Elektronik II

Current Mirrors, Widlar/Wilson, Cascode Amplifier

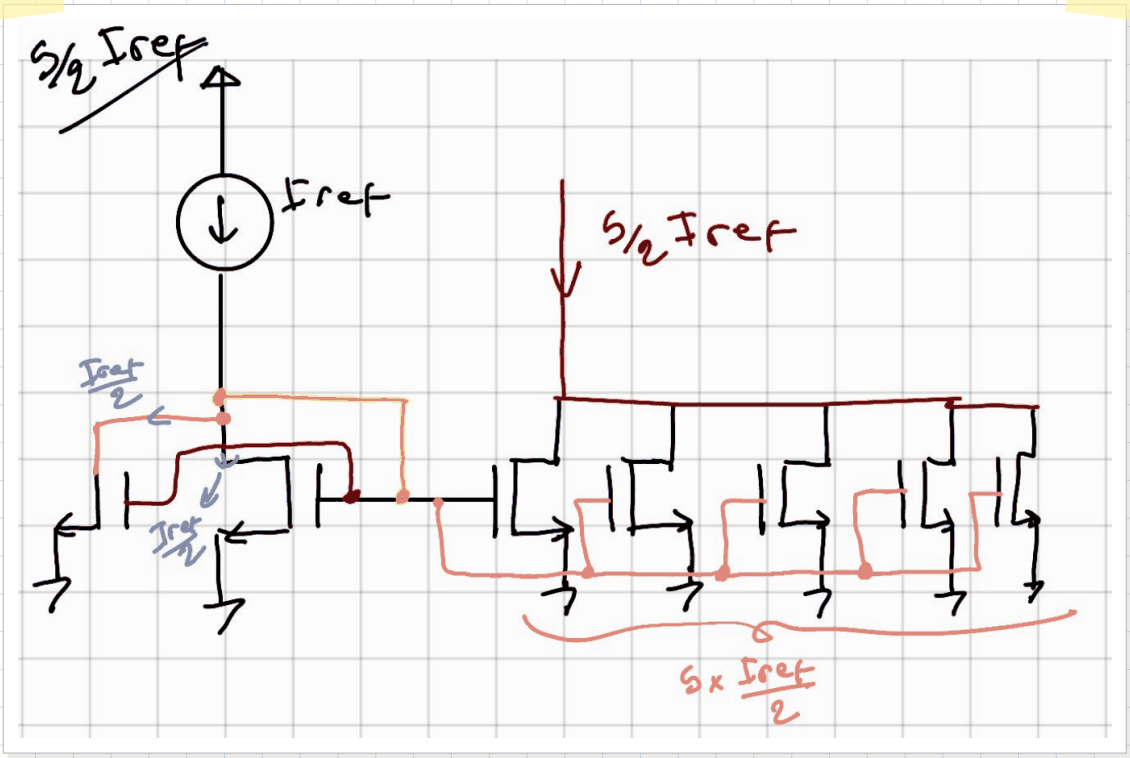
Orijinal not: Ders3.pdf

UYARI Bu belge, el yazısı ders notlarından Claude (Anthropic) yardımıyla dijitale aktarılmıştır. Yardımcı kaynak olarak hazırlanmıştır; hata veya eksik içerebilir. Lütfen orijinal notları ve ders kaynaklarını esas alın.

NOTICE *This document was transcribed from handwritten lecture notes with the help of Claude (Anthropic). It is meant as a supplementary resource and may contain errors or omissions. Always check against the original notes and official course material.*

Not: Orijinal dosyadaki basılı sayfalar (s. 1) dijitalleştirilmedi; yalnızca el yazısı sayfalar aktarıldı.

orj. s. 2



orijinal çizim, s. 2

BJT Circuits



Şekil: Printed figure of the basic BJT current mirror (I_{REF} source, Q_1 and Q_2 with joined bases and emitters, V_{BE}, output current I_O at V_O); handwritten additions: $2I_B$ (arrow) on the wire from the Q_1 collector node to the bases, I_C (arrow down) at the Q_1 collector and at the Q_2 collector, red I_B arrows at the two bases.
(orijinal notta, s. 2)

$$I_C = \beta I_B$$
$$I_B = I_C/\beta$$

$$I_{ref} = I_C + 2I_B$$
$$I_{ref} = I_C\left(1 + \frac{2}{\beta}\right)$$
$$I_O = I_C$$

$$\boxed{\frac{I_O}{I_{ref}} = \frac{1}{1 + 2/\beta}} \approx 1$$

β büyüyünce akım aynasının kalitesi artar

what happens if

$$EBJ_1 = 1 \qquad EBJ_2 = m$$

$$I_{C1} = I_S e^{V_{BE}/V_T}$$
$$I_{C2} = m I_S e^{V_{BE}/V_T}$$
$$I_{C1}\, m = I_{C2}$$



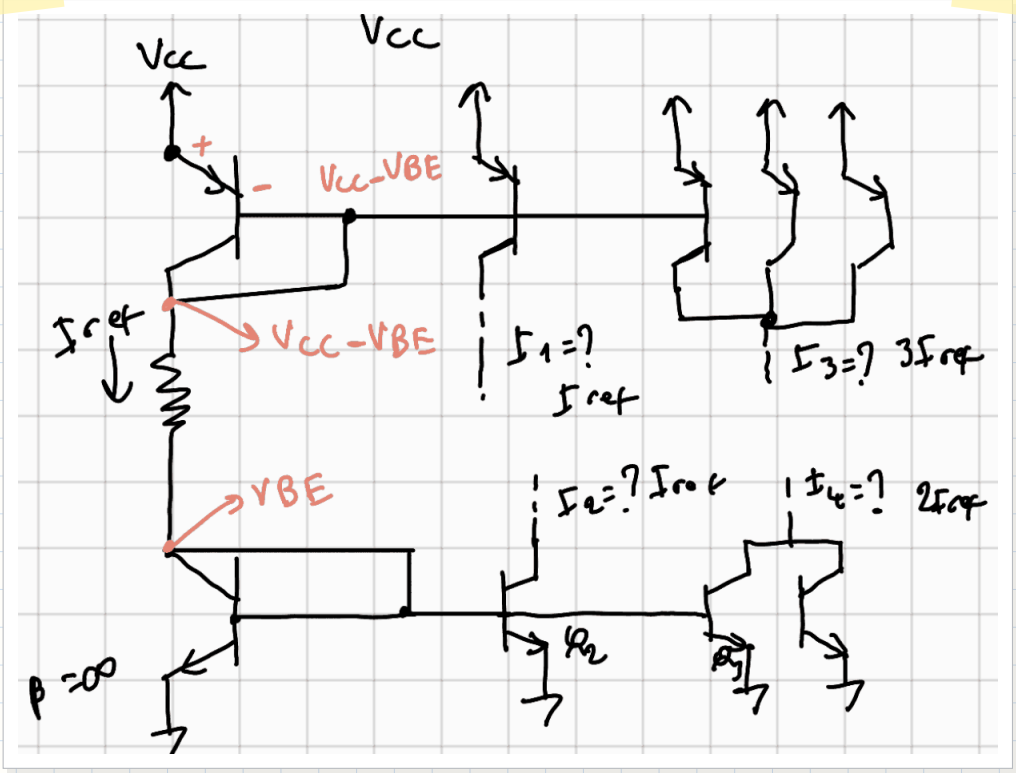
Şekil: Printed figure of the BJT current mirror (I_{REF}, Q_1, Q_2, I_O, V_O, V_{BE}), reached by an arrow ⇒ from the equations on the left; purple additions: I_{C1} (arrow down) at the Q_1 collector, base currents $\frac{I_{C1}}{\beta}$ (at Q_1) and $\frac{m I_{C1}}{\beta}$ (at Q_2), and $I_{C1}\, m$ (arrow down) at the Q_2 collector.
(orijinal notta, s. 2)

$$I_{ref} = I_{C1} + \frac{(1+m)I_{C1}}{\beta}$$
$$= I_{C1}\left(1 + \frac{(m+1)}{\beta}\right)$$
$$I_O = I_C m$$
$$\frac{I_O}{I_{ref}} = \frac{m}{1 + \frac{(m+1)}{\beta}}$$

$$\frac{I_O}{I_{ref}} = \frac{m}{1 + \frac{(m+1)}{\beta}}$$

orj. s. 3

Current Steering BJT



orijinal çizim, s. 3

$$I_{ref} = \frac{(V_{CC} - V_{BE}) - V_{BE}}{R}$$
$$= \frac{V_{CC} - 2V_{BE}}{R} = \frac{V_{CC} - V_{BE} - V_{EB}}{R}$$

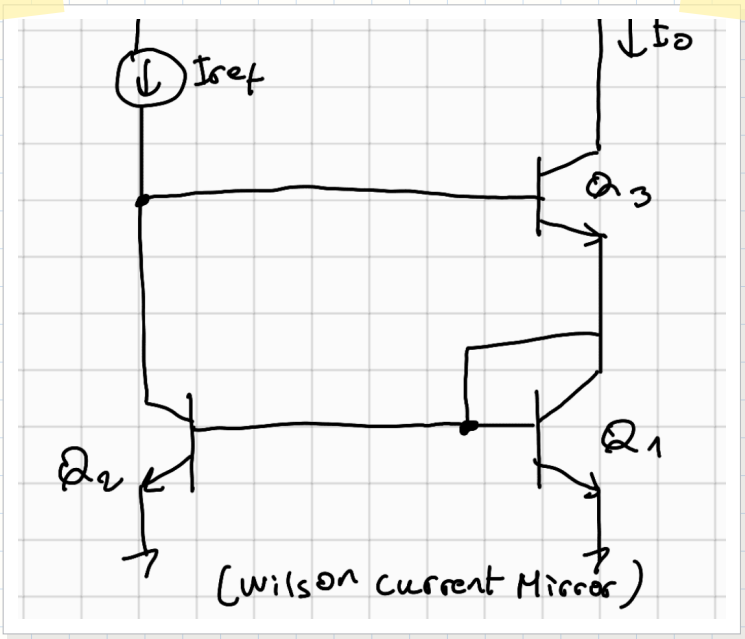
Şekil: Basılı BJT akım aynası şeması (I_{REF}, Q_1, Q_2, V_{BE}); el yazısı ekleme: Q_2 kolektörüne çizilmiş direnç ve yanında "r_o görünür". *(orijinal notta, s. 3)*

$$r_o = \frac{V_A}{I_C} \Rightarrow \text{BJT}$$

$$r_o = \frac{V_A}{I_D} = \frac{V'_A L}{I_D} \Rightarrow \text{MOSFET}$$

orj. s. 4

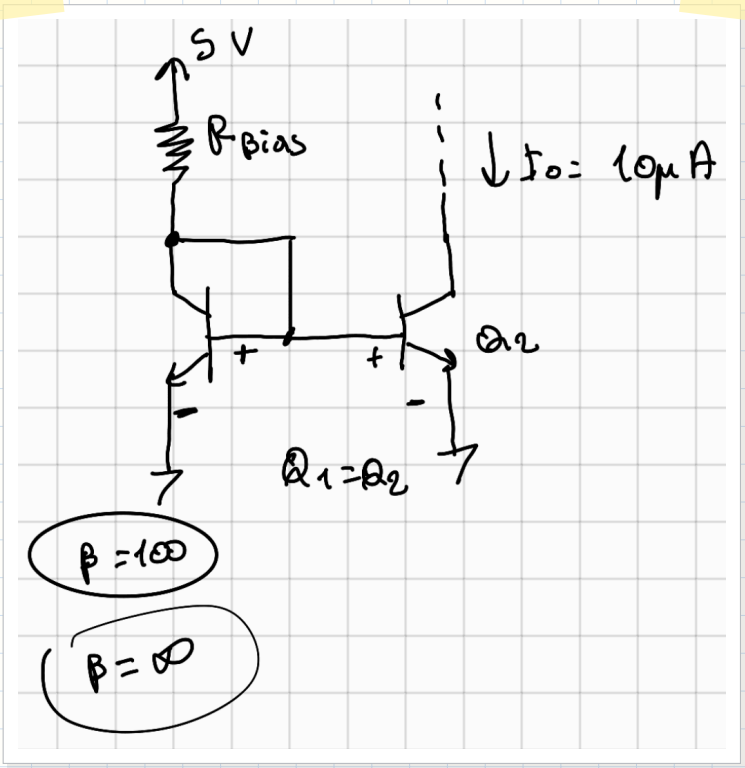
Wilson Current Mirror



orijinal çizim, s. 4

$$\frac{I_o}{I_{ref}} = ?$$

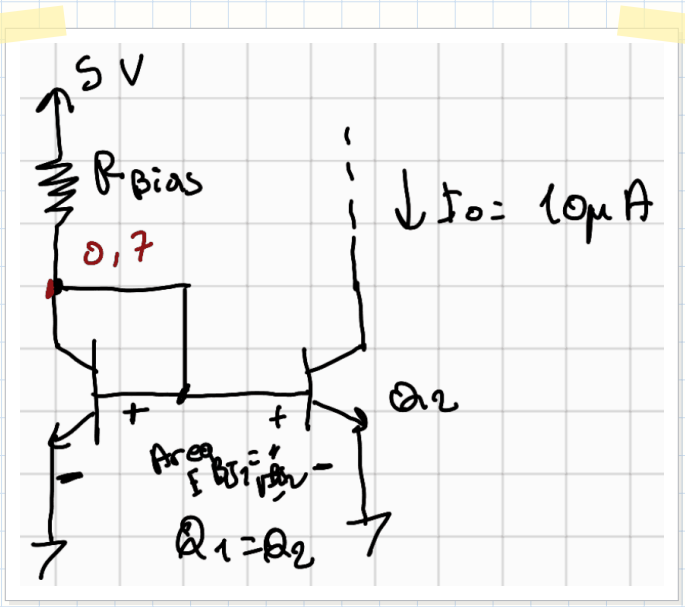
Bob Widlar Current Source



orijinal çizim, s. 4

What is the value of R_{Bias}

orj. s. 5



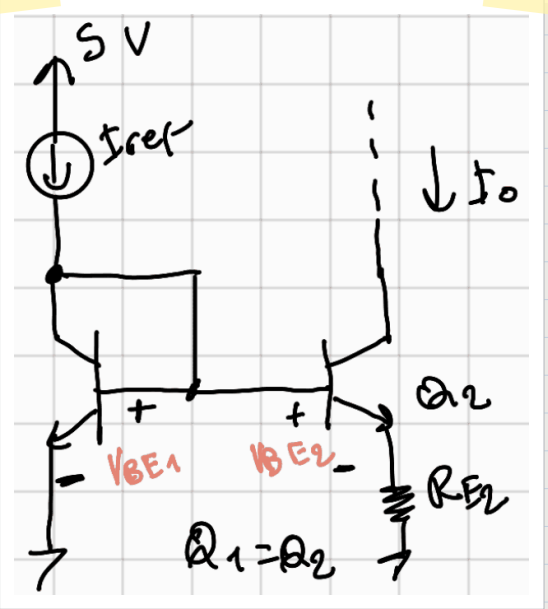
orijinal çizim, s. 5

$$R_{BIAS} = \frac{4{,}3}{10\ \mu A} \qquad R_{BIAS} \Rightarrow 430\ k\Omega\ (\beta = \infty)$$

$$R_{BIAS} = 421{,}6\ k\Omega\ (\beta = 100)$$

$$\frac{I_o}{I_{ref}} = \frac{1}{1 + 2/\beta}$$

Bob Widlar bunu önermiş



orijinal çizim, s. 5

if $\beta = \infty$

$$I_{ref} = I_s e^{\frac{V_{BE1}}{V_T}}$$
$$I_o = I_s e^{\frac{V_{BE2}}{V_T}}$$

$$V_{BE1} = V_{BE2} + I_o \cdot R_{E2}$$
$$V_{BE1} - V_{BE2} = I_o R_{E2}$$

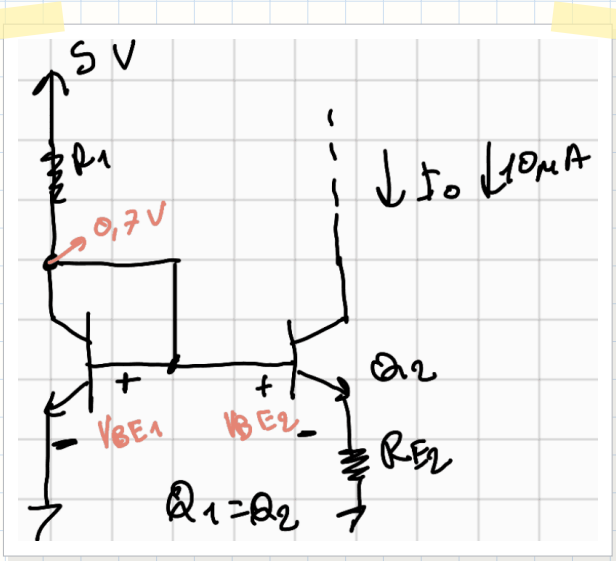
$$\frac{I_o}{I_{ref}} = \frac{e^{\frac{V_{BE2}}{V_T}}}{e^{\frac{V_{BE1}}{V_T}}}$$

orj. s. 6

$$\ln\left(\frac{I_o}{I_{ref}}\right) = \frac{V_{BE2} - V_{BE1}}{V_T}$$

$$V_{BE2} - V_{BE1} = V_T \ln\left(\frac{I_o}{I_{ref}}\right) = -I_o \cdot R_{E2}$$

$$I_o = \frac{V_T \ln\left(\frac{I_{ref}}{I_o}\right)}{R_{E2}}$$



orijinal çizim, s. 6

R_1 =?
R_2 =?
ΔR_{total} with previous design

$$\frac{5-0,7}{R_1} = I_{ref} = \frac{4,3}{R_1}$$

$$I_o = \frac{V_T \cdot \ln\left(\frac{4,3}{I_o R_1}\right)}{R_{E2}}$$

$$10\,\mu A = \frac{25\,mV \cdot \ln\left(\frac{I_{ref}}{10\,\mu A}\right)}{R_2}$$

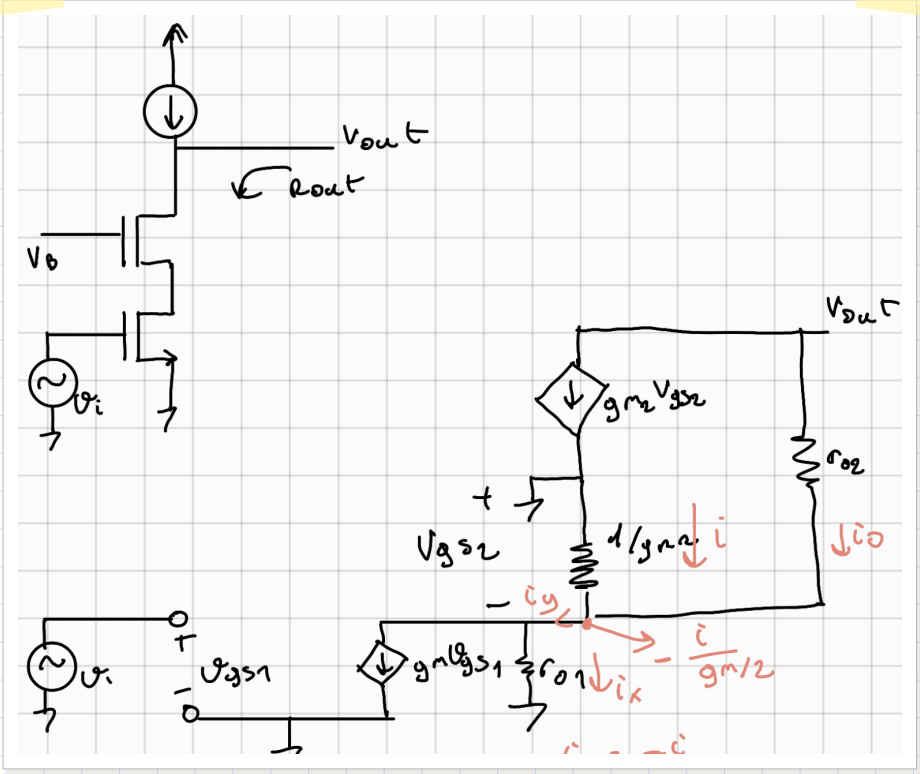
$$I_{ref} = \frac{5-0,7}{R_1} \rightarrow 100k$$

$$I_{ref} = 43\,\mu A$$

orj. s. 7

$$R_2 = \frac{\ln(4,3)\ 25\,mV}{10^{-5}\quad 10^{-2}} \Rightarrow R_2 = 3,6\,k\Omega$$

7.3 The Cascode Amplifier



orijinal çizim, s. 7

$$v_i = V_{gs1}$$

$$i_x = \frac{-i}{r_{o1} g_{m2}}$$

$$i_y = \frac{-i}{r_{o1} g_{m2}} + g_m v_i$$

$$i_o = \frac{-i}{r_{o1} g_{m2}} + g_{m1} v_i - i$$

$$v_{out} = r_{o2} \cdot i_o + \frac{-i}{g_{m2}}$$

$$v_{out} = r_{o2} \left[\frac{-i}{r_{o1} g_{m2}} + g_{m1} v_i - i \right] - \frac{i}{g_{m2}}$$

$$i_o = \frac{V_{out} - r_{o1} i_x}{r_{o2}} = \frac{V_{out} - V_{gs2}}{r_{o2}}$$

orj. s. 8

$$g_{m1} = g_{m2}$$

$$\frac{v_{out}}{v_i} = \frac{r_o \left[\frac{-i}{g_m r_{o1}} + g_m v_i \right] - \frac{i}{g_m}}{v_i}$$

Ödev

$$i_o = \frac{-g_{m2} v_{gs2}}{r_o g_{m2}} + g_{m1} v_i - g_{m2} v_{gs2}$$

$$g_{m1} v_i = i_o + \frac{v_{gs2}}{r_{o2}} + g_{m2} v_{gs2}$$

$$R_o \simeq (g_{m2} r_{o2}) r_{o1}$$

$$A_{vo} = \frac{v_o}{v_i} = -g_{m1} R_o$$

orj. s. 9

$$A_{vo} = -(g_{m1} r_{o1})(g_{m2} r_{o2})$$

For the case $g_{m1} = g_{m2} = g_m$ and $r_{o1} = r_{o2} = r_o$

$$A_{vo} = -$$