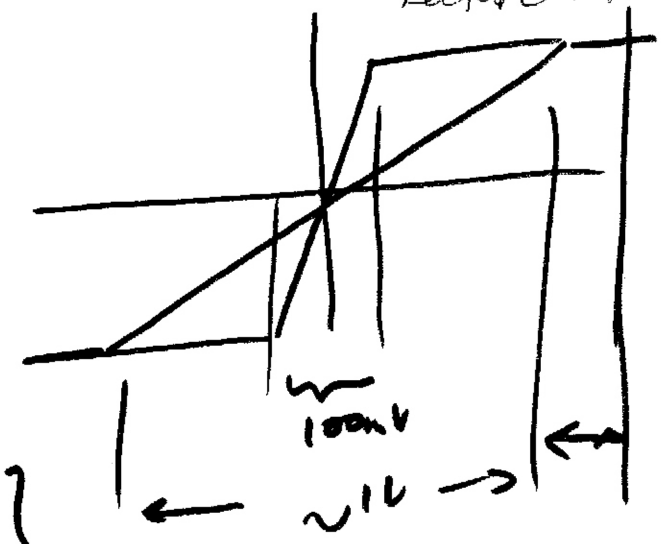
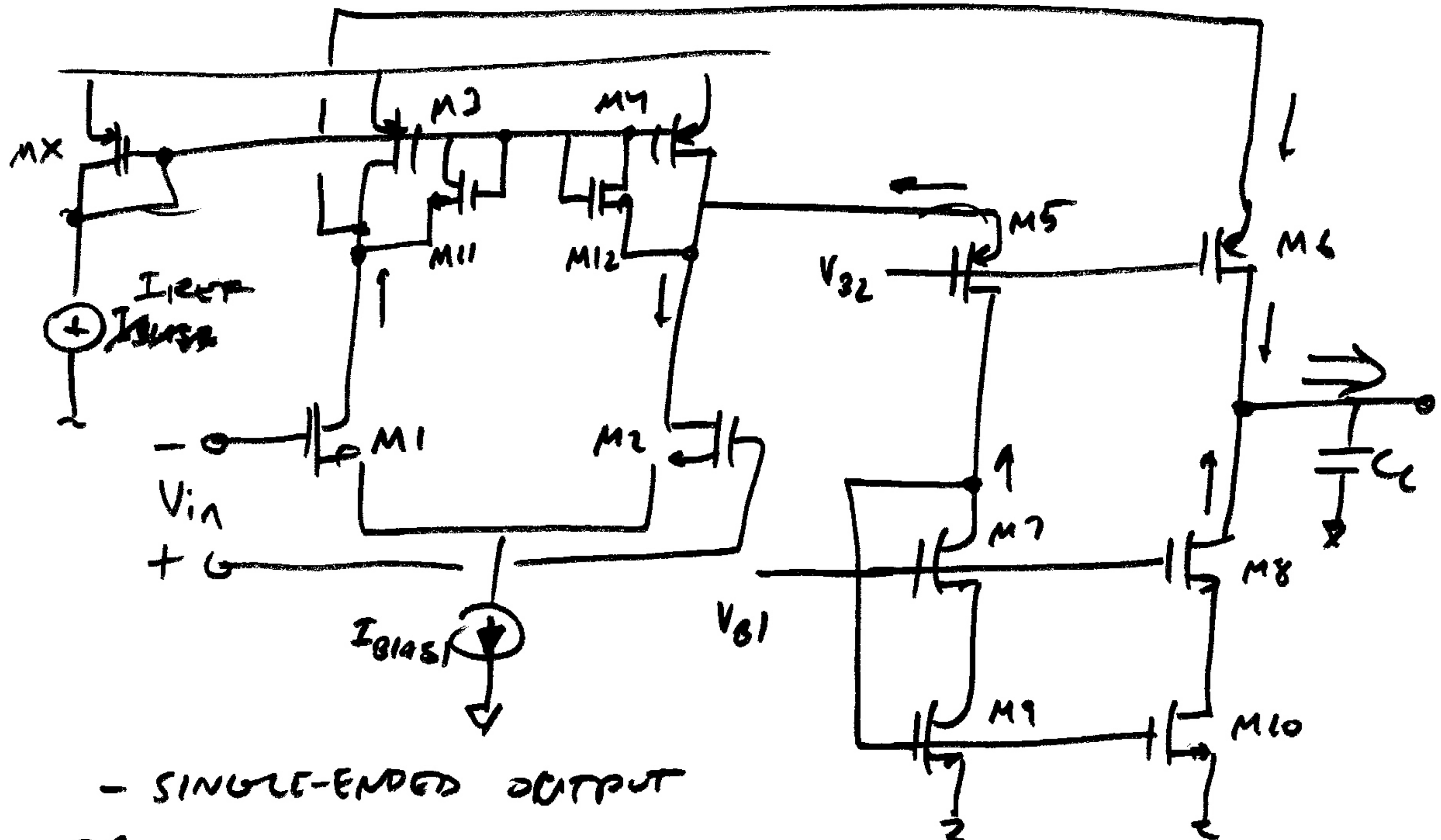
IMPROVING SLEW RATE

- DEGENERATE INPUT STAGE
- BIAS CURRENT SCALING
- PMOS I/P STAGE

$\frac{g_m}{I} \downarrow$ $\left\{ \begin{array}{c} 1/f \text{ NOISE} \\ \text{LOWER} \end{array} \right\}$



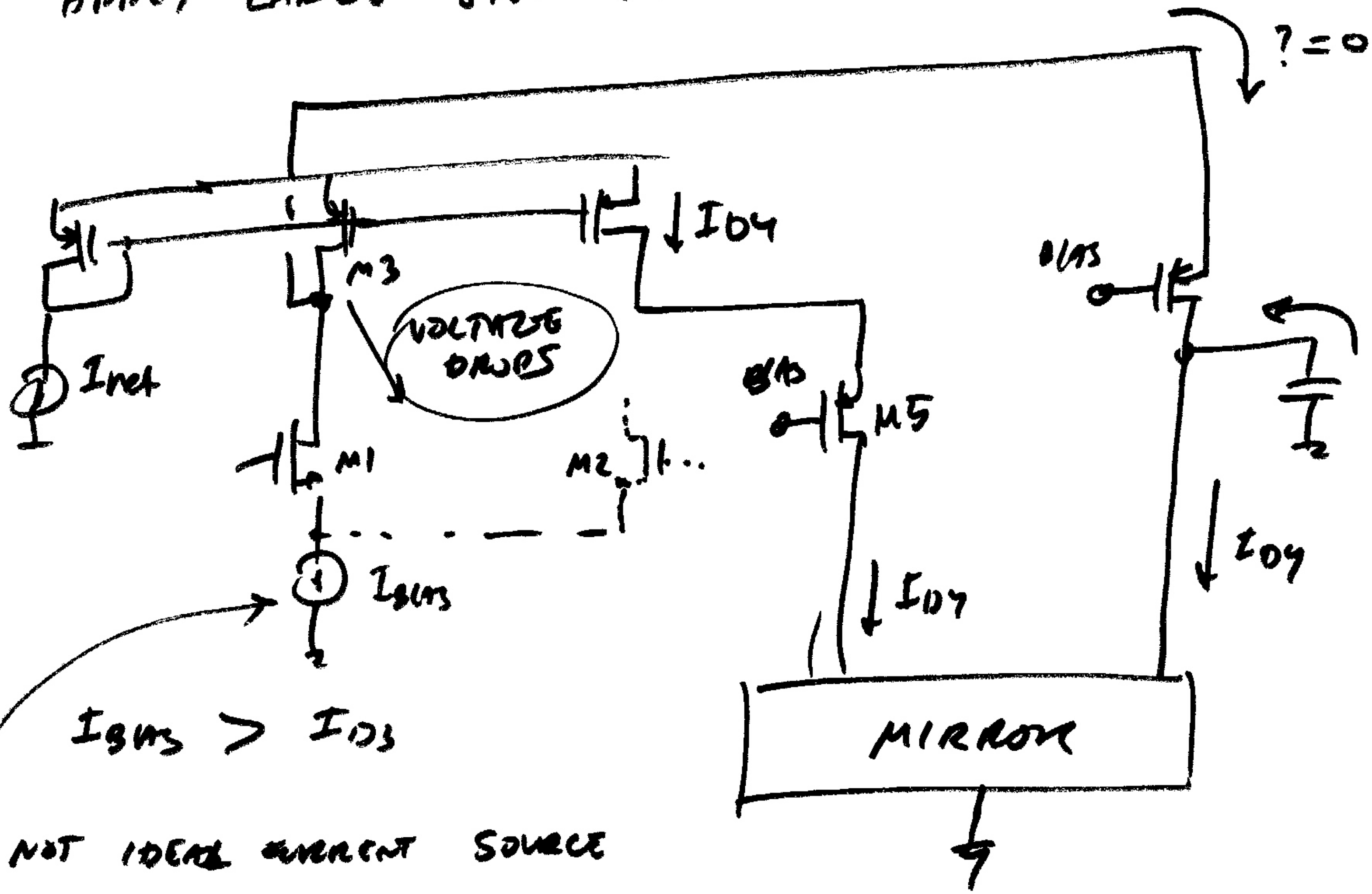


- SINGLE-ENDED OUTPUT

<u>DC</u> $I_{D5} = I_{D3} - I_{D1}$

$$= M\, I_{\cancel{BIAS2}\ REF} - \frac{I_{BIAS1}}{2} = \left(M - \frac{N}{2}\right) I_{REF}$$

APPLY LARGE STEP INPUT



$I_{BIAS} > I_{D3}$

NOT IDEAL CURRENT SOURCE

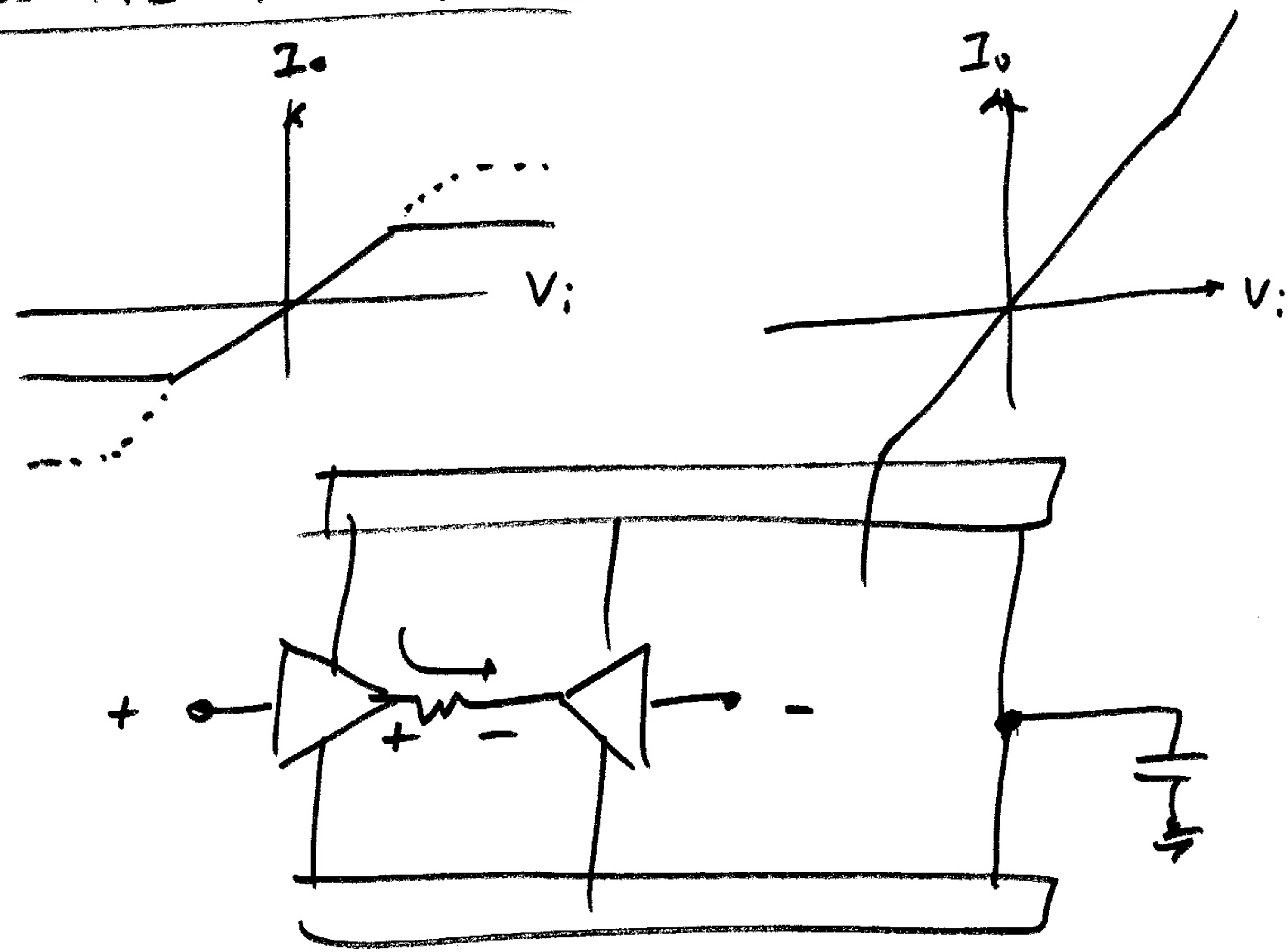
TRANSISTORS M11 & M12 ARE VOLTAGE CLAMPS TO LIMIT THE CHANGE IN VOLTAGE DURING SLEWING.

$\hookrightarrow$ IMPROVE RECOVERY TIME!!!

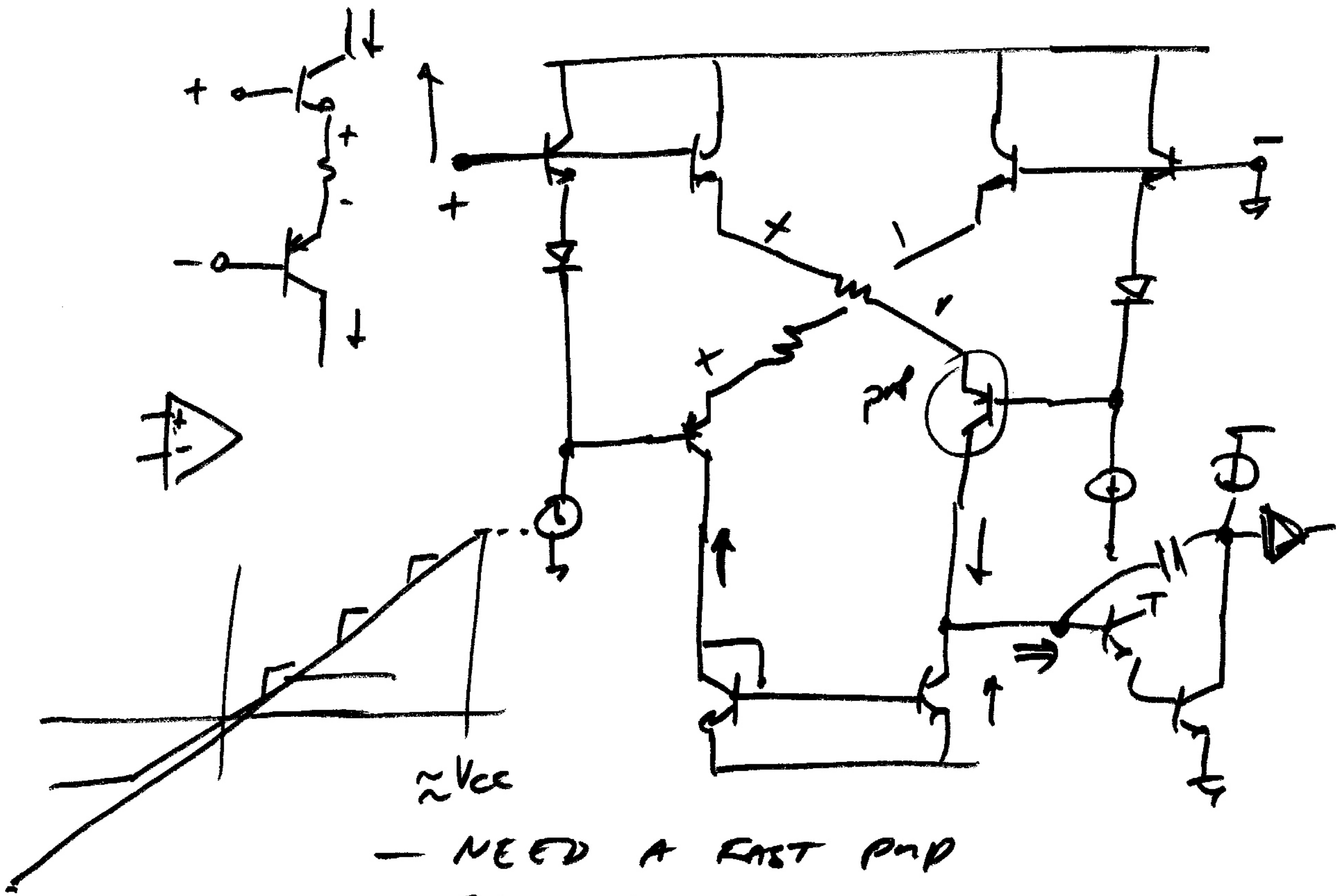
ALSO EXTRA CURRENT OF M11 (SAY DURING A NEGATIVE STEP INPUT) IS DRAWN FROM TRANSISTOR MX $\Rightarrow$ ~~MORE~~ M4 CURRENT ALSO INCREASES $\Rightarrow$

MORE SLEWING CURRENT

CLASS A/B INPUT STAGE



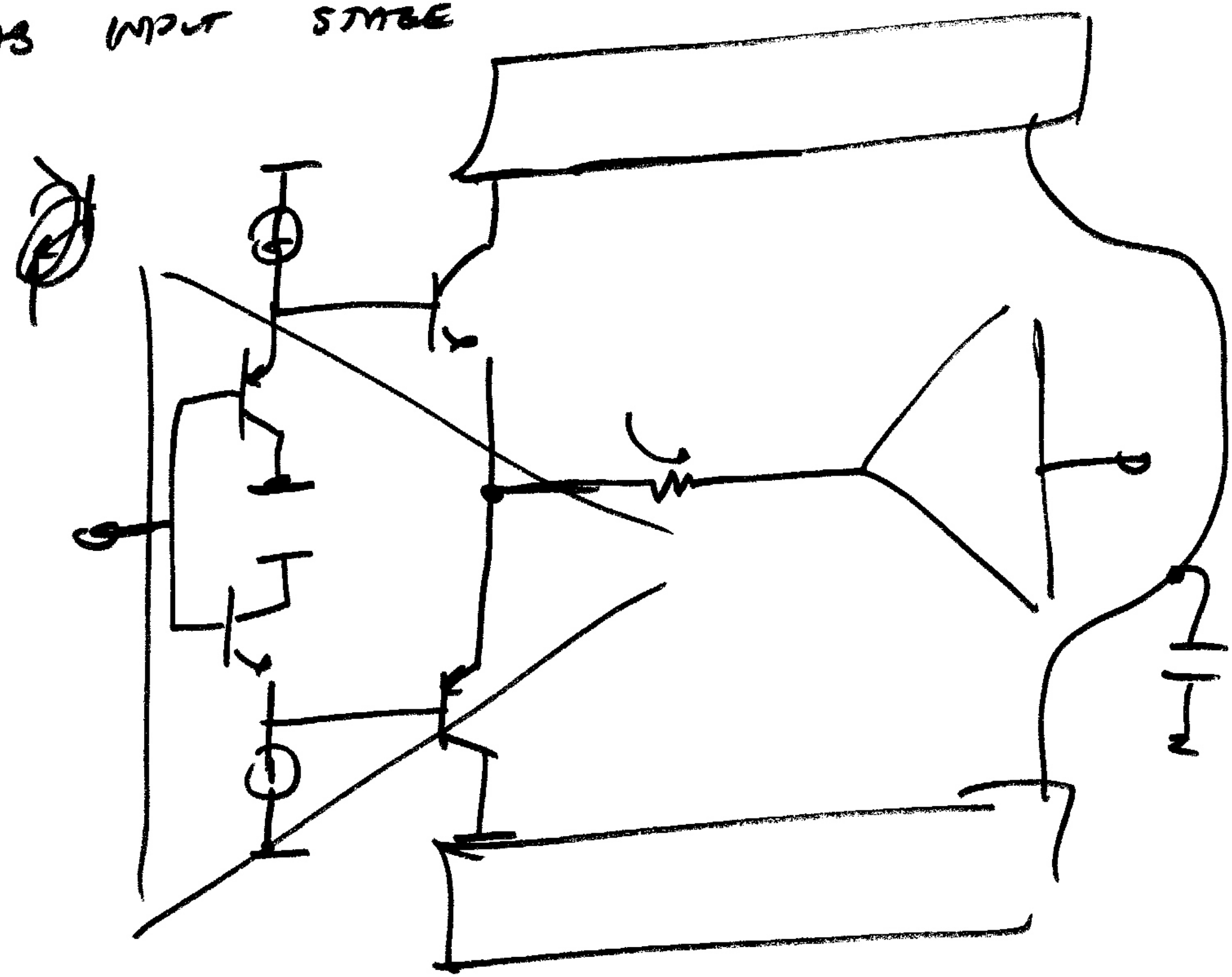
BJT CLASS AB INPUT STAGE



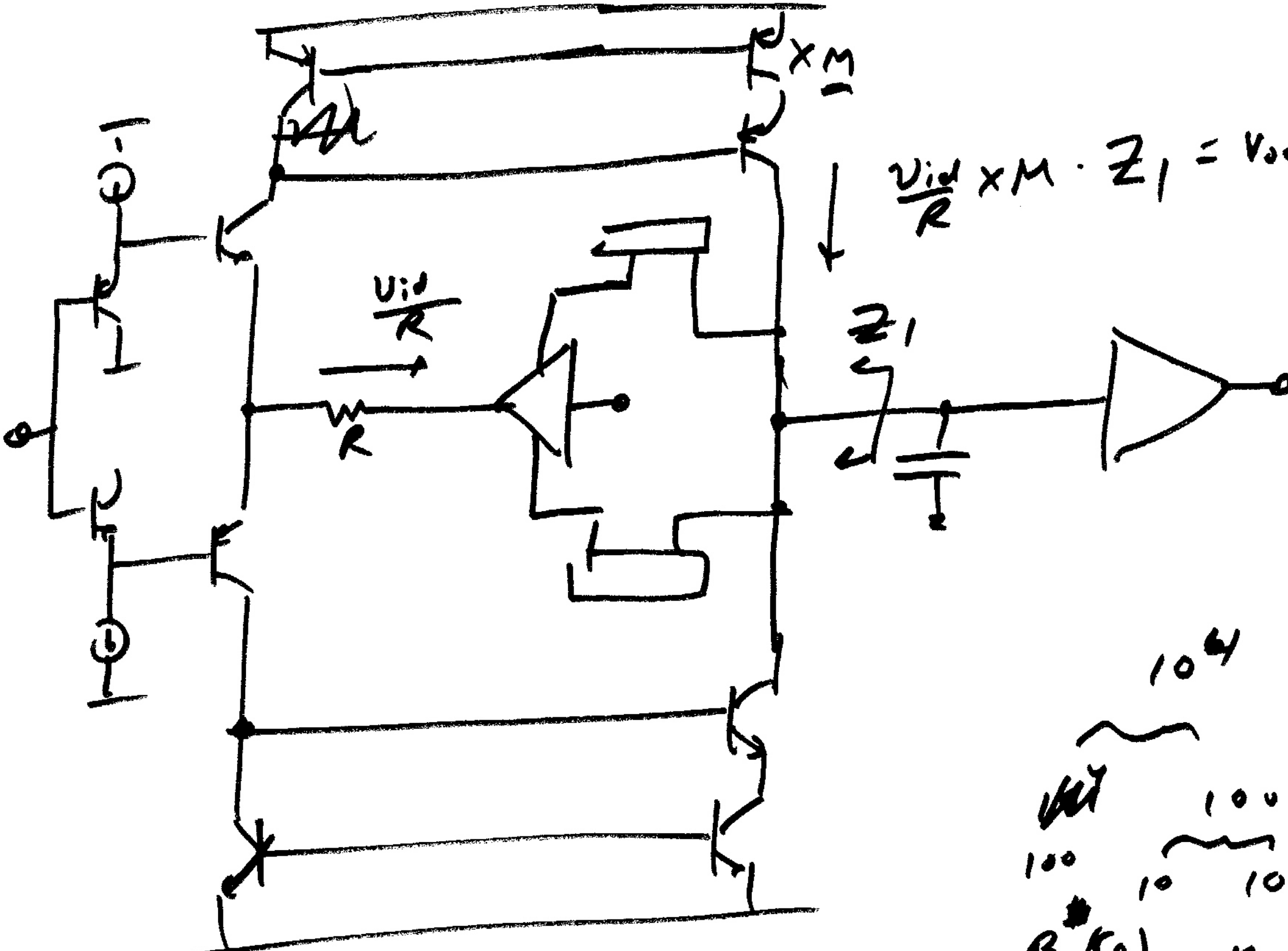
— NEED A FAST PNP

— BAD INPUT OFFSET VOLTAGE

CLASS AB INPUT STAGE



HIGHER INPUT IMPEDANCE

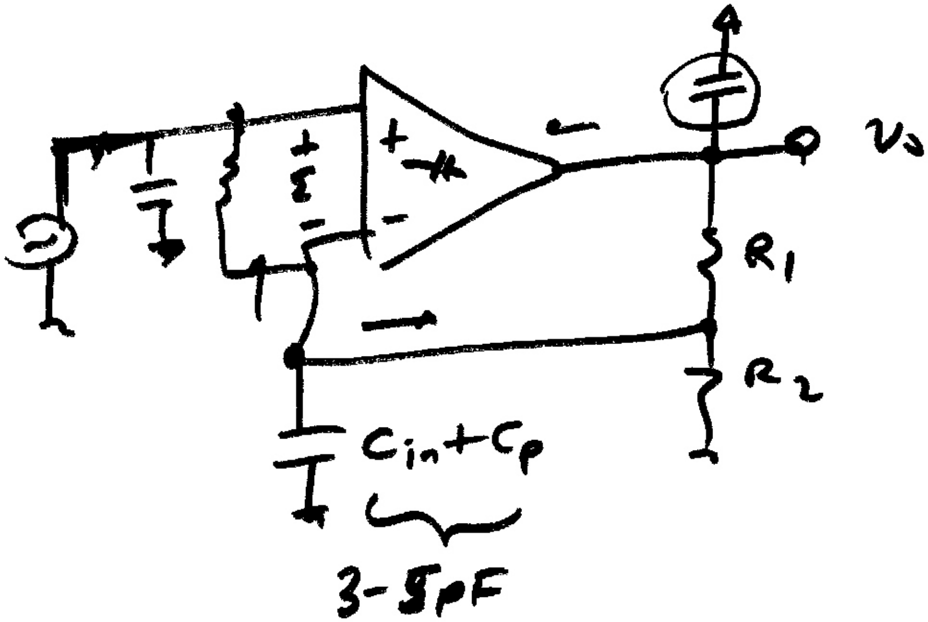


$\frac{V_{id}}{R} \times M \cdot Z_1 = V_{od}$

$\overbrace{100 \quad \overbrace{10 \quad 10}^{100}}^{10^4}$

OPEN LOOP GAIN $= \frac{Z_1}{R} \times M = \frac{\beta (r_0)}{R} \times M$

"CURRENT FB" AMPLIFIERS



$R_1 \| R_2 \sim 1k\Omega$

SIZE IS SET BY

DRIVE CURRENT

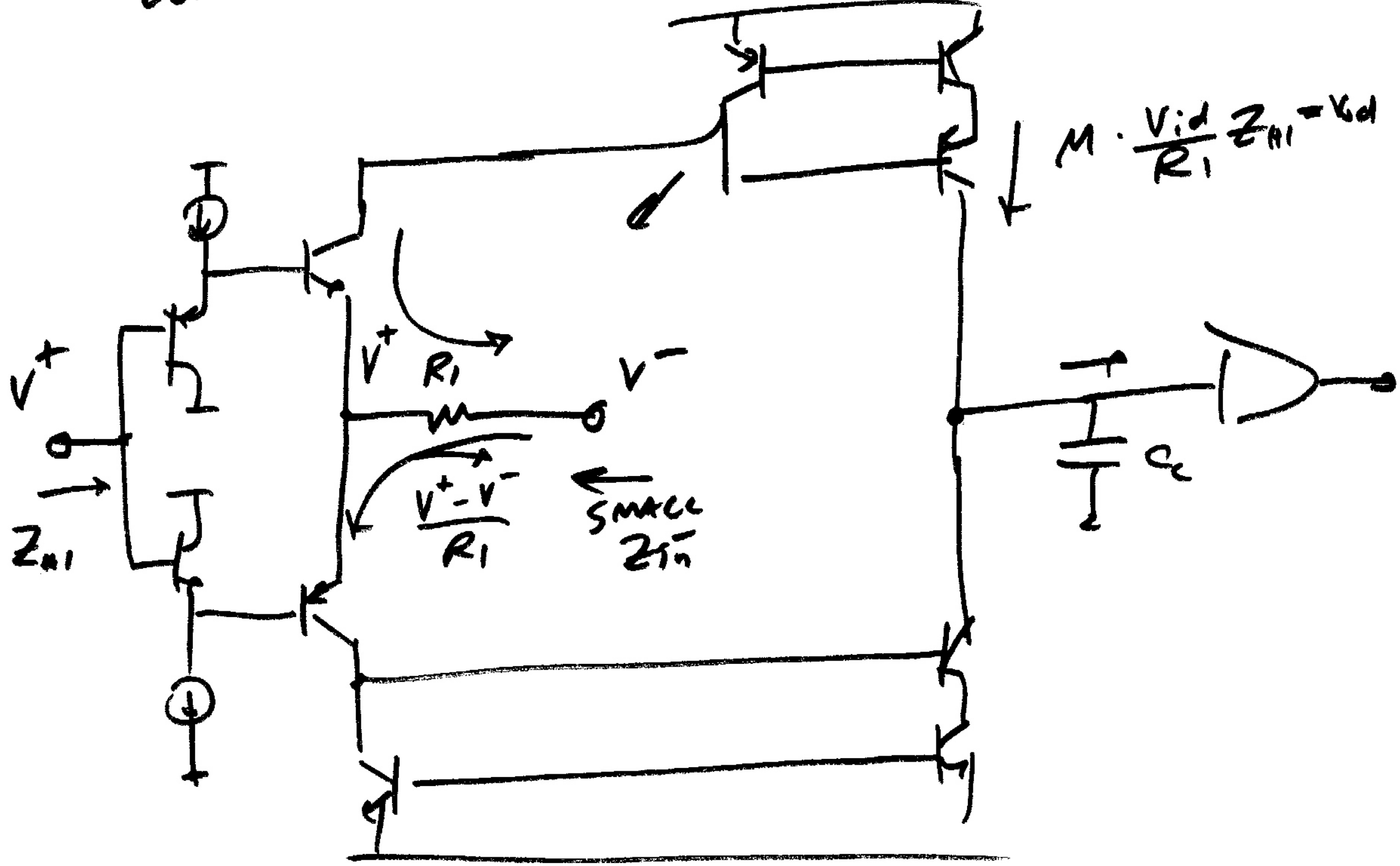
NOISE

$\tau = 5p \times 1k\Omega$

$\sim 5ns$

$f = 1/\tau = 50\,MHz$

LOW IMPEDANCE SUMMING NODE



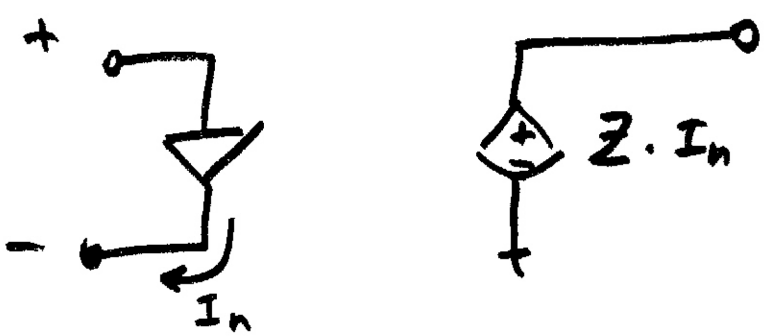
$$G = \frac{ZH1}{R_1} = \frac{\frac{\beta}{2} r_o}{R}$$

$$= \frac{500}{2} \cdot \frac{r_o}{R} = \frac{500}{2} \cdot \frac{\cancel{10} k\Omega}{\cancel{10}\,\Omega}$$

$$= 250{,}000$$

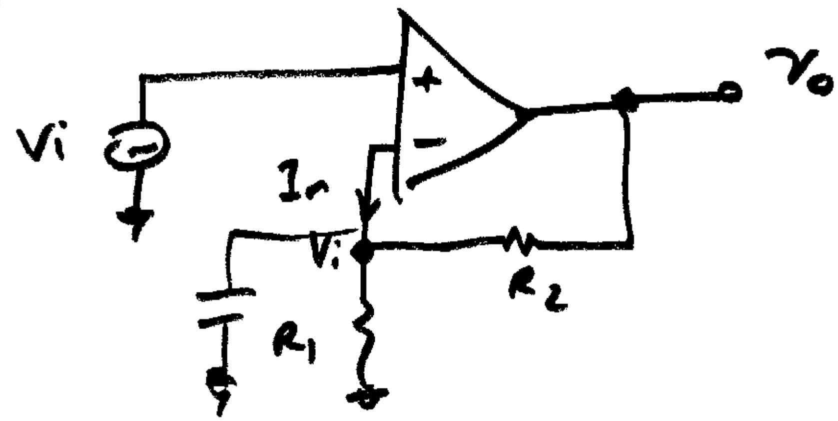
EQ CIRCUIT

IDEAL OP-AMP



"CURRENT" OP-AMP

EX



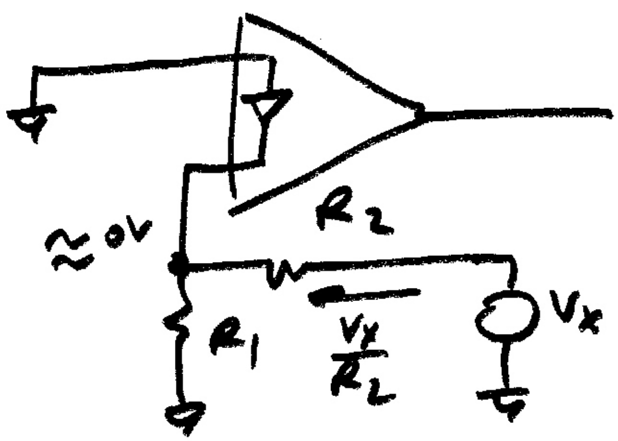
$$\underbrace{I_n}_{\text{ERROR SIGNAL}} = \frac{V_i}{R1} + \frac{V_i - V_o}{R_2} = V_i\left(\frac{1}{R_1} + \frac{1}{R_2}\right) - \underbrace{\frac{V_o}{R_2}}_{\text{CURRENT FB SIGNAL}}$$

$$V_o = Z\, I_n$$

$$\frac{V_o}{Z} + \frac{V_o}{R_2} = \frac{V_i}{R_1 \| R_2} = \frac{V_o}{Z \| R_2}$$

$$\frac{V_o}{V_i} = \frac{Z \| R_2}{R_1 \| R_2} \simeq \frac{R_2}{R_1 \cancel{R_2}}(R_1 + R_2)$$

$$= \underbrace{1 + \frac{R_2}{R_1}}_{\text{IDEAL GAIN}} \Leftarrow \text{LOOP GAIN} = \infty$$



$$v_r = Z \cdot I_n = Z \cdot \left(-\frac{V_x}{R_2}\right)$$

$$\underbrace{T = -\frac{v_r}{v_x} = \frac{Z}{R_2}}_{\text{LOOP GAIN}}$$

$$V_o\left(\frac{1}{Z}+\frac{1}{R_2}\right)=\frac{V_i}{R_1 \| R_2}$$

$$\frac{V_o}{Z}\left(1+\underbrace{\frac{Z}{R_2}}_{T}\right)=\frac{V_i}{R_1 \| R_2}$$

$$\frac{V_o}{V_i}=\frac{Z\,(R_1+R_2)}{R_1 R_2\,(1+T)}$$

$$=\underbrace{\left(1+\frac{R_2}{R_1}\right)}_{\text{IDEAL GAIN}}\ \underbrace{\frac{T}{1+T}}_{\text{ERROR}}\approx 1$$

GAIN/BANDWIDTH TRADEOFF

$$Z = \frac{Z_0}{1 + j\frac{\omega}{\omega_0}} \qquad T = \frac{Z}{R_2}$$

$$A = \left(1 + \frac{R_2}{R_1}\right)\frac{1}{1 + 1/T}$$

$$= \left(1 + \frac{R_2}{R_1}\right)\frac{1}{1 + \frac{R_2}{Z_0}\left(1 + j\frac{\omega}{\omega_0}\right)}$$

$$= \frac{\left(1 + \frac{R_2}{R_1}\right)}{1 + j\underbrace{\frac{\omega}{\omega_0}\frac{R_2}{Z_0}}}$$

$$\omega_a = \frac{Z_0\,\omega_0}{R_2}$$ CLOSED LOOP BANDWIDTH!

DEPENDS ON R_2

$\uparrow G \times BW \downarrow = \text{CONSTANT}$

$$= \left(1 + \frac{R_2}{R_1}\right) \times \frac{Z_0 \omega_0}{R_2} \cong \frac{Z_0 \omega_0}{R_1}$$