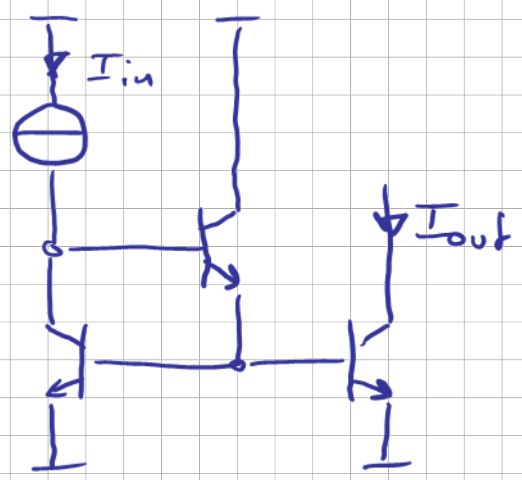
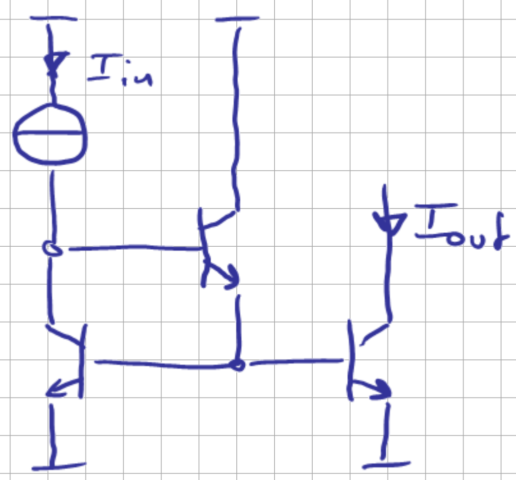
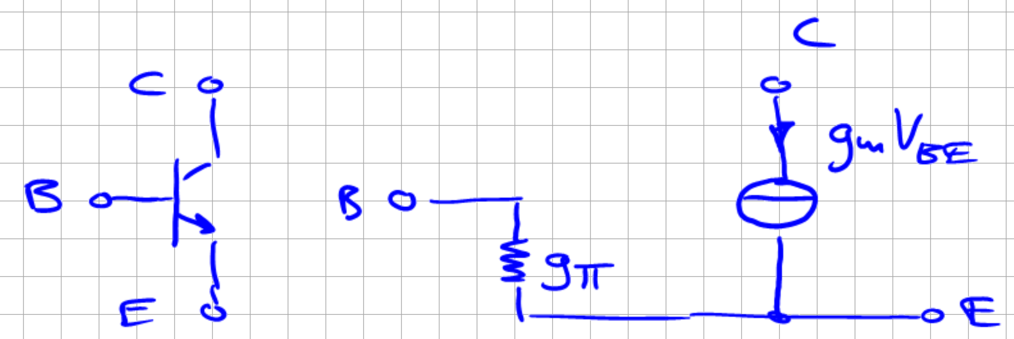
Bipolar current mirror with beta helper



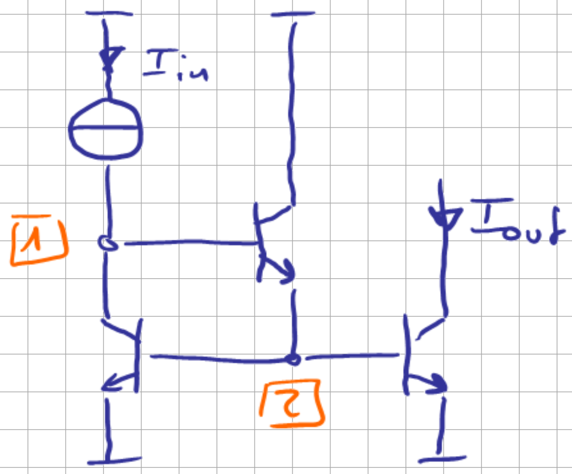
Bipolar current mirror with beta helper

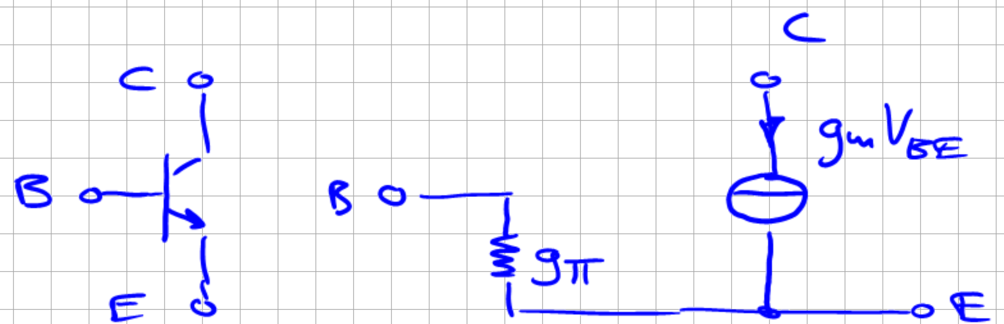




with $g_\pi = \frac{1}{\beta} \cdot g_m$

Bipolar current mirror with beta helper

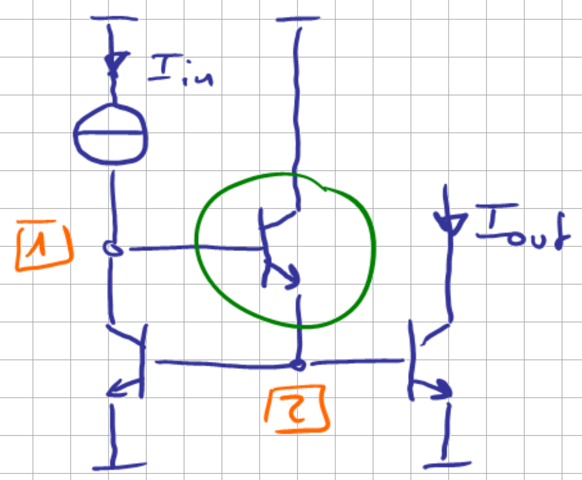


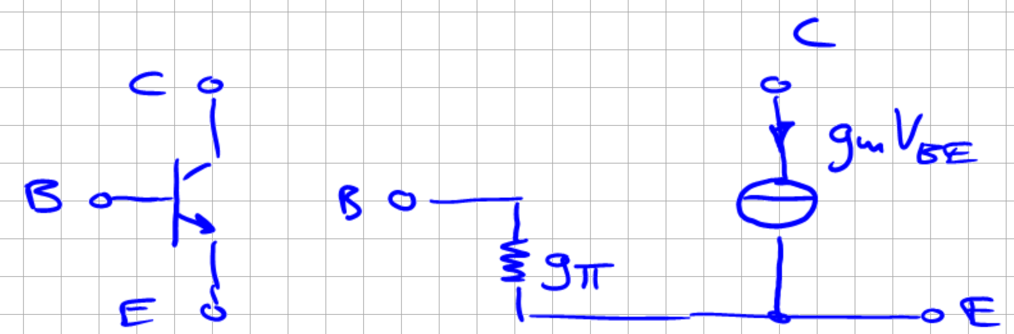


with $g_\pi = \frac{1}{\beta} \cdot g_m$

$Y_1 = \frac{1}{Z_1} = g_\pi \qquad Y_2 = \frac{1}{Z_2} = 3 g_\pi$

Bipolar current mirror with beta helper

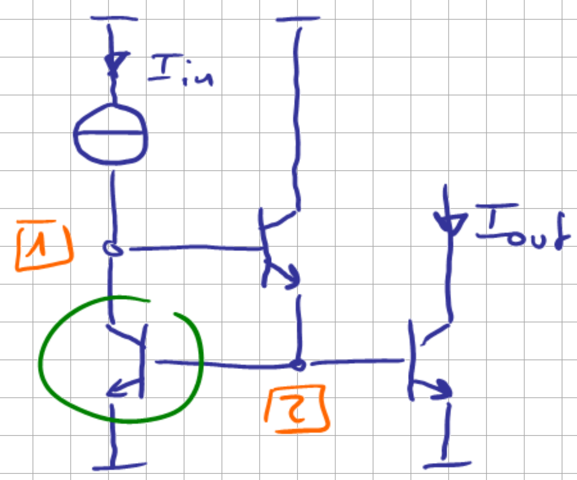


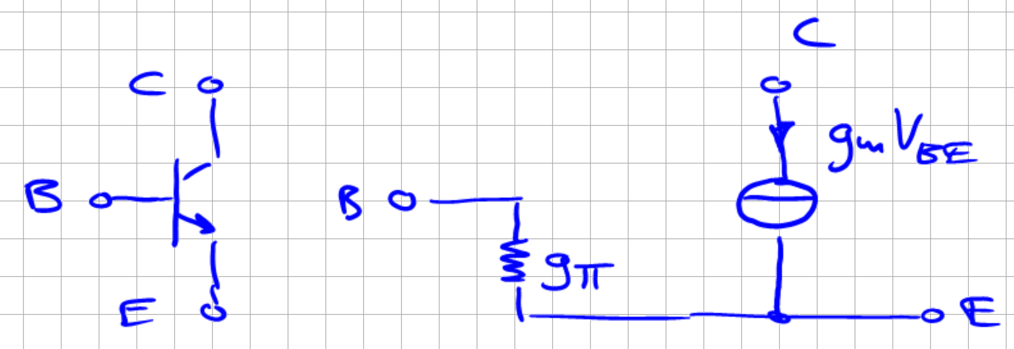


with $g_\pi = \frac{1}{\beta} \cdot g_m$

$Y_1 = \frac{1}{Z_1} = g_\pi \qquad Y_2 = \frac{1}{Z_2} = 3 g_\pi + g_m$

Bipolar current mirror with beta helper

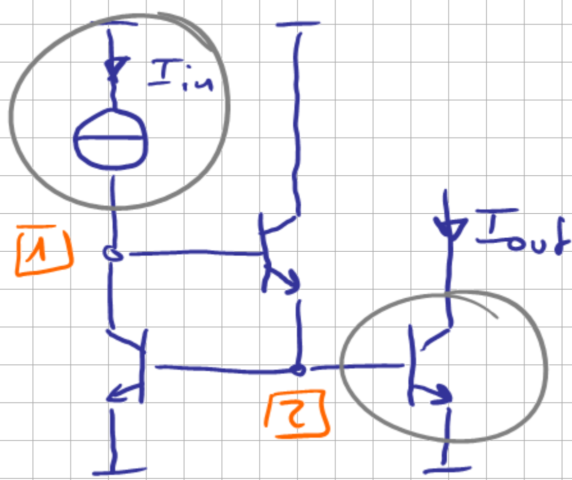


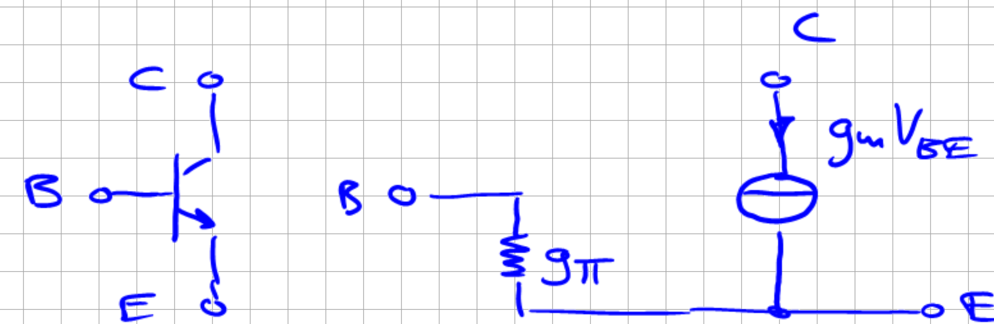


with $g_\pi = \frac{1}{\beta} \cdot g_m$

$Y_1 = \frac{1}{Z_1} = g_\pi$ $\quad$ $Y_2 = \frac{1}{Z_2} = 3g_\pi + g_m$

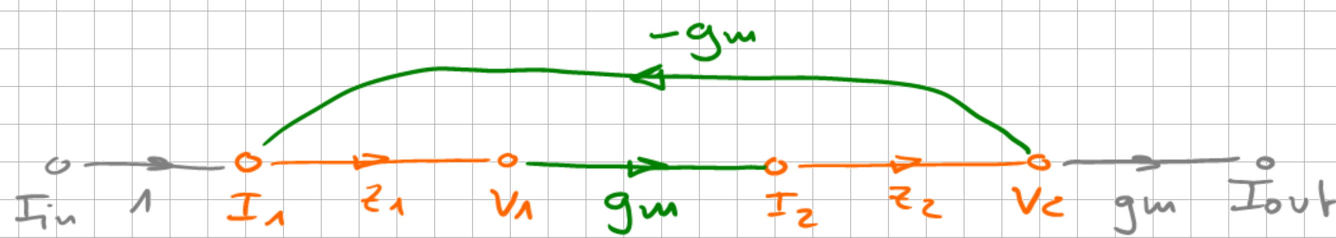
Bipolar current mirror with beta helper



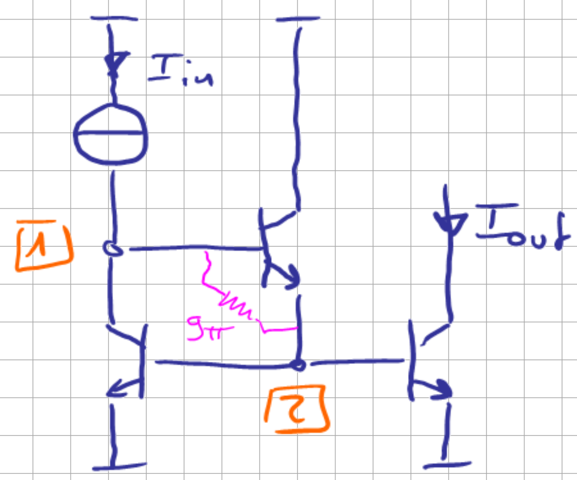


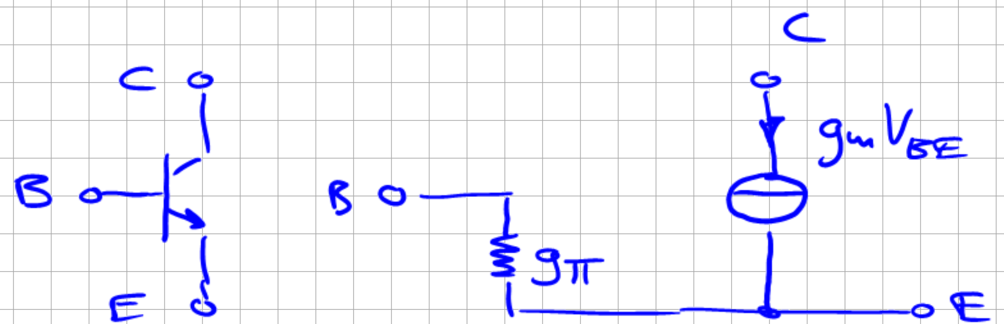
with $g_\pi = \frac{1}{\beta} \cdot g_m$

$Y_1 = \frac{1}{Z_1} = g_\pi \qquad Y_2 = \frac{1}{Z_2} = 3g_\pi + g_m$



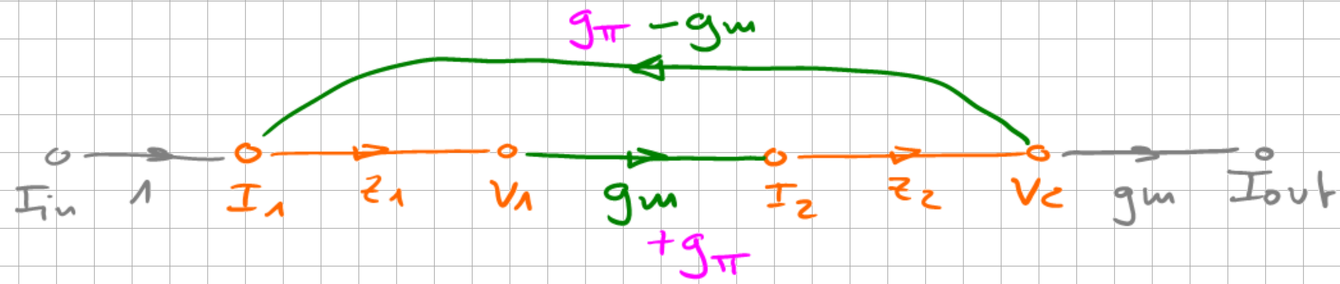
Bipolar current mirror with beta helper



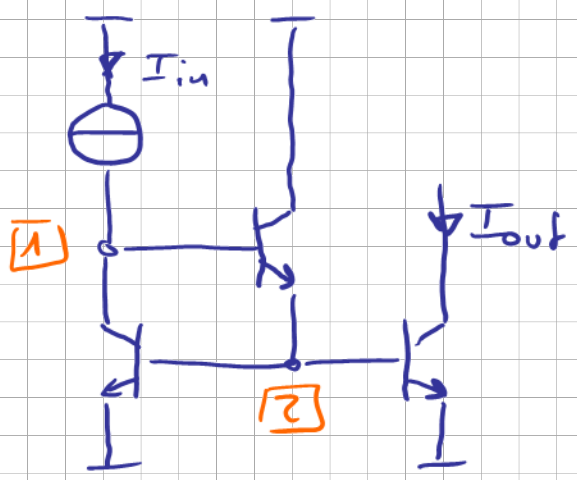


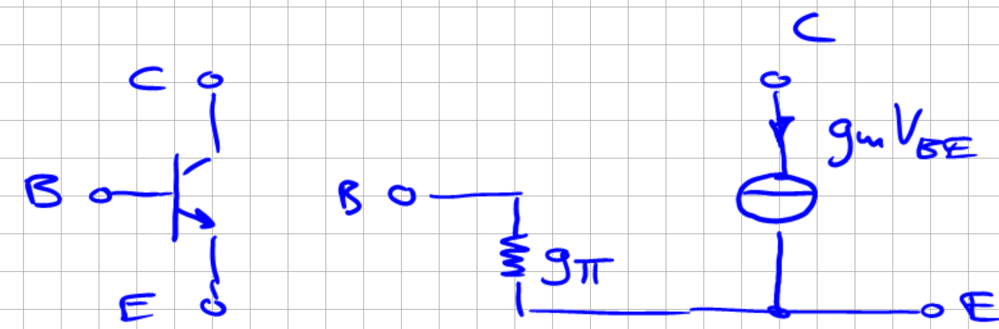
with $g_\pi = \frac{1}{\beta} \cdot g_m$

$Y_1 = \frac{1}{Z_1} = g_\pi$ $\quad Y_2 = \frac{1}{Z_2} = 3g_\pi + g_m$



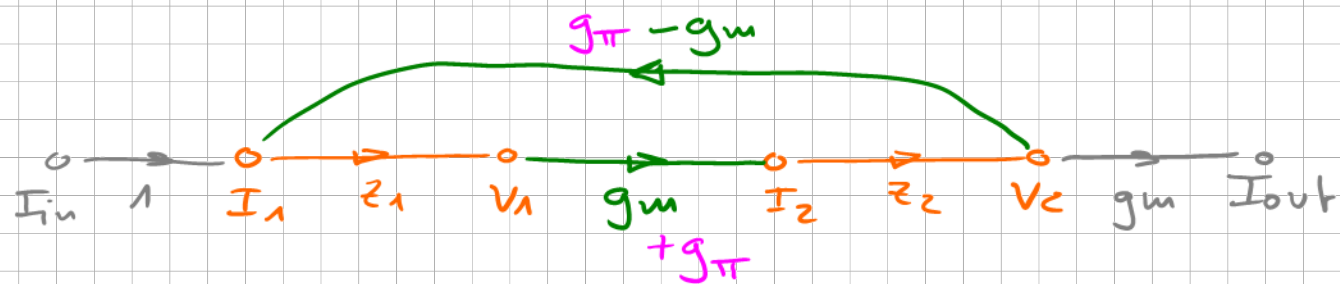
Bipolar current mirror with beta helper





with $g_\pi = \frac{1}{\beta} \cdot g_m$

$$y_1 = \frac{1}{z_1} = g_\pi \qquad y_2 = \frac{1}{z_2} = 3g_\pi + g_m$$



$$y_1 y_2 \Delta = y_1 y_2 - (g_\pi - g_m)(g_\pi + g_m) = 3g_\pi^2 + g_\pi g_m - g_\pi^2 + g_m^2$$

$$= 2g_\pi^2 + g_\pi g_m + g_m^2$$

$$= g_m^2 \left(1 + \frac{1}{\beta} + \frac{2}{\beta^2}\right)$$

$$y_1 y_2 P_1 \Delta = g_m^2 + g_m g_\pi = g_m^2 \left(1 + \frac{1}{\beta}\right)$$

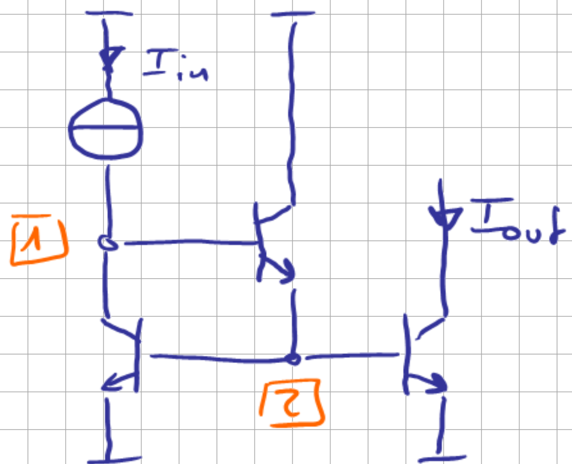
$$T = \frac{I_{out}}{I_{in}} = \frac{\left(1 + \frac{1}{\beta}\right)}{\left(1 + \frac{1}{\beta} + \frac{2}{\beta^2}\right)} = \frac{\beta^2 + \beta}{\beta^2 + \beta + 2}.$$

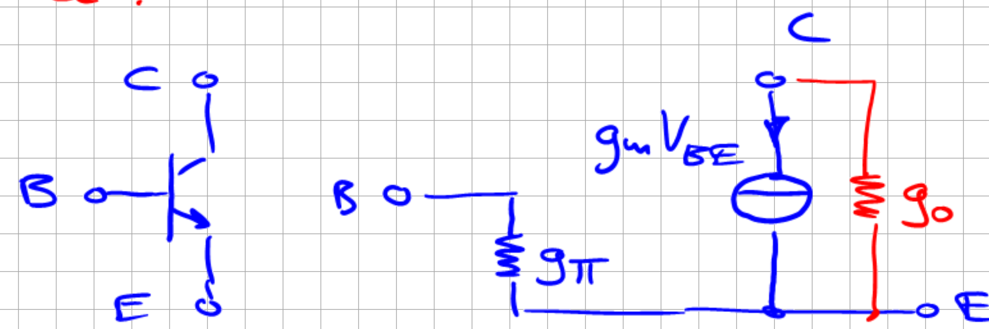
E.g., $\beta = 100 \rightarrow T = \frac{10\,100}{10\,102} \approx 0.9998$

Hanspeter Schmid, FHNW/ISE, November 2018.

Bipolar current mirror with beta helper

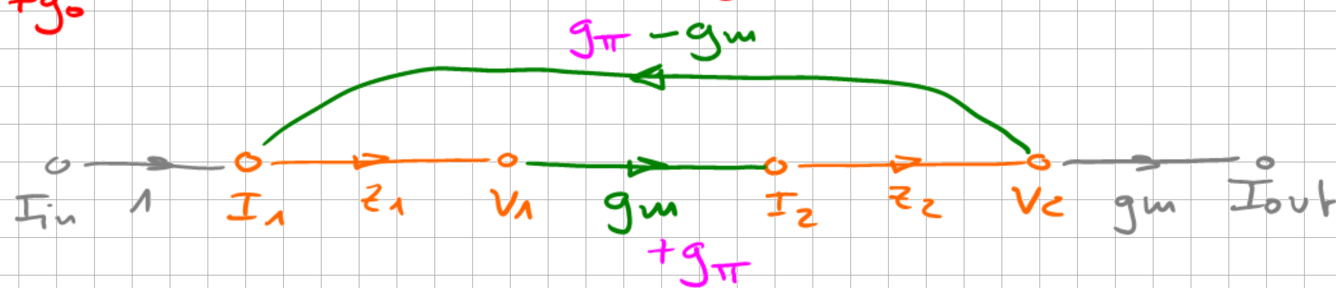
Effect of output conductance?





with $g_\pi = \frac{1}{\beta} \cdot g_m$ and $g_o = k\, g_m$ for some small k

$$Y_1 = \frac{1}{Z_1} = g_\pi + g_o \qquad Y_2 = \frac{1}{Z_2} = 3g_\pi + g_m + g_o$$



$$Y_1 Y_2 \Delta = Y_1 Y_2 - (g_\pi - g_m)(g_\pi + g_m)$$

$$= 2 g_\pi^2 + g_\pi g_m + g_\pi g_o + 3 g_\pi g_o + g_m g_o + g_o^2 + g_m^2$$

$$= g_m^2 \left(\frac{2}{\beta^2} + \frac{1+4k}{\beta} + 1 + k + k^2 \right).$$

For $4k \ll 1$, nothing really changes.

$$Y_1 Y_2 P_1 \Delta = g_m^2 + g_m g_\pi = g_m^2 \left(1 + \frac{1}{\beta}\right)$$

$$T = \frac{I_{out}}{I_{in}} = \frac{\left(1 + \frac{1}{\beta}\right)}{\left(1 + \frac{1}{\beta} + \frac{2}{\beta^2}\right)} = \frac{\beta^2 + \beta}{\beta^2 + \beta + 2}.$$

E.g., $\beta = 100 \rightarrow T = \frac{10100}{10102} \approx 0.9998$

Hanspeter Schmid, FHNW/ISE, November 2018.