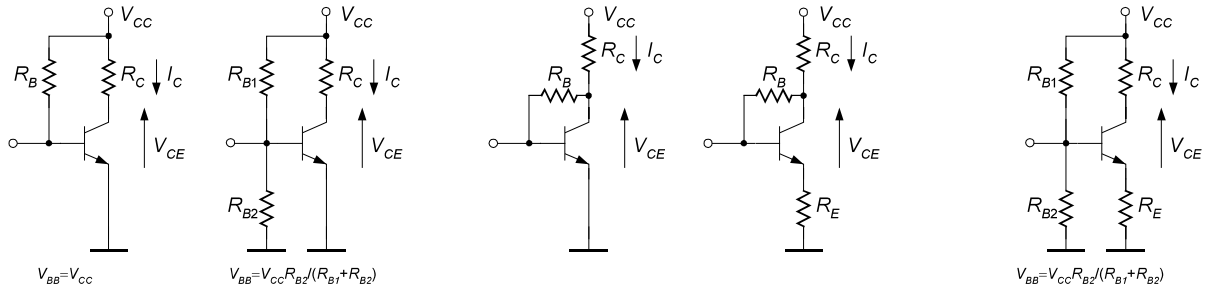
5 ממתח הטרנזיסטור

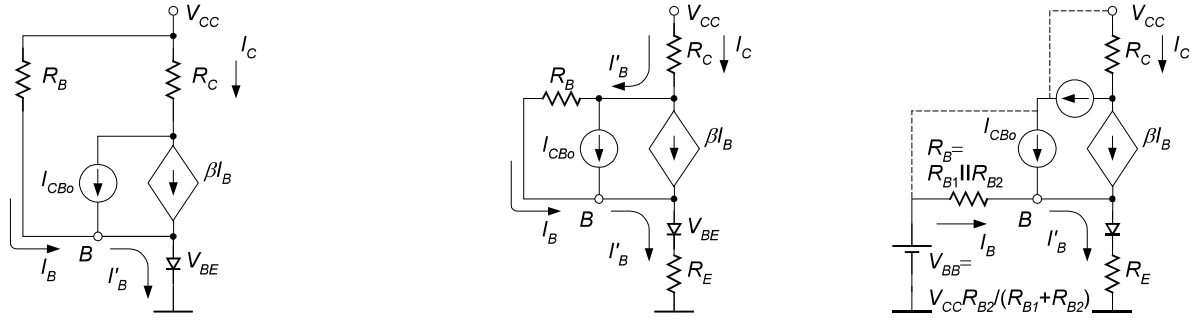
5.1 ממתח בתכנון מעגלים בדידים

5.1.1 סוגים שונים של ממתח

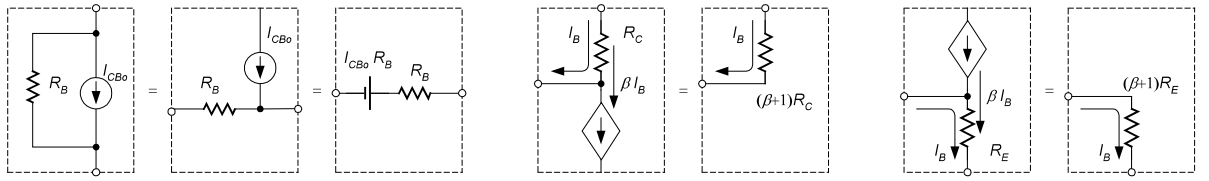
Fixed-bias circuit	Fixed-bias circuit		Self-bias circuit
	with collector feedback	with collector and emitter feedback	



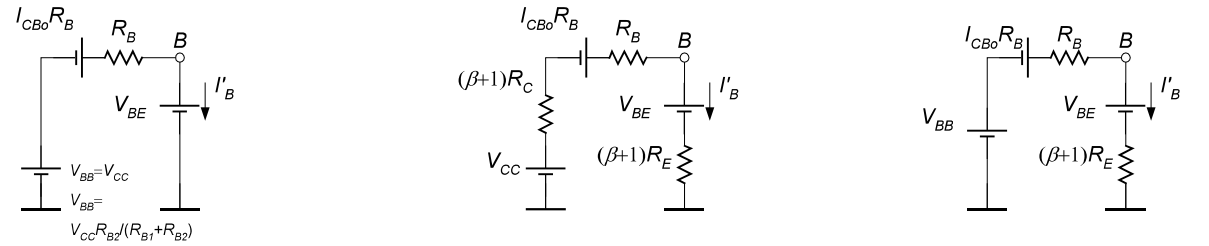
Large signal equivalent circuits



Transformations used to construct equivalent input circuits



Equivalent input circuits



$$I_B = f(I_{CBo}, V_{BE}, \beta)$$

$I'_B = \dfrac{V_{BB} - V_{BE} + I_{CBo}R_B}{R_B}$	$I'_B = \dfrac{V_{BB} - V_{BE} + I_{CBo}R_B}{R_B + (\beta+1)(R_E + R_C)}$	$I'_B = \dfrac{V_{BB} - V_{BE} + I_{CBo}R_B}{R_B + (\beta+1)R_E}$

$$I_C = \beta I'_B + I_{CBo} \quad \Rightarrow \quad I_C = f(I_{CBo}, V_{BE}, \beta)$$

חישוב זרם הקולקטור כפונקציה של β, V_{BE}, I_{CBo} עבור מעגל ממתח עצמי.

$$I_C = \beta\, I'_B + I_{CBo} = \frac{\beta(V_{BB} - V_{BE}) + I_{CBo}(\beta+1)(R_B + R_E)}{R_B + (\beta+1)R_E}$$

$$\Delta I_C = f(\Delta I_{CBo},\, \Delta V_{BE}, \Delta\beta)$$

$$\Delta I_{CBo} \approx \times 2 \,/\, 10^{\circ}\,\mathrm{C}$$

$$\Delta V_{BE} \approx -2.5\,\mathrm{mV} \,/\, ^{\circ}\,\mathrm{C}$$

$$\Delta\beta \approx 0.1 - 0.3\,\% \,/\, ^{\circ}\,\mathrm{C}; \qquad \Delta\beta_{specimen} = 500...1000\%$$

5.1.2 יציבות של ממתח (יציבות של I_C)

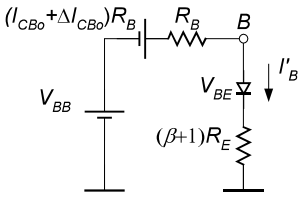
$$\Delta I_C = \frac{\partial I_C}{\partial I_{CBo}}\Delta I_{CBo} + \frac{\partial I_C}{\partial V_{BE}}\Delta V_{BE} + \frac{\partial I_C}{\partial \beta}\Delta\beta \quad = \quad S_{I_{CBo}}\Delta I_{CBo} + S_{V_{BE}}\Delta V_{BE} + S_\beta \Delta\beta$$

◄ S_i – גורמי היציבות עבור מעגל ממתח עצמי.

$S_{I_{CBo}}$

$R_B \downarrow \Rightarrow S_{I_{CBo}} \downarrow$

$R_E \uparrow \Rightarrow S_{I_{CBo}} \downarrow$



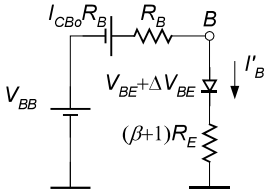
$$S_{I_{CBo}} = \frac{(\beta+1)(R_B + R_E)}{R_B + (\beta+1)R_E}$$

$$S_{I_{CBo}\max} = S_{I_{CBo}}\Big|_{R_E \to 0} = \frac{(\beta+1)R_B}{R_B} = (\beta+1)$$

$$S_{I_{CBo}\min} = S_{I_{CBo}}\Big|_{R_B << R_E} = \frac{(\beta+1)R_E}{(\beta+1)R_E} = 1$$

$S_{V_{BE}}$

$R_E \uparrow \Rightarrow S_{V_{BE}} \downarrow$

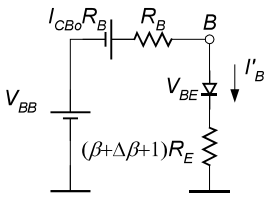


$$S_{V_{BE}} = \frac{-\beta}{R_B + (\beta+1)R_E} \approx \frac{-1}{R_B/\beta + R_E}$$

$$\underbrace{S_{V_{BE}}}_{<0}\,\underbrace{\Delta V_{BE}}_{<0} > 0\ !$$

S_β

$\beta \uparrow, R_E \uparrow \Rightarrow S \downarrow$



$$S_\beta = \frac{(V_{BB} - V_{BE} + I_{CBo}R_B)(R_B + R_E)}{\left[R_B + (\beta+1)R_E\right]^2}$$

שינוי יחסי של I_C כתלות בשינוי יחסי של-β

$$\Delta I_{C\,\beta} = S_\beta \Delta\beta\Big|_{I_{CBo}R_B\to 0} \approx \frac{V_{BB}-V_{BE}}{R_B+(\beta+1)R_E}\frac{R_B+R_E}{R_B+(\beta+1)R_E}\Delta\beta \approx I_B\frac{R_B+R_E}{R_B+(\beta+1)R_E}\Delta\beta$$

$$\approx \frac{I_C}{\beta}\frac{R_B+R_E}{R_B+(\beta+1)R_E}\Delta\beta \qquad \Rightarrow$$

$$\boxed{\frac{\Delta I_C}{I_C} \approx \frac{\Delta\beta}{\beta}\frac{R_B+R_E}{R_B+(\beta+1)R_E}\Big|_{R_B<<R_E} \approx \frac{\Delta\beta}{\beta}\frac{1}{\beta}}$$

$$\boxed{\frac{\Delta I_C}{I_C}\Big|_{R_B<<R_E}\times 100\% \approx \frac{\Delta\beta}{\beta}\frac{1}{\beta}\times 100\%}$$

לדוגמה: כאשר $R_B << R_E$, אזי שינוי של 100% ב- 100=β גורם לשינוי I_C רק ב 1%.

סיכום:

S	Fixed-bias circuit	Fixed-bias circuit		Self-bias circuit
		with collector feedback	with collector and emitter feedback	
$S_{I_{CBo}}$	$\beta+1$	$\frac{(\beta+1)(R_B+R_C)}{R_B+(\beta+1)R_C}$	$\frac{(\beta+1)(R_B+R_C+R_E)}{R_B+(\beta+1)(R_C+R_E)}$	$\frac{(\beta+1)(R_B+R_E)}{R_B+(\beta+1)R_E}$
$S_{V_{BE}}$	$-\frac{\beta}{R_B}$	$\frac{-\beta}{R_B+(\beta+1)R_C}$	$\frac{-\beta}{R_B+(\beta+1)(R_C+R_E)}$	$\frac{-\beta}{R_B+(\beta+1)R_E}$
S_β	$\frac{V_{CC}-V_{BE}}{R_B}$	$\frac{(V_{BB}-V_{BE})(R_B+R_C)}{[R_B+(\beta+1)R_C]^2}$	$\frac{(V_{BB}-V_{BE})(R_B+R_C+R_E)}{[R_B+(\beta+1)(R_C+R_E)]^2}$	$\frac{(V_{BB}-V_{BE})(R_B+R_E)}{[R_B+(\beta+1)R_E]^2}$
$S_{\beta\,specimen}$	$\frac{\Delta I_C}{I_C}=\frac{\Delta\beta}{\beta}$	$\frac{(V_{BB}-V_{BE})(R_B+R_C)}{([R_B+(\beta_1+1)R_C]\times[R_B+(\beta_2+1)R_C])}$	$\frac{(V_{BB}-V_{BE})(R_B+R_C+R_E)}{([R_B+(\beta_1+1)(R_C+R_E)]\times[R_B+(\beta_2+1)(R_C+R_E)])}$	$\frac{(V_{BB}-V_{BE})(R_B+R_E)}{([R_B+(\beta_1+1)R_E]\times[R_B+(\beta_2+1)R_E])}$

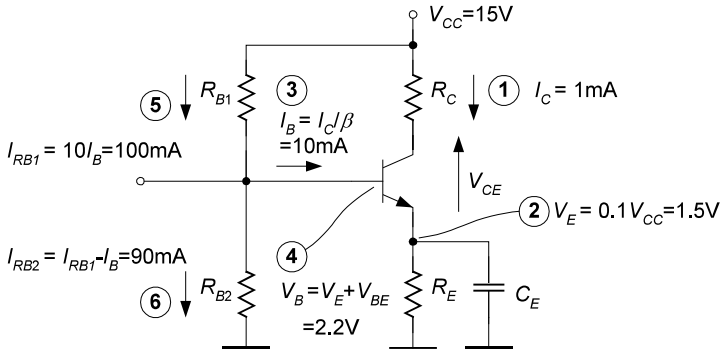
5.1.3 שקולי התכנון לבחירת R_E ו- R_B

$$1)\quad I_E R_E \approx 0.1\ V_{CC}$$

$$2)\quad R_B \le 0.1(\beta+1)R_E$$

$$\Rightarrow I_{R_{B1}} \approx I_{R_{B2}} \approx 10 \cdot I_B$$

<u>דוגמה מספרית</u>



β= 100

I_C= 1mA

$V_{CE} = V_{RC} = (V_{CC}-V_E)/2$

R_{B1}= ?

R_{B2}= ?

R_E= ?

R_C= ?

(7) $R_{B1} = (V_{CC}-V_B)/\ I_{RB1}$=(15-2.2)/100mA=128k

(8) $R_{B2} = V_B/\ I_{RB2}$=2.2/90mA=24.4k

(9) $R_E = V_E/\ I_C$=1.5/1mA=1.5k

(10) $R_C = [(V_{CC}-V_E)/2]/\ I_C$=[(15-1.5)/2]/1mA=6.75k