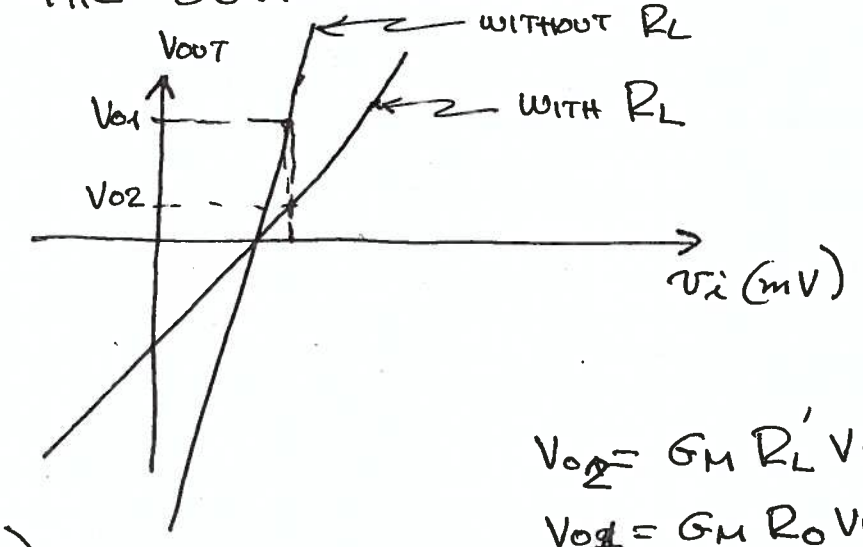
$$V_{OUT} = \frac{A_{dd} V_{dd}}{1 + A_{dm}} \cong \frac{A_{dd}}{A_{dm}} V_{dd}$$

$$\frac{V_{OUT}}{V_{dd}} \cong \frac{1}{PSRR^+}$$

NOTE. IN REAL CIRCUIT A DRIVER MIGHT BE NEEDED TO APPLY $V_{dd}$ OR/AND $V_{ss}$.

- SIMULATING (MEASURING) THE OUTPUT RESISTANCE




$$V_{o2} = G_M R_L' V_{in}$$

$$V_{o1} = G_M R_o V_{in}$$

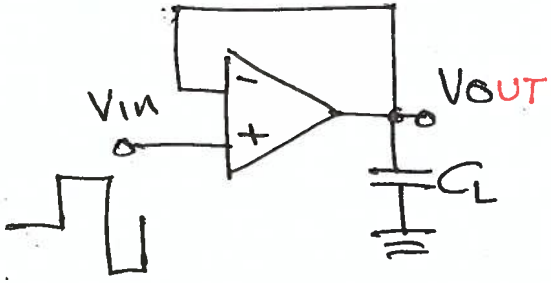
$$\frac{V_{o2}}{V_{o1}} = \frac{1}{1+\frac{R_o}{R_L}} \; ; \; R_L' = R_o // R_L$$

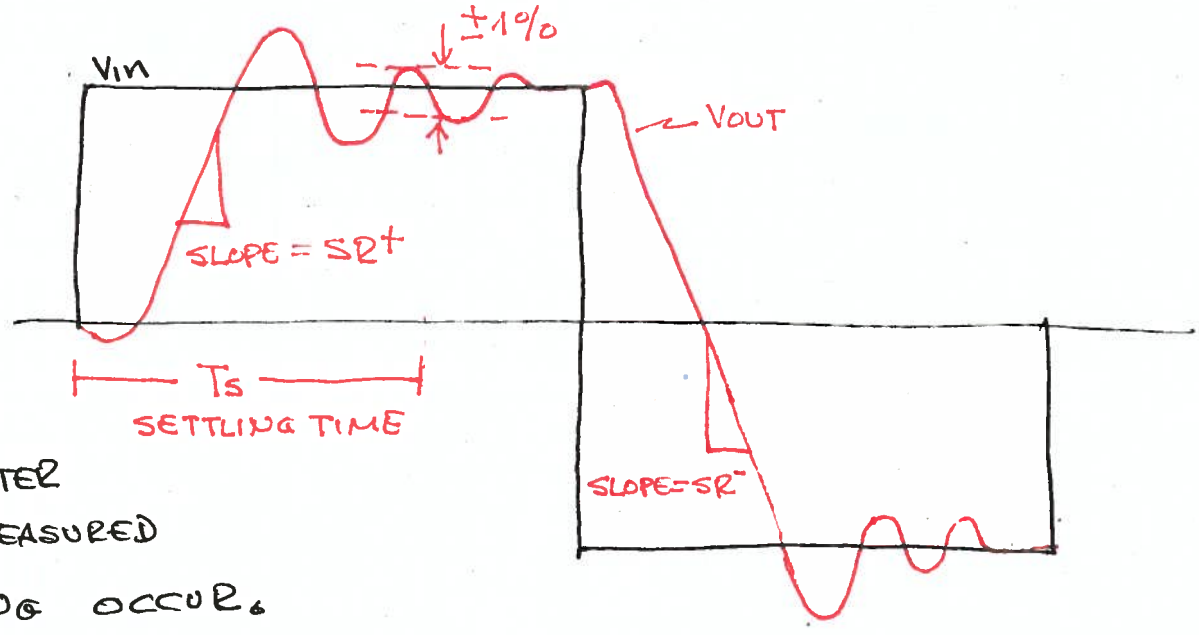
$$R_{OUT} = \left(\frac{V_{o1}}{V_{o2}} - 1\right) R_L$$

AN ALTERNATIVE WAY IS BY USING FEEBACK ($\beta$)

$$R_{out} = \frac{r_o}{1+\beta A} \cong \frac{r_o}{\beta A} =$$

# - MEASURING SR AND 1% SETTLING TIME

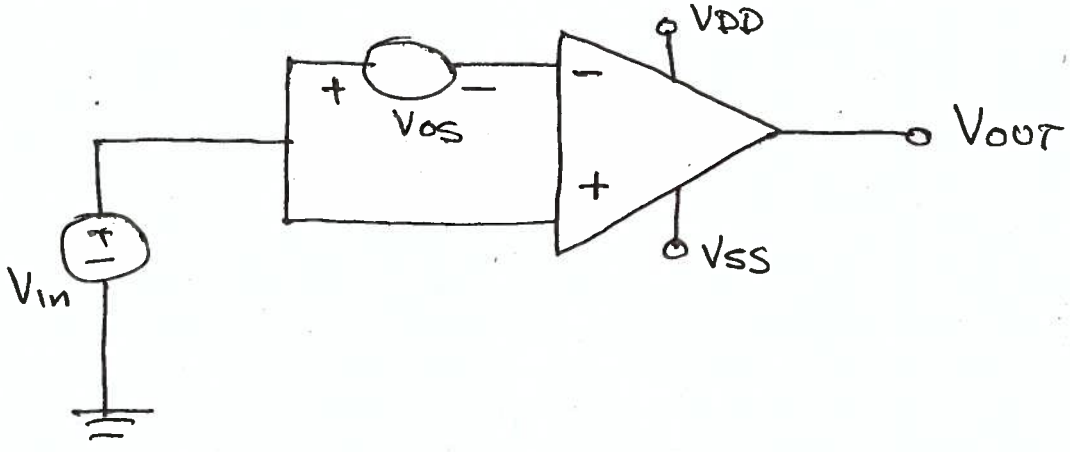


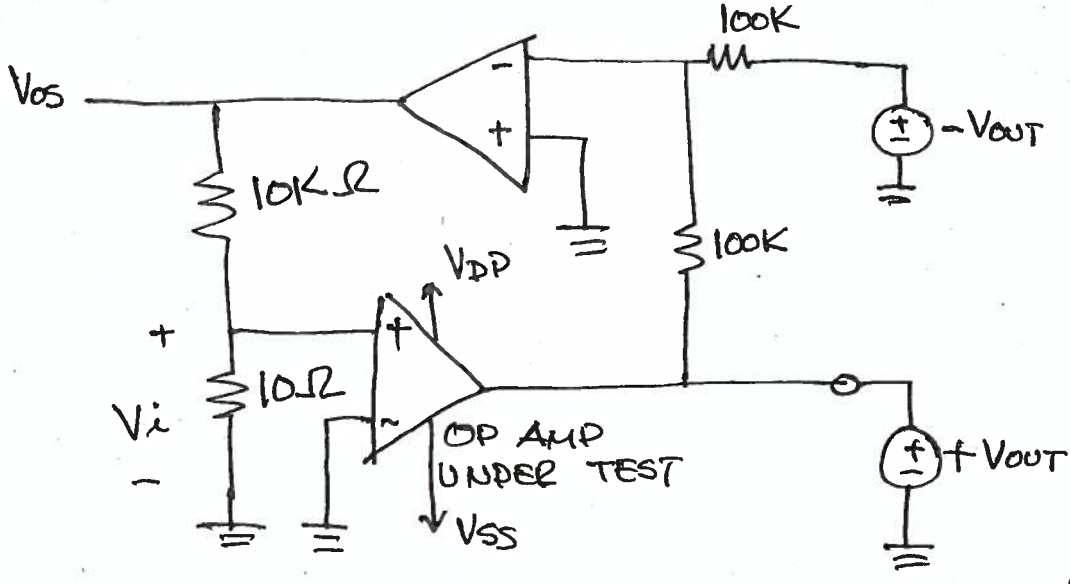

BETTER

NOTE.— $T_S$ CAN BE MEASURED SUCH THAT NO SLEWING OCCUR. THAT IS THE OP AMP SHOULD BE GB LIMITED FOR THIS ($T_S$) MEASUREMENT.

- SIMULATING COMMON-MODE GAIN $A_{CM}$




- MEASURING CMRR AND PSRR




- CMRR

TWO MEASUREMENTS:

FIRST

VDD → VDD +1V
VSS → VSS +1V
−VOUT = −1V
} $V_{OS1}$

SECOND

VDD → VDD − 1V
VSS → VSS −1V
−VOUT = +1V
} $V_{OS2}$

$$CMRR = \frac{2000}{|V_{OS1} - V_{OS2}|}$$