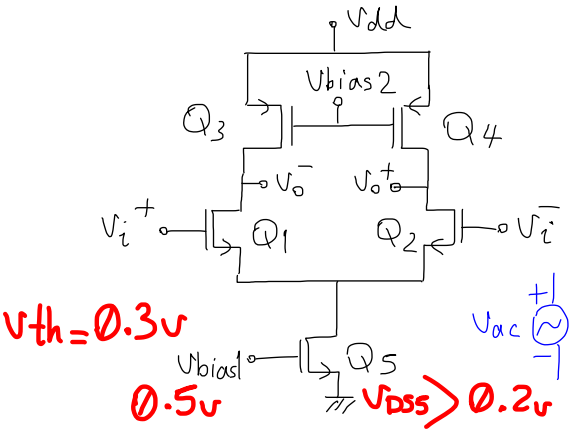
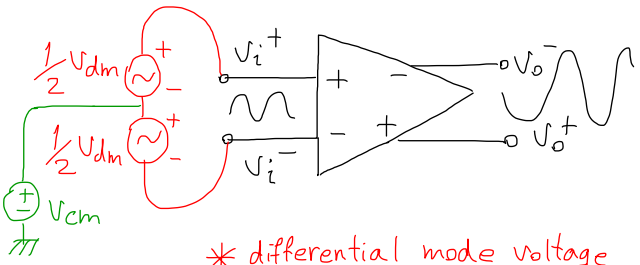
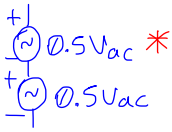
* Differential-pair Amplifiers:





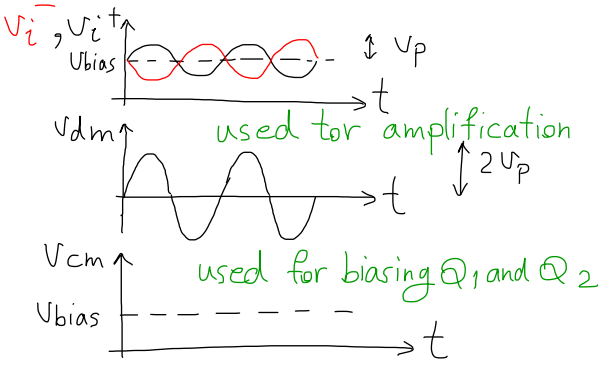
* differential mode voltage

$$V_{dm} = V_i^+ - V_i^-$$



* common mode voltage

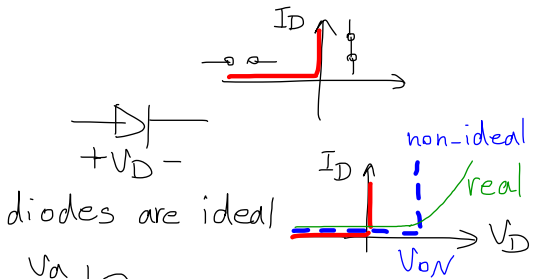
$$V_{cm} = \frac{1}{2}\left[V_i^+ + V_i^-\right]$$

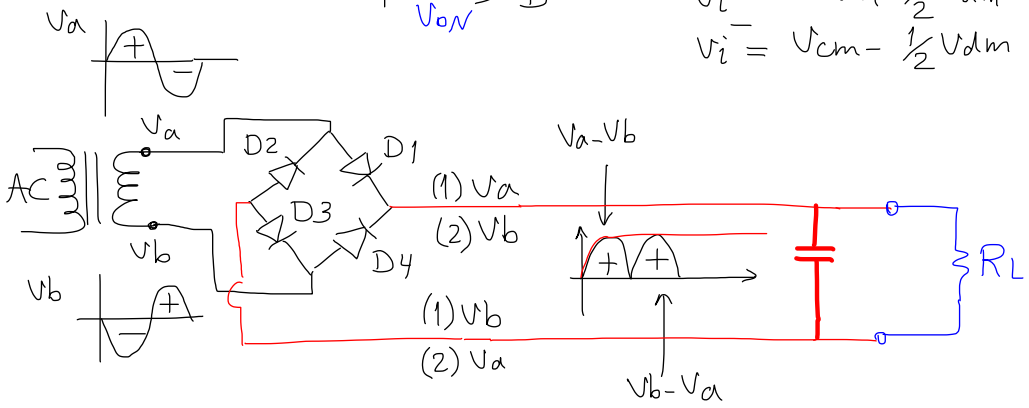


$$V_i^+ = V_{cm} + \frac{1}{2}V_{dm}$$

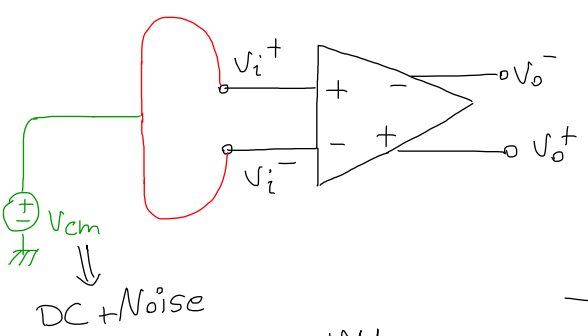
$$V_i^- = V_{cm} - \frac{1}{2}V_{dm}$$

* use superposition to analyze a differential-pair amplifier

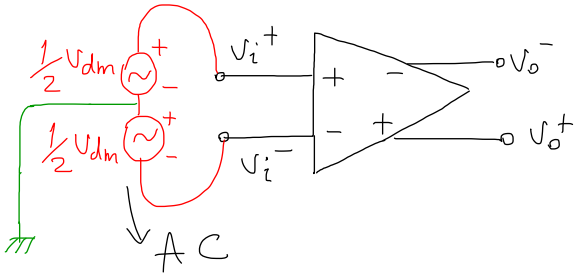




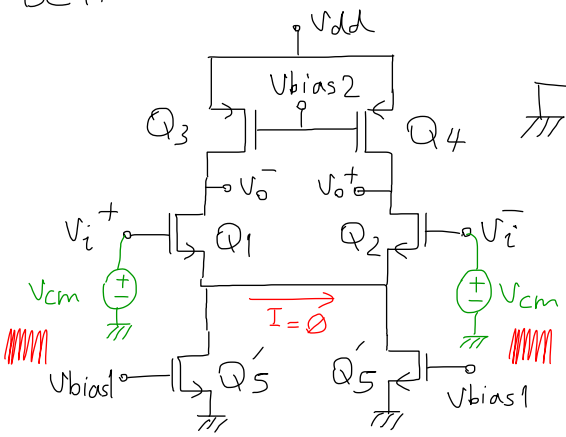
(1) first cycle: $\begin{cases} V_a > 0 \\ V_b < 0 \end{cases} \Rightarrow$ D1: ON , D3: ON
D2: OFF , D4: OFF

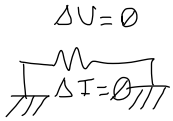


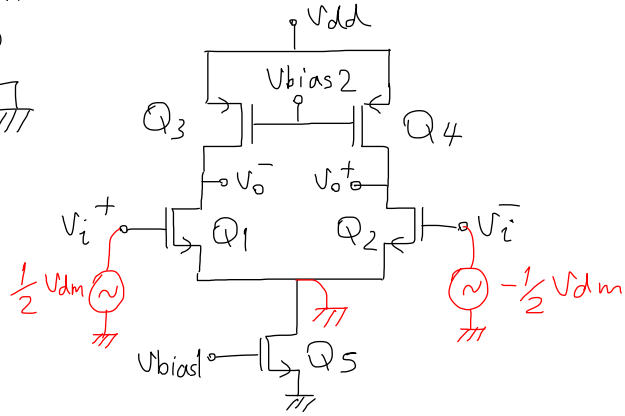
DC + Noise



AC





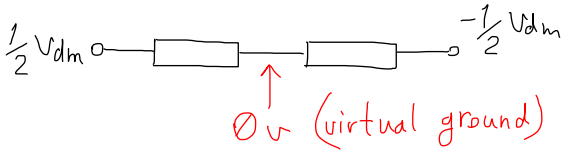


Q_1 and Q_2 are source degeneration amplifiers

$W_5 = 2W_5'$, $r_{ds} = \frac{1}{\lambda I_{DS}}$

$$A_{v01} = \frac{-r_{ds3}}{2r_{ds5}}$$
$$A_{v02} = \frac{-r_{ds4}}{2r_{ds5}}$$

} are equal because of symmetry



Q_1 and Q_2 are common source amplifiers

$$A_{v01} = -g_{m1}(r_{ds1} \| r_{ds3})$$
$$A_{v02} = -g_{m2}(r_{ds2} \| r_{ds4})$$

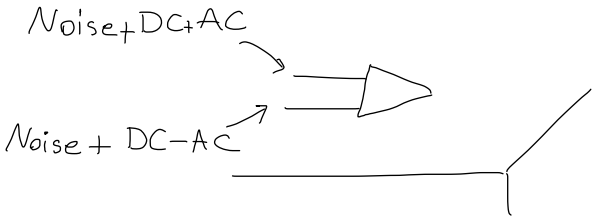
} these two are equal because of symmetrical design

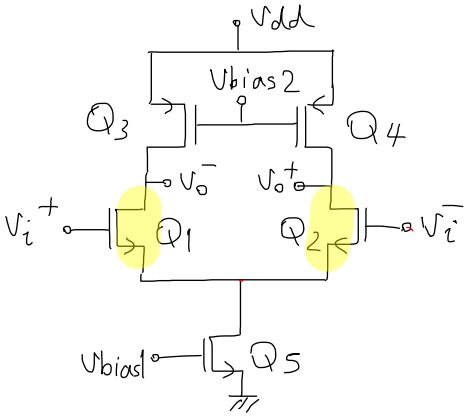
*** Note:** $g_m \cdot r_{ds} \gg 1$, $\frac{r_{ds}}{r_{ds}} \approx 1$

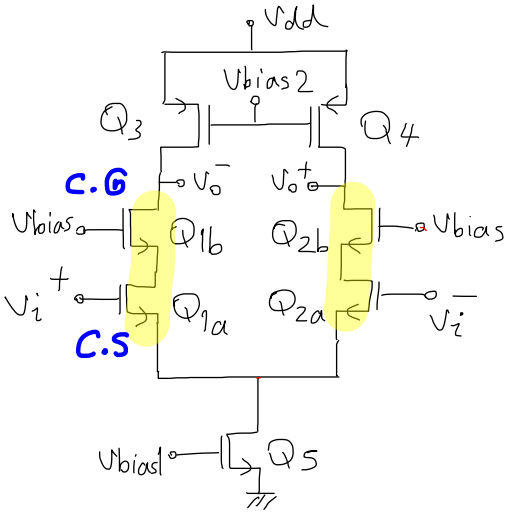
Figure of Merit: $CMRR = \frac{A_{dm}}{A_{cm}} \gg 1$

$$CMRR = \frac{-g_{m1}(r_{ds1} \| r_{ds3})}{\frac{-r_{ds3}}{2r_{ds5}}}$$

C.S Amp $\Longrightarrow$ $FOM = \frac{W_{3dB} \uparrow \cdot A_{v0} \uparrow}{P_{diss} \downarrow \cdot Noise \downarrow \cdot Distortion \downarrow}$







$$A_{vo1} = -g_{m1a}(r_{ds1b} \,||\, r_{ds3})$$