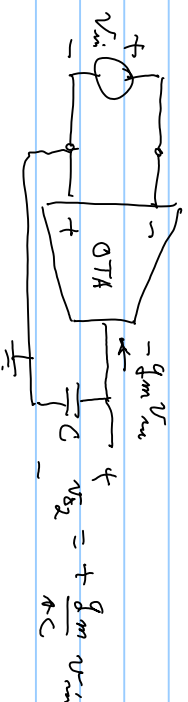
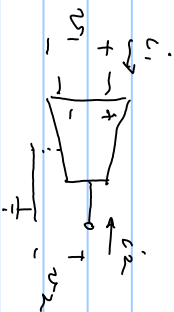


$$i_c = C \frac{dv_o}{dt} = AC \cdot v_o = -i_{out} = -g_m v_{in}$$

$$v_o = \frac{-g_m v_{in}}{AC}$$

$$A_{v1} = \frac{-g_m}{AC} \Rightarrow \text{integrator}$$

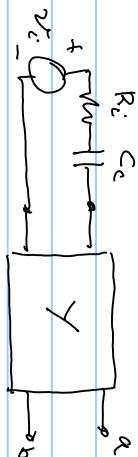




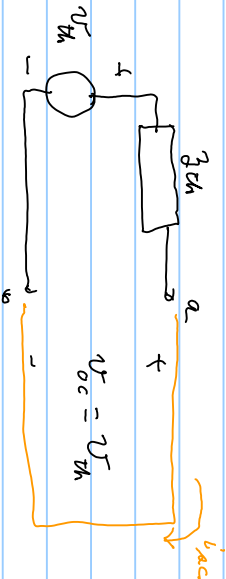
$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ g_m & 0 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

$$i_1 \equiv 0$$

$$i_2 = i_{out} = g_m v_1$$



all other elements equivalent
valid for small signal & linear



$$v_{oc} = \text{open circuit voltage} = v_{th}$$

$$i_{ac} = \text{short circuit current}$$

$$g_m = \frac{v_{th}}{v_{ac}} = \frac{v_{oc}}{v_{ac}}$$



$$v_{th} = v_{oc}$$

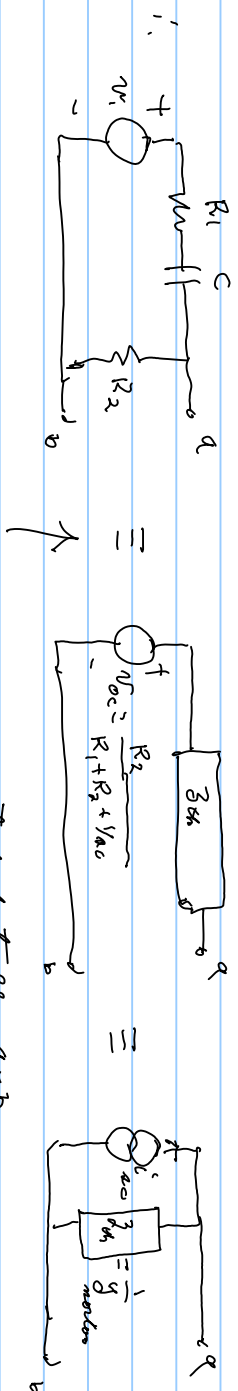
$$i_{ac} = \frac{v_{th}}{R_1 + R_2 + \frac{1}{g_c}}$$

$$v_1 = (R_1 + \frac{1}{g_c} + R_2) i_{ac}$$

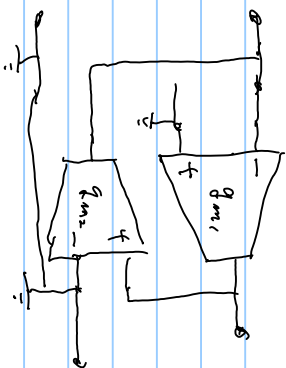
$$v_2 = R_2 i_{ac}$$

$$v_{ac} = \frac{R_2 i_{ac}}{C(R_1 + \frac{1}{g_c} + R_2) i_{ac}}$$

$$(R_1 + 1/s_c) i_{ac} = v_1 \Rightarrow i_{ac} = \frac{v_1}{R_1 + 1/s_c} \Rightarrow \beta_{th} = \frac{v_{oc}}{i_{sc}} = \frac{\frac{v_1}{R_1 + R_2 + 1/s_c} \cdot \frac{R_2}{R_1 + R_2 + 1/s_c}}{\frac{1}{R_1 + 1/s_c} \cdot v_1} = \frac{R_2 (R_1 + 1/s_c)}{R_2 + (R_1 + 1/s_c)} = \beta_{th}$$

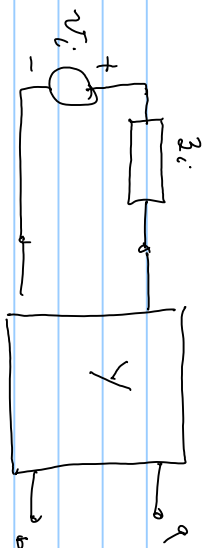


for anything connected between a-b



$$Y_1 + Y_2 = Y = \begin{bmatrix} 0 & 0 \\ -g_{m1} & 0 \end{bmatrix} + \begin{bmatrix} 0 & g_{m2} \\ 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & g_{m2} \\ -g_{m1} & 0 \end{bmatrix}$$

$$\Delta Y = g_{m1}, g_{m2}$$



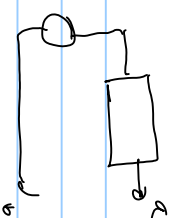
$$V_{oc} = \frac{-y_{21}}{y_{22} + z_i \Delta_y} V_i$$

$$i_{ac} = \frac{-y_{21} \cancel{z_i}}{\cancel{z_i} y_{22} + z_i \Delta_y} V_i$$

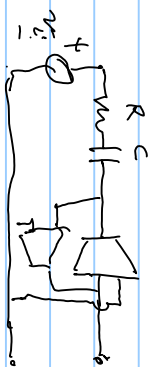
$$z_i = \frac{V_{oc}}{i_{ac}}$$

$$z_i = \frac{\frac{-y_{21}}{y_{22} + z_i \Delta_y} V_i}{\frac{-y_{21} \cancel{z_i}}{\cancel{z_i} y_{22} + z_i \Delta_y} V_i} = \frac{1 + z_i \Delta_y}{\Delta_y} (y_{22} + z_i \Delta_y)$$

$$\Delta_y = \det Y = y_{11} y_{22} - y_{12} y_{21}$$



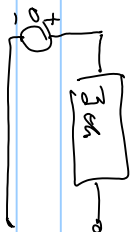
Ex: back to back OTA's, $Y = \begin{bmatrix} 0 & g_{m2} \\ -g_{m1} & 0 \end{bmatrix}$



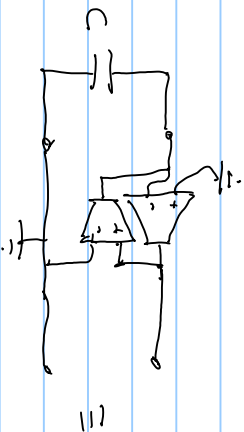
$$z_{in} = \frac{1 + 0 \cdot z_i}{0 + z_i \Delta_y} = \frac{1}{z_i [g_{m1} g_{m2}]} = \frac{1}{(R_i + 1/a_c) g_{m1} g_{m2}}$$

$$V_u = \frac{-(-g_{m1})}{0 + z_i \Delta_y} V_i = \frac{g_{m1}}{z_i g_{m1} g_{m2}} V_i = \frac{1}{g_{m2} z_i} V_i$$

$$\text{if } v_c = 0 \Rightarrow$$



$$R = 0 \quad \left[\frac{1}{(1/r_c) \underbrace{g_{m1} g_{m2}}_{3v_x}} \right] \quad \frac{R C}{g_{m1} g_{m2}} = R L_{eq} \quad L_{eq} = \frac{C}{g_{m1} g_{m2}}$$



$$L_{eq} = \frac{C}{g_{m1} g_{m2}}$$

$$\text{if } C = 1 \mu F = 10^{-6} \quad g_{m1} = g_{m2} = 10^{-3} \text{ S}$$

$$L_{eq} = \frac{10^{-6}}{10^{-3} \times 10^{-3}} = 1 \text{ H}$$