

Inductieve relaxatieoscillator

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Opdracht

Opdracht: ontwerp een inductieve relaxatieoscillator

Defenitie relaxatieoscillator

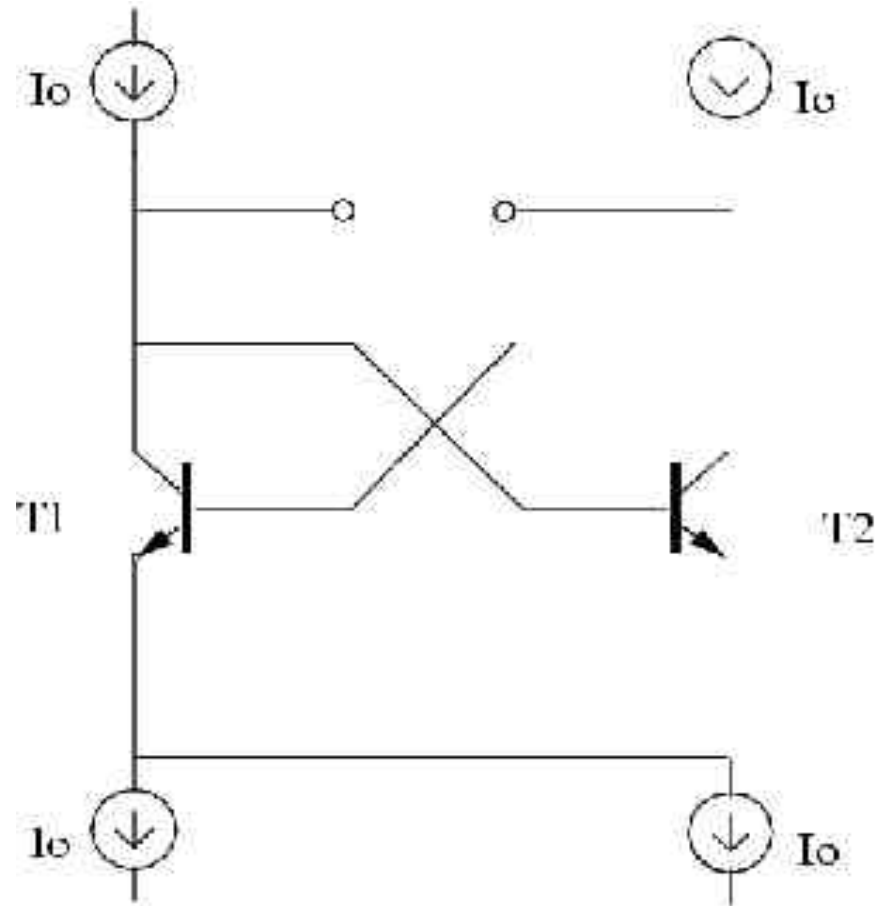
**Er bestaan twee typen oscillatoren:
relaxatieoscillator en harmonische oscillator**

- Relaxatieoscillator: één energieresevoir die telkens op- en ontladen wordt dmv van een actief circuit met referentieinstellingen
- Harmonische oscillator: twee of meerdere energieresevoirs die energie met elkaar uitwisselen, actief circuit alleen voor verliescompensatie

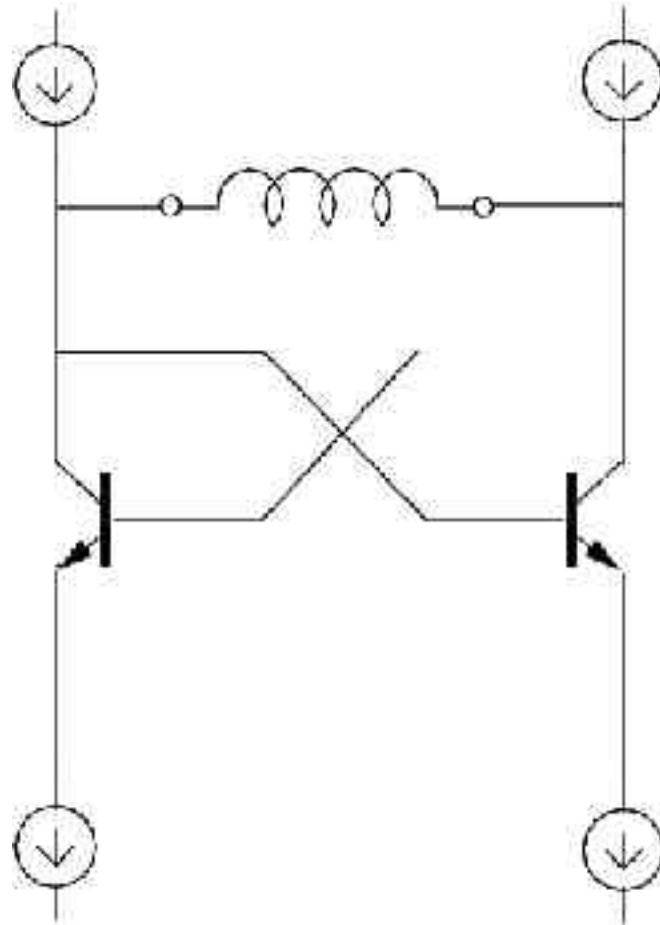
Specificaties oscillator

- **Spoel van $680\mu\text{H}$**
- Frequentie 50kHz
- Voedingsspanning 5V
- Minimaal vermogensgebruik
- **Gebaseerd op twee-transistor
balansschakeling**

Twée-transistor balansschakeling



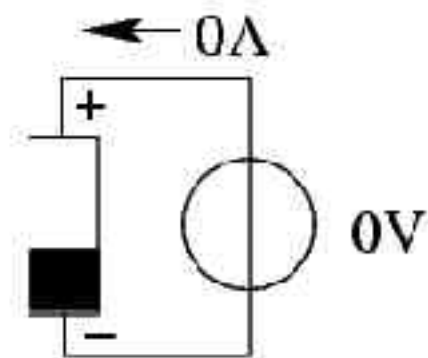
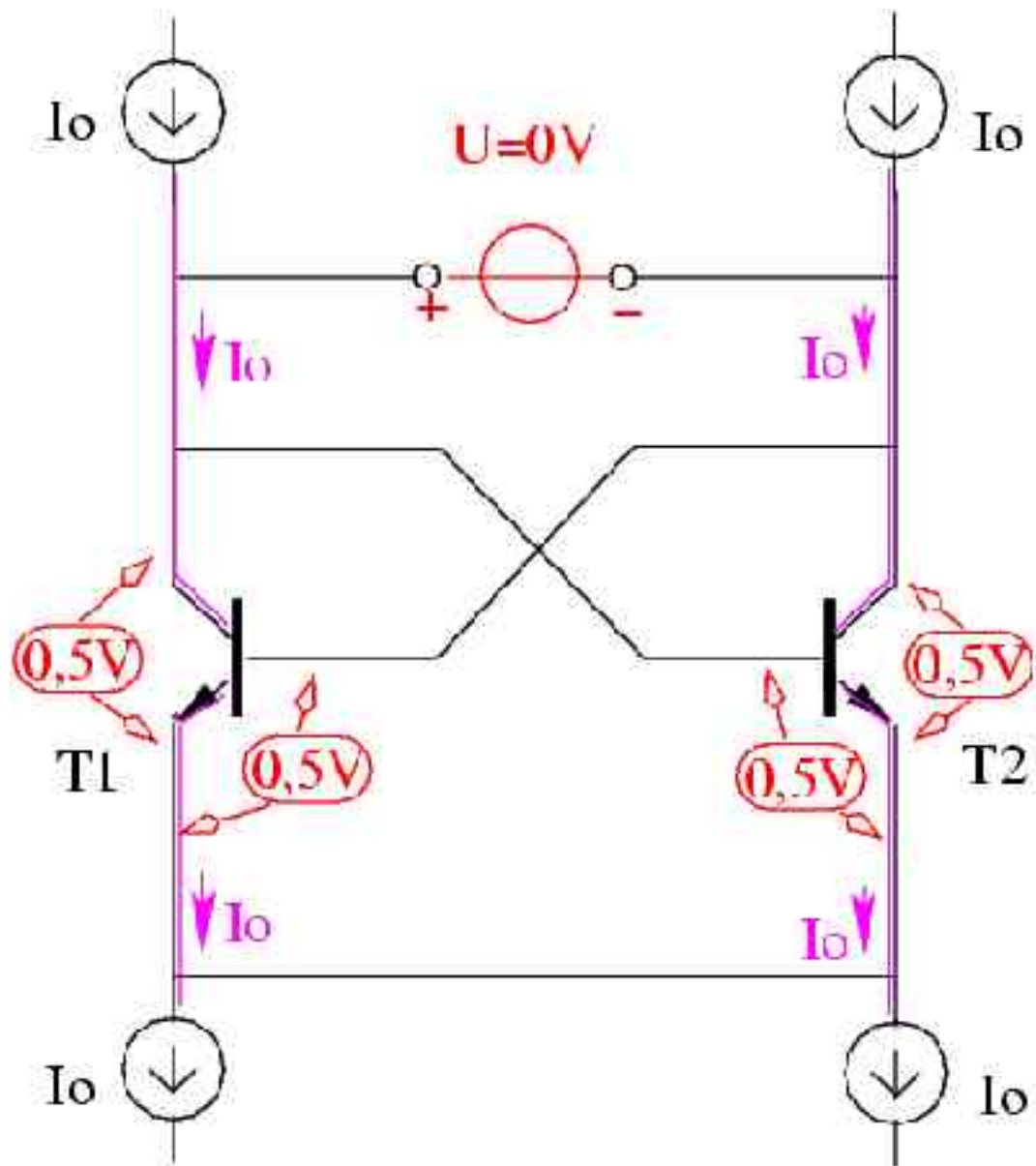
Twée-transistor balansschakeling

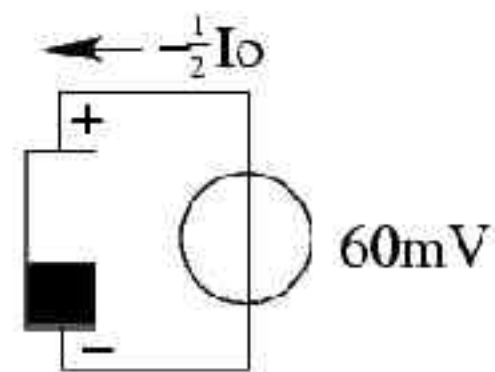
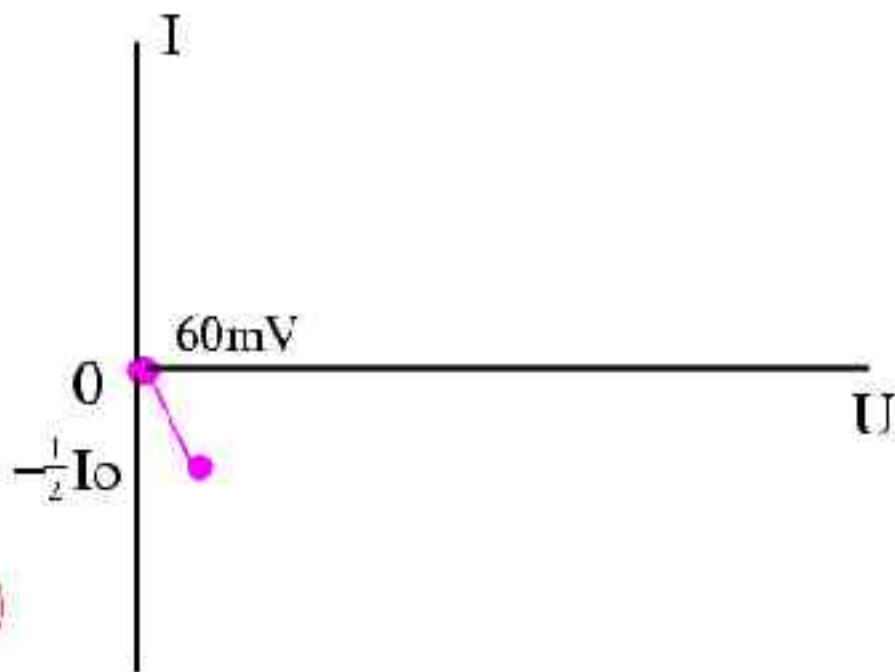
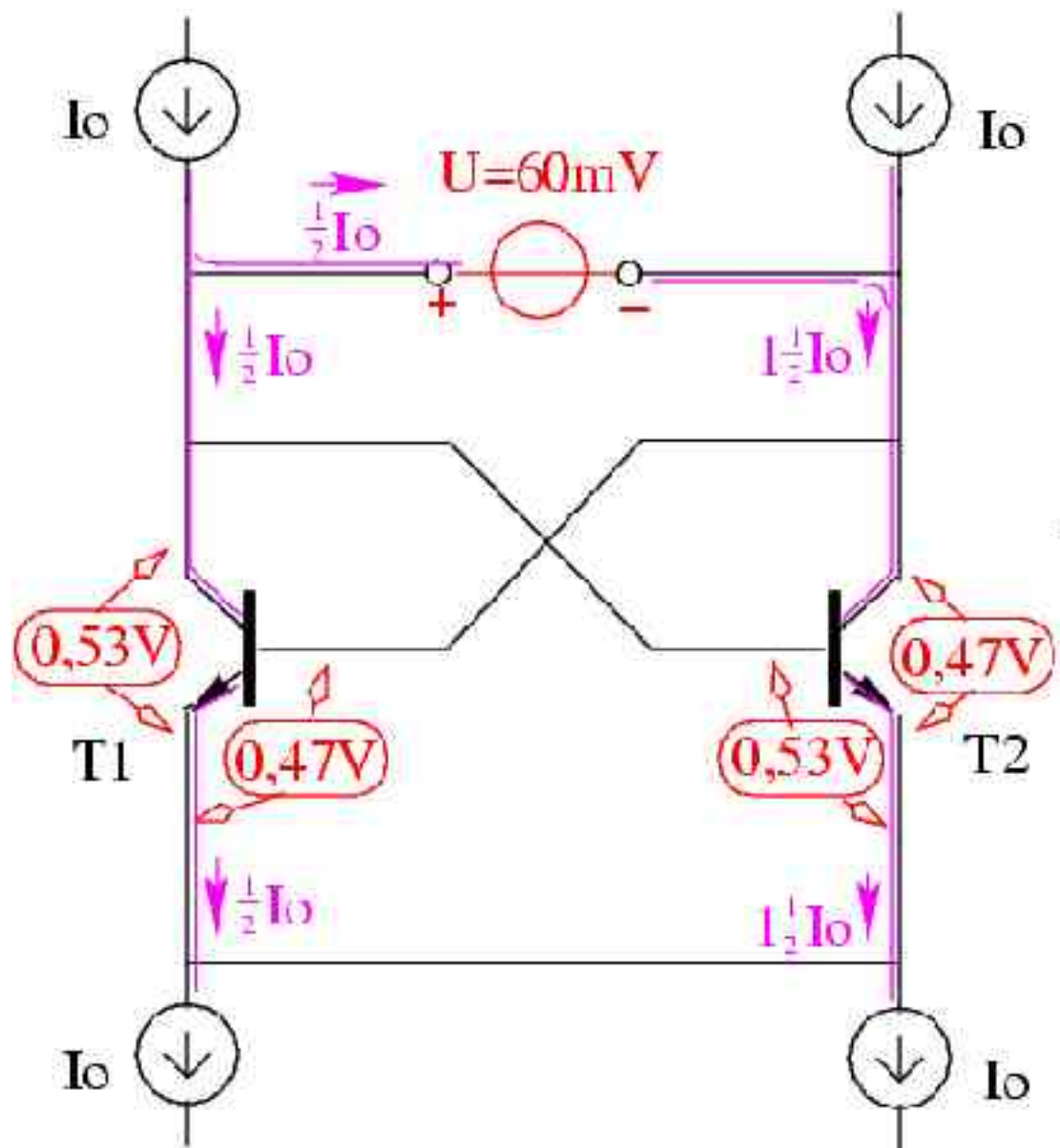


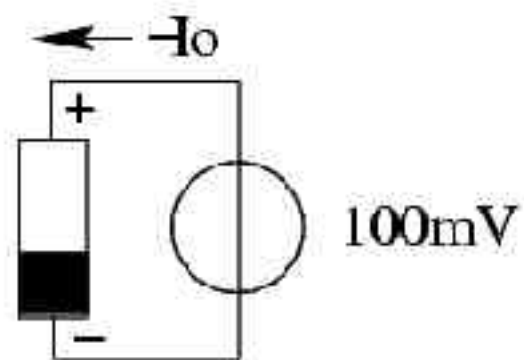
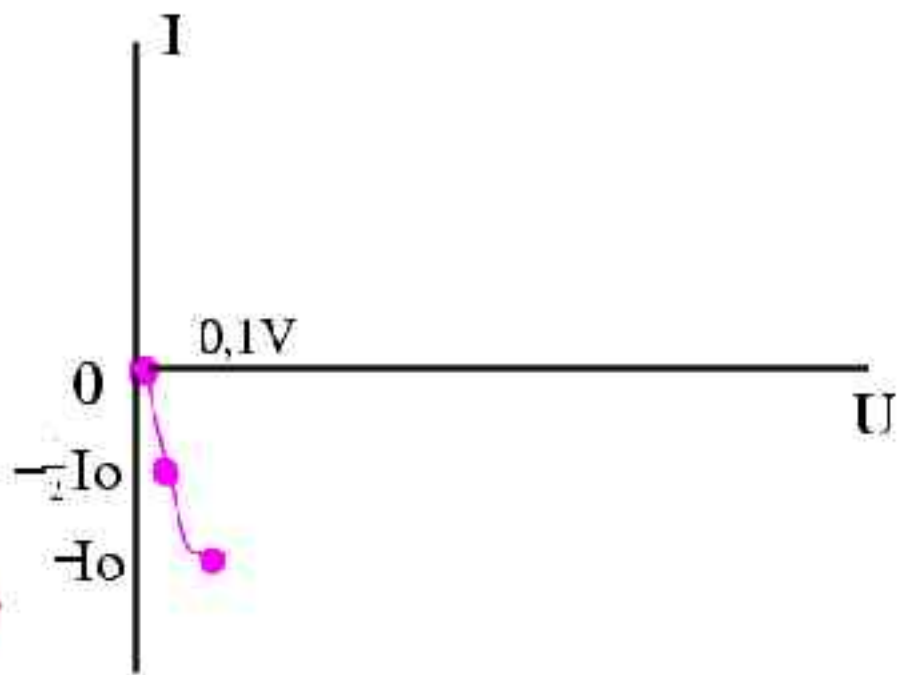
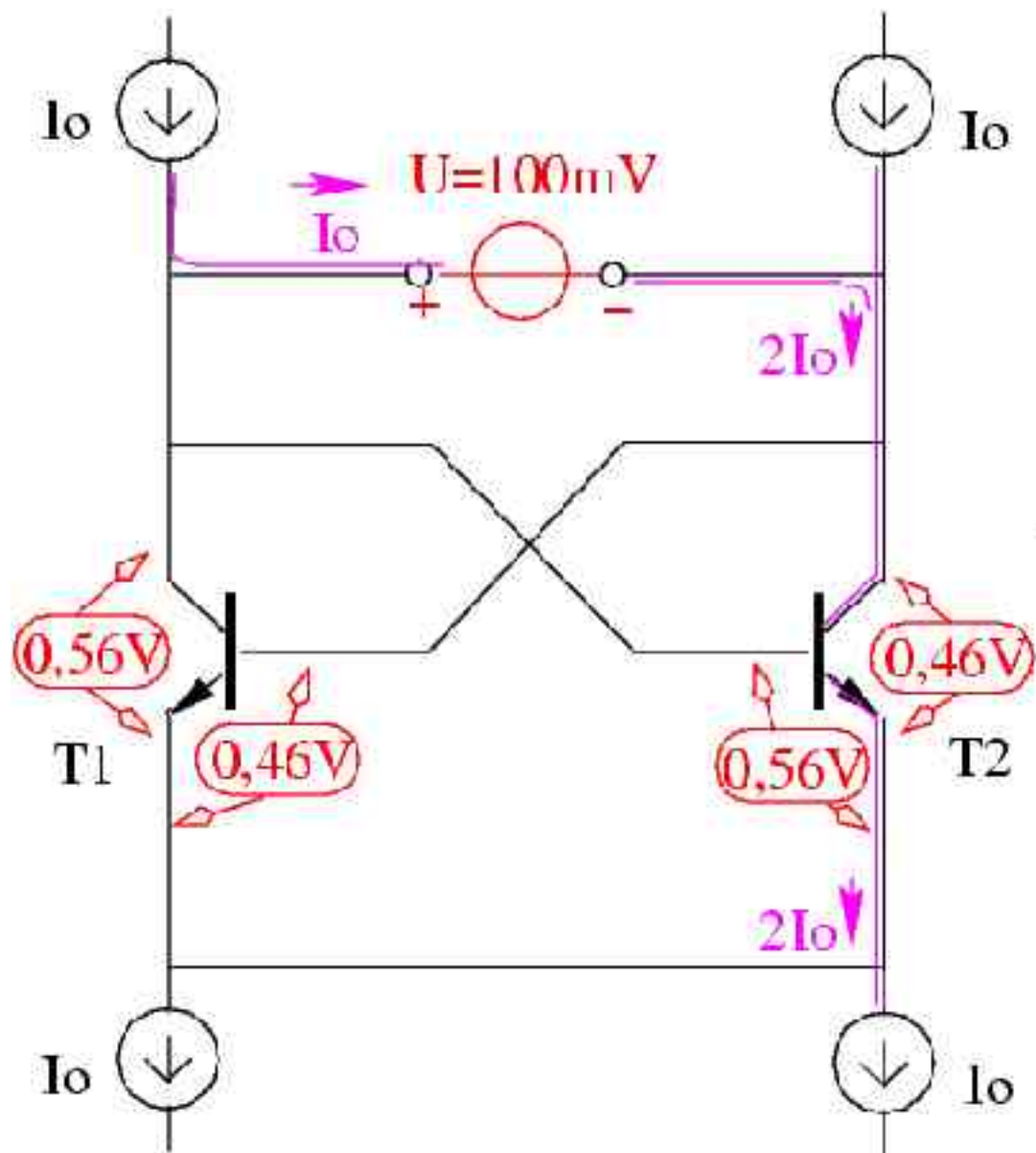
Twee-transistor balansschakeling

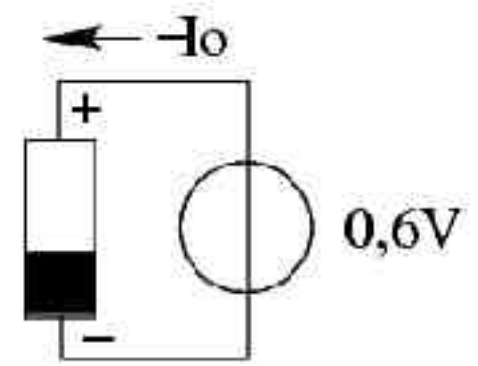
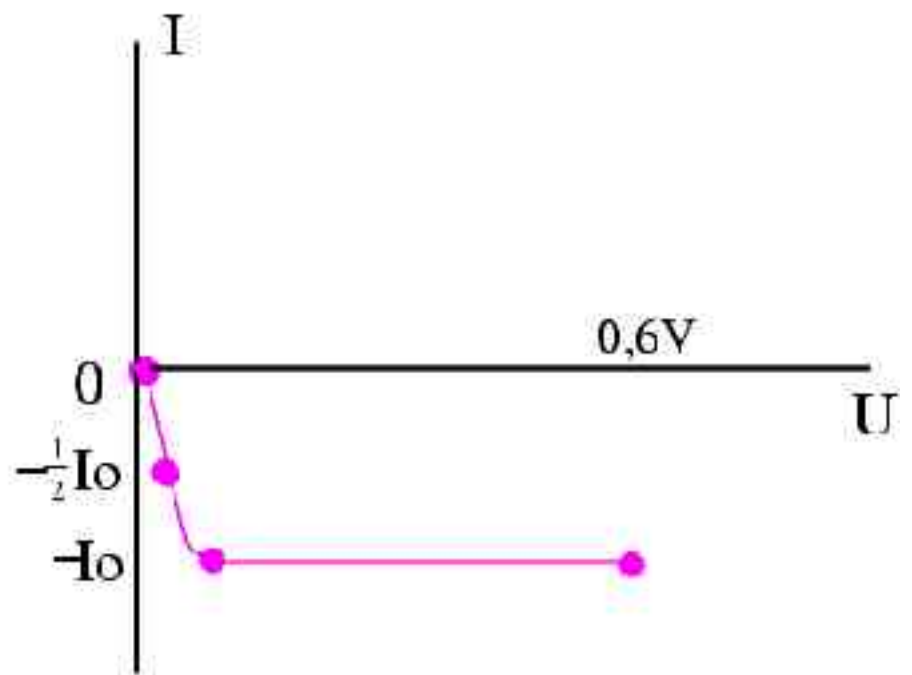
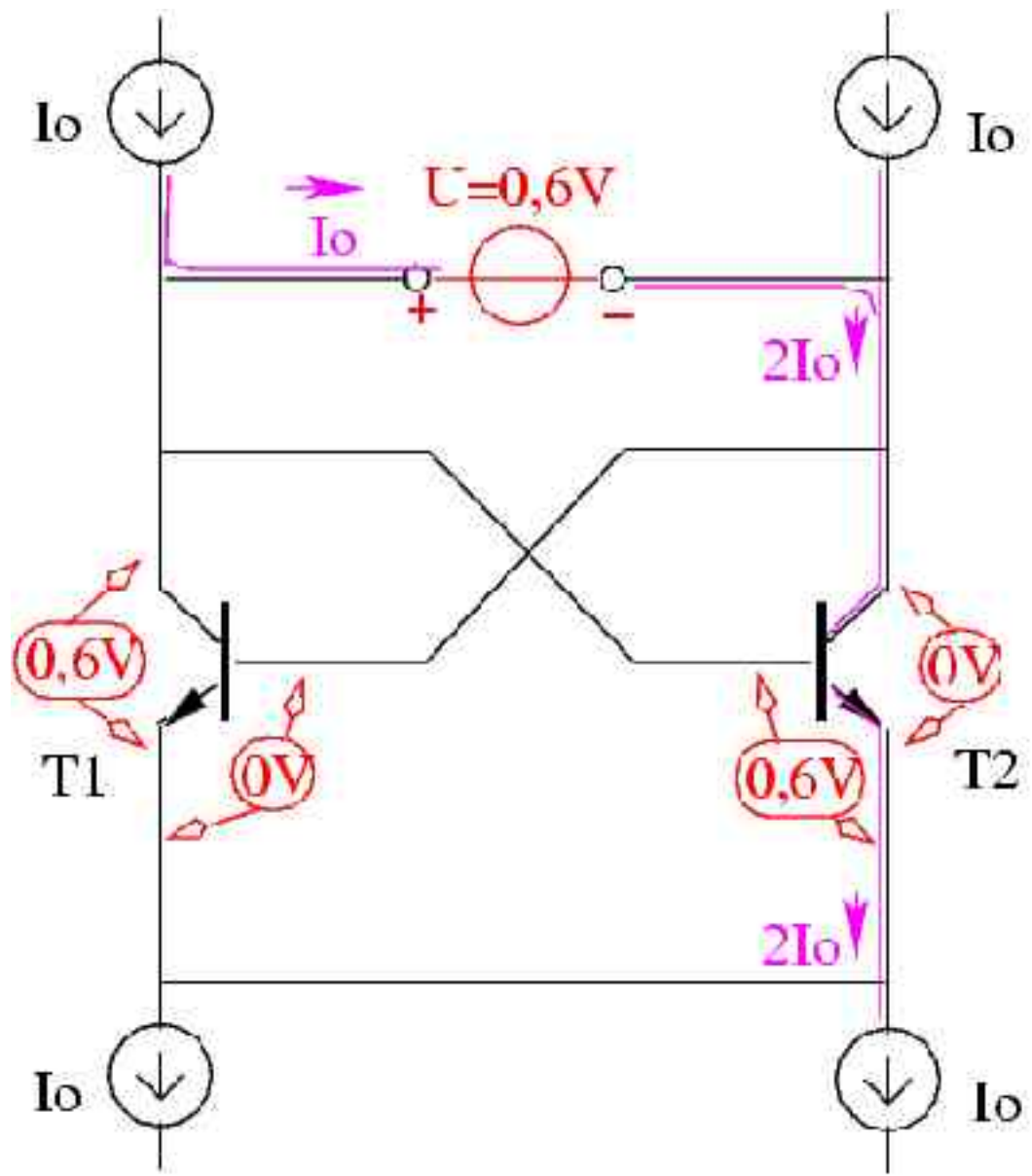
Hoe werkt deze schakeling?

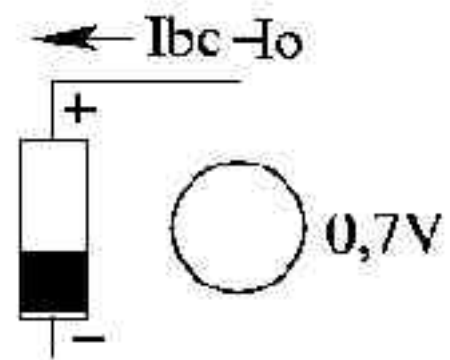
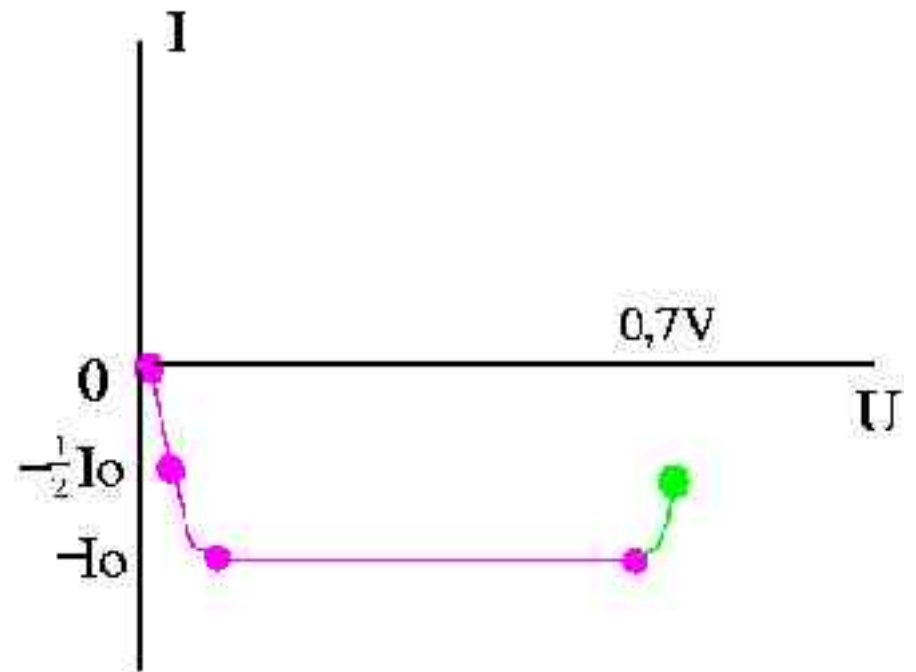
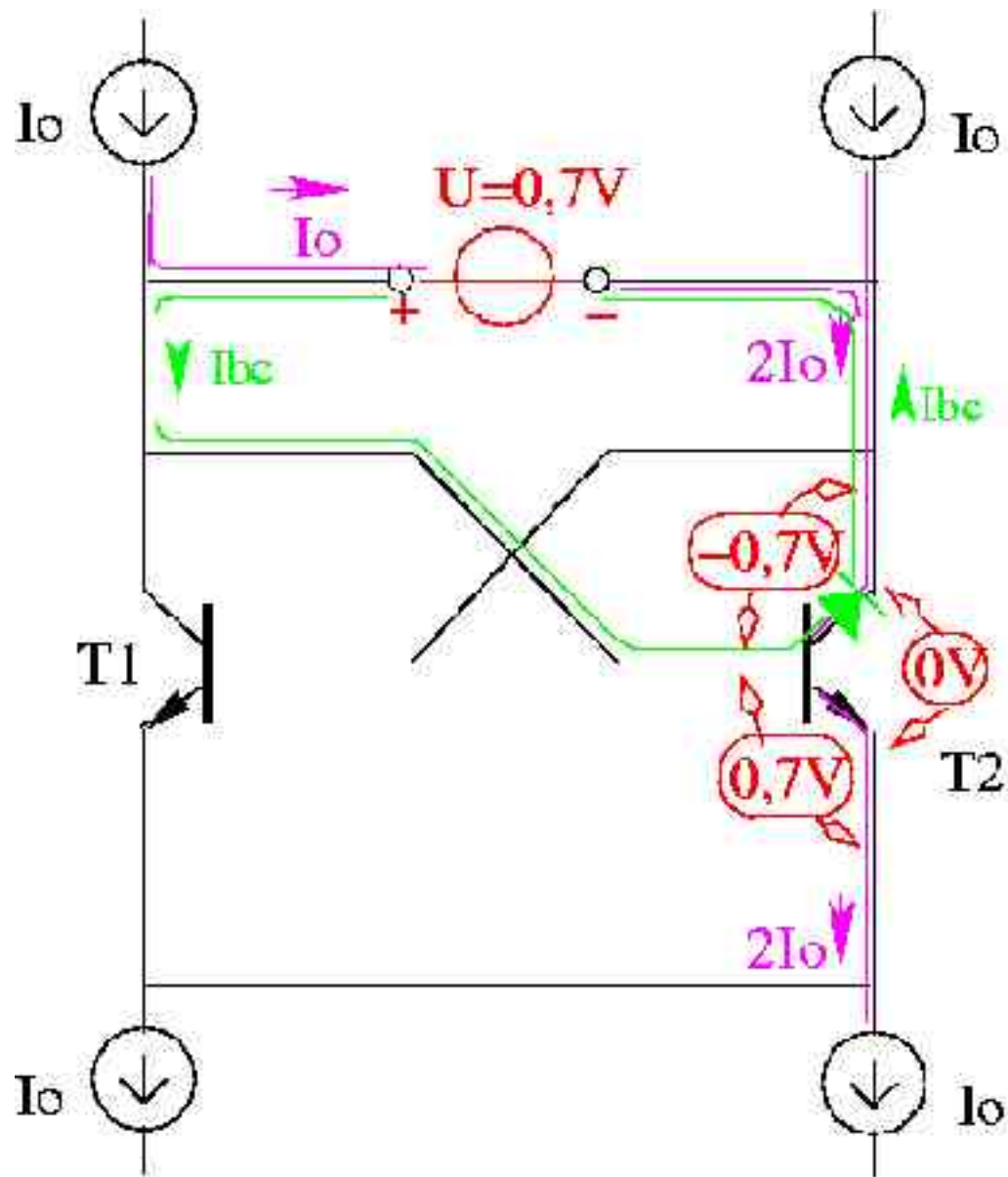
Wat is de UI karakteristiek aan de twee klemmen?

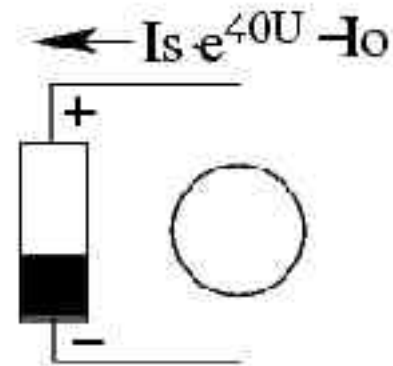
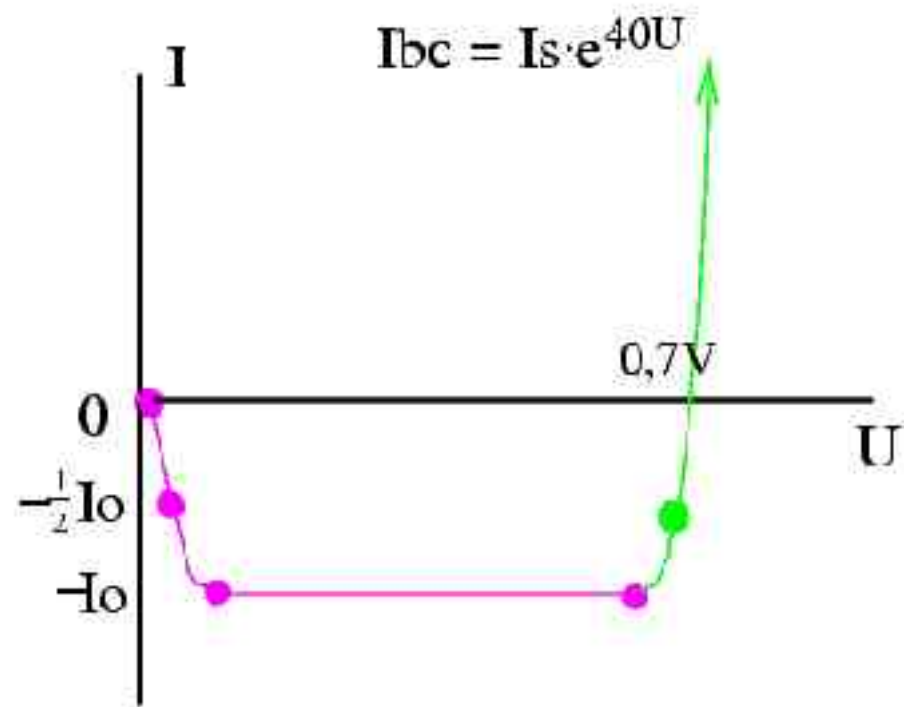
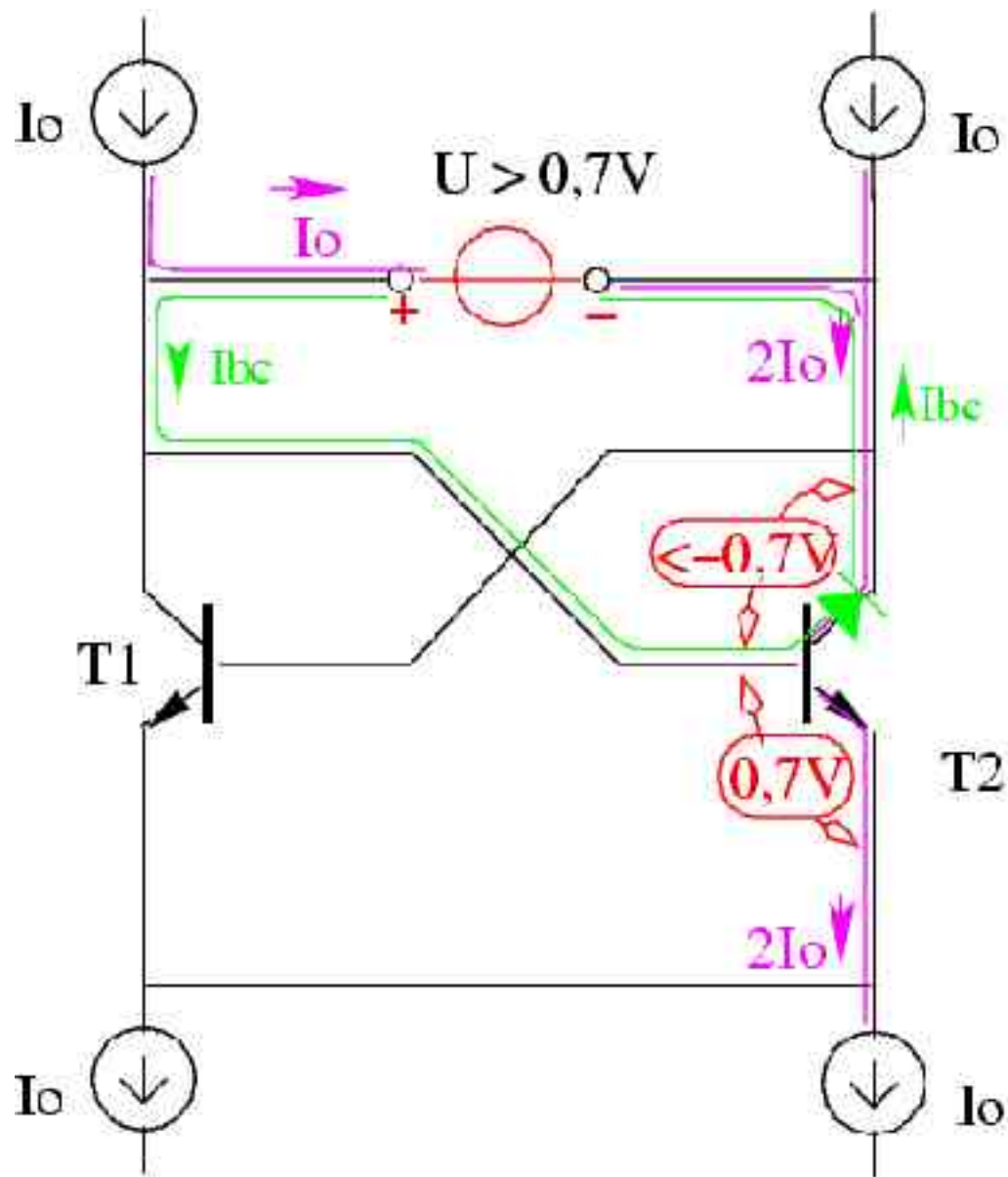




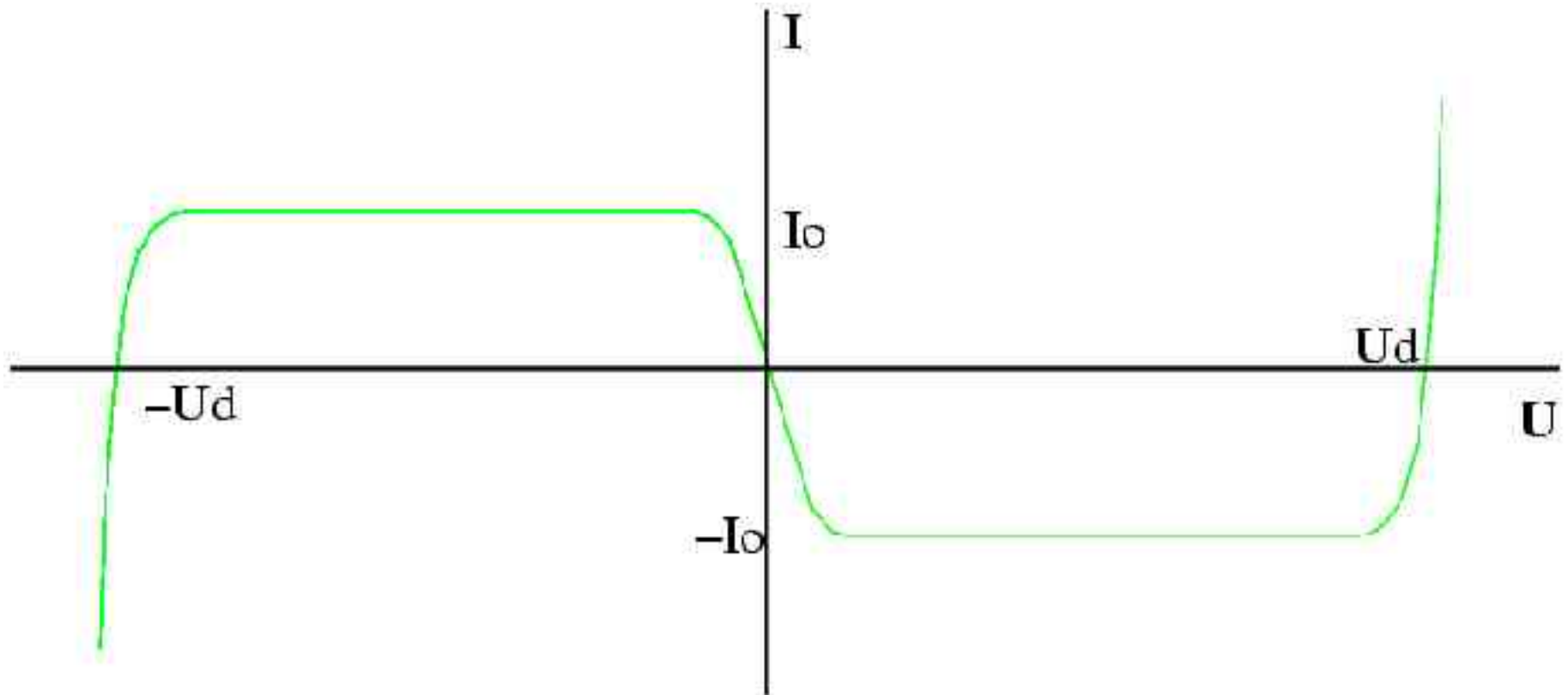




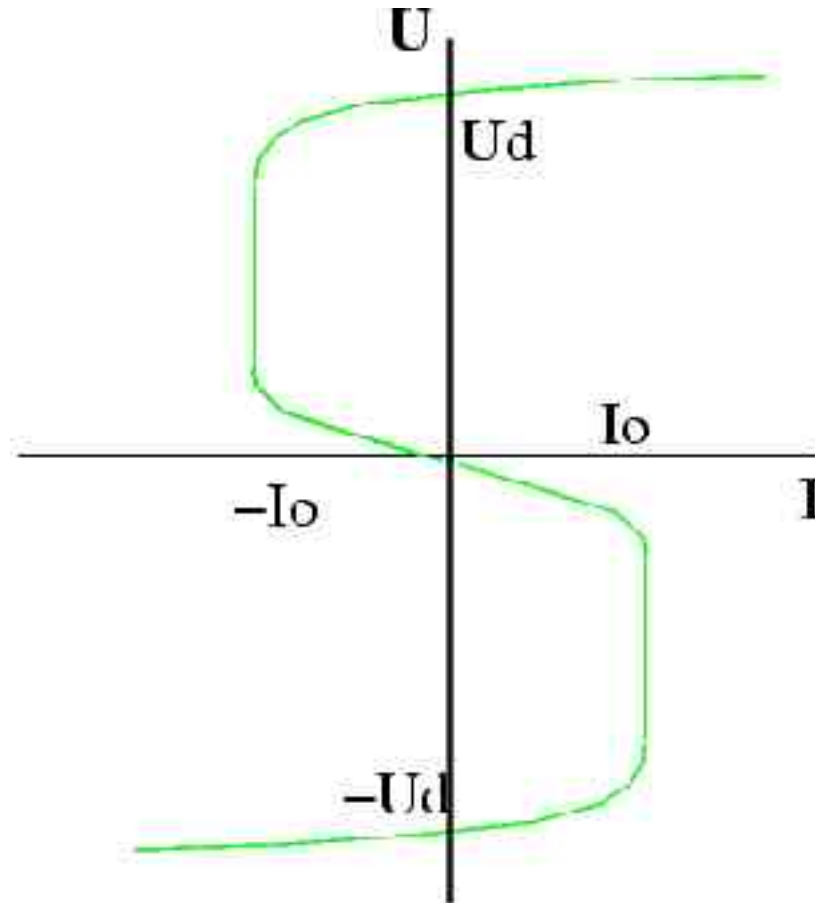




Balansschakeling: UI grafiek

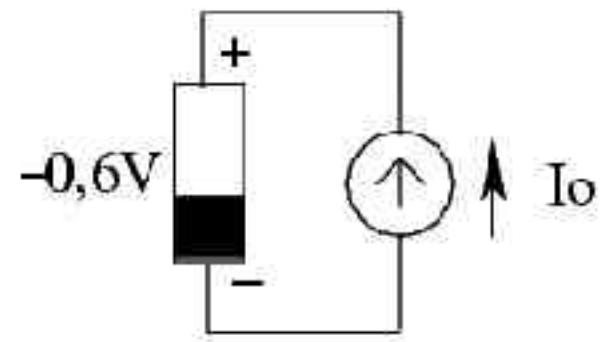
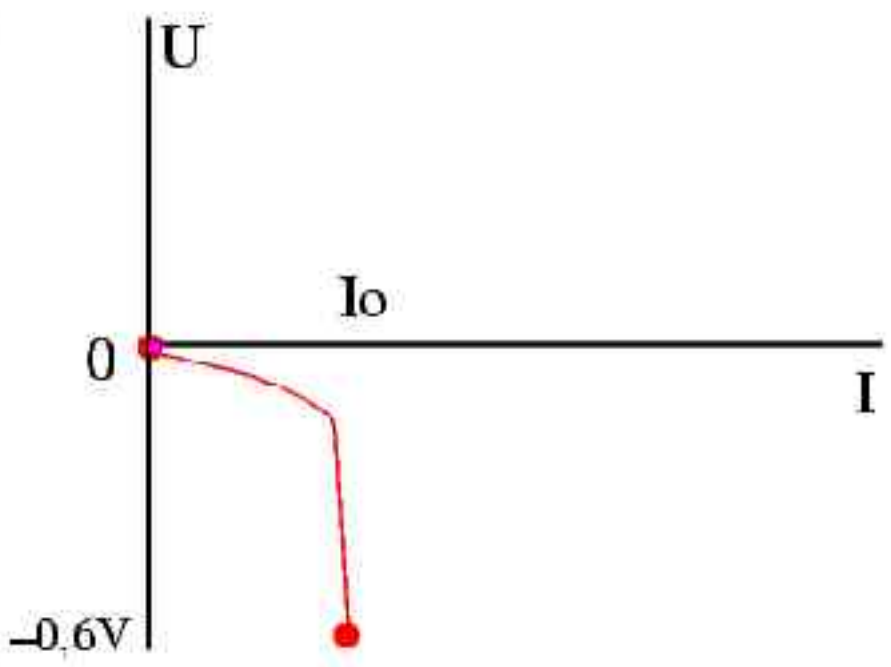
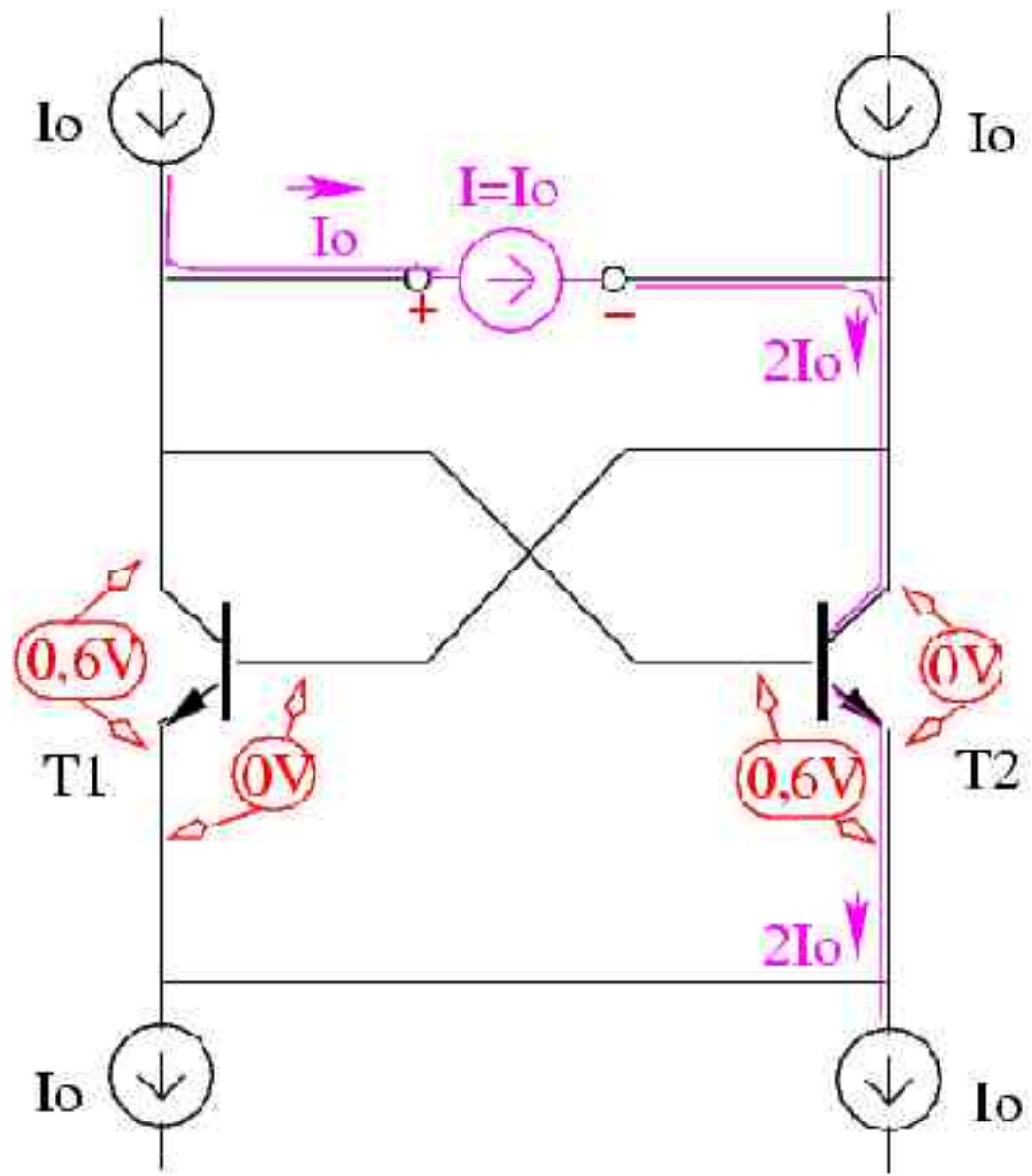


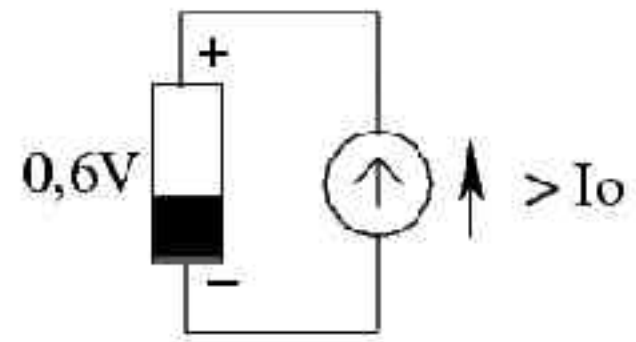
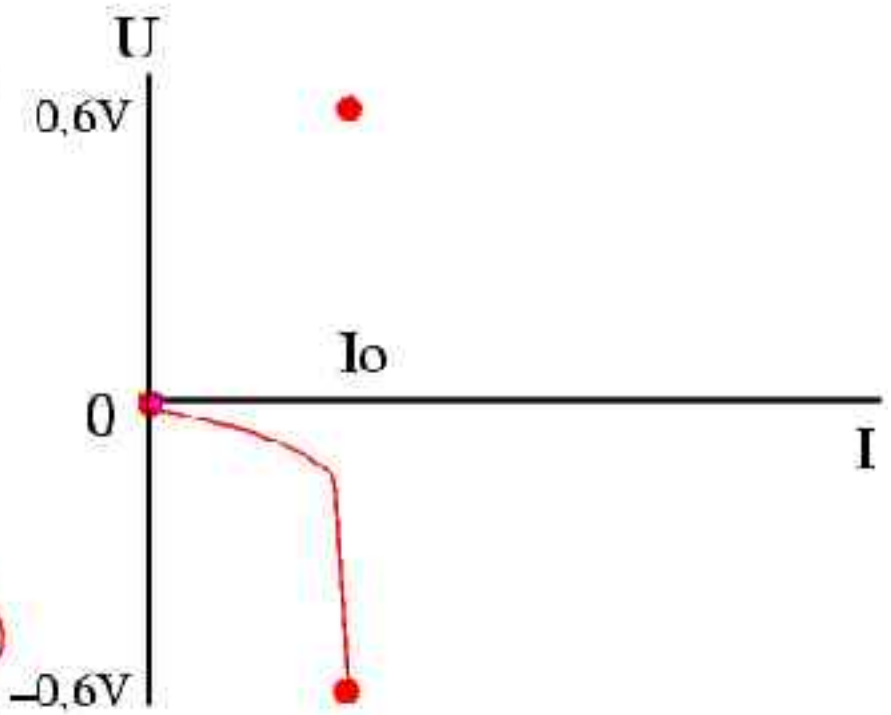
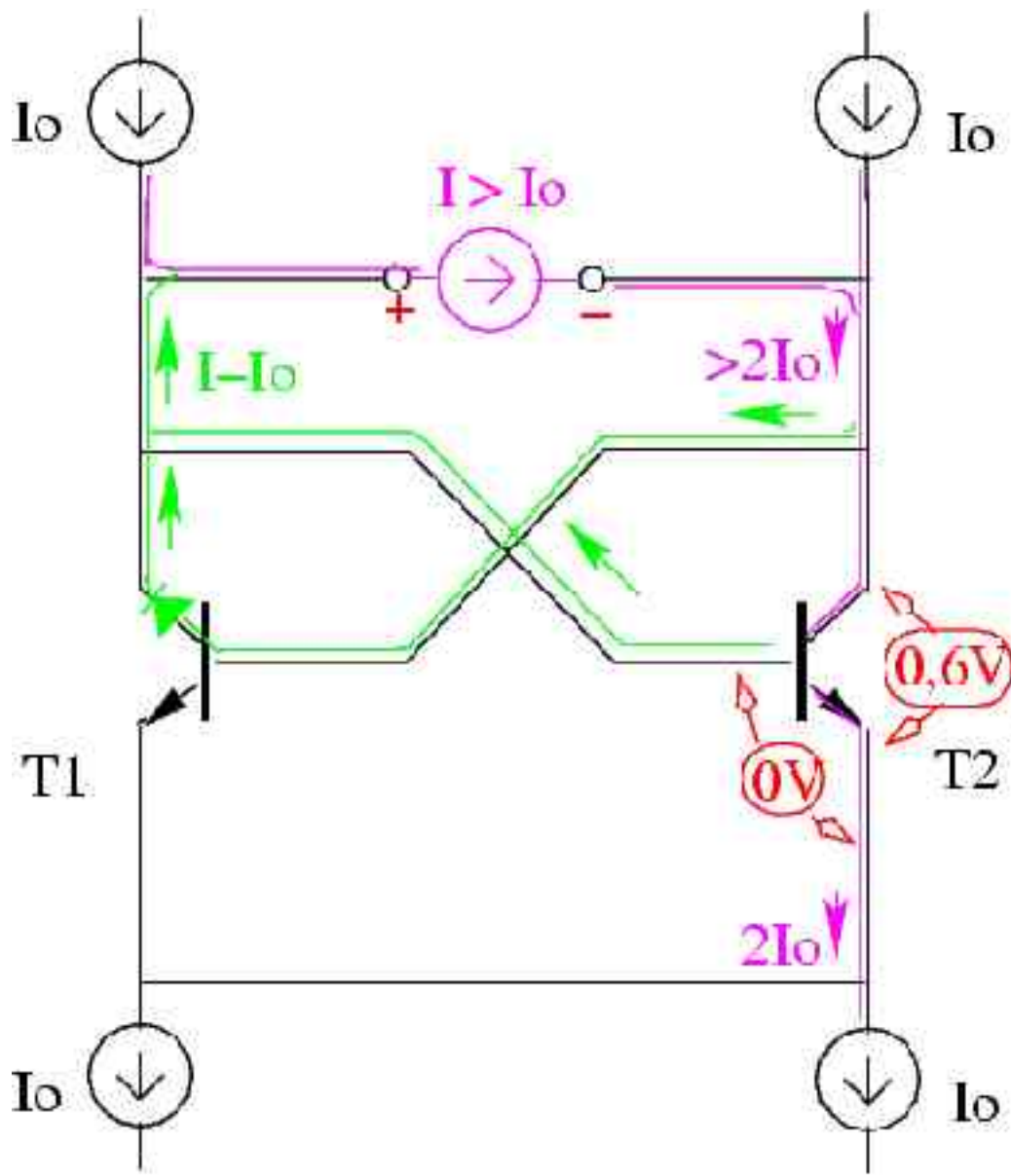
Balansschakeling: IU grafiek

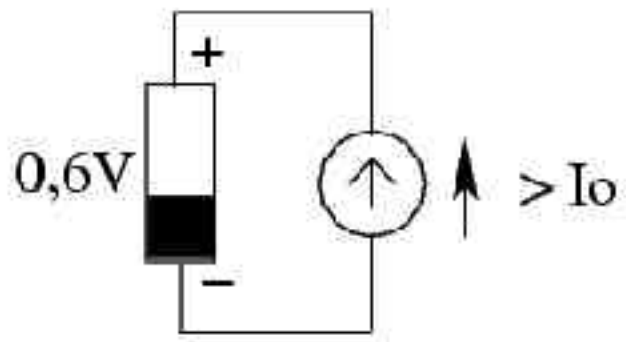
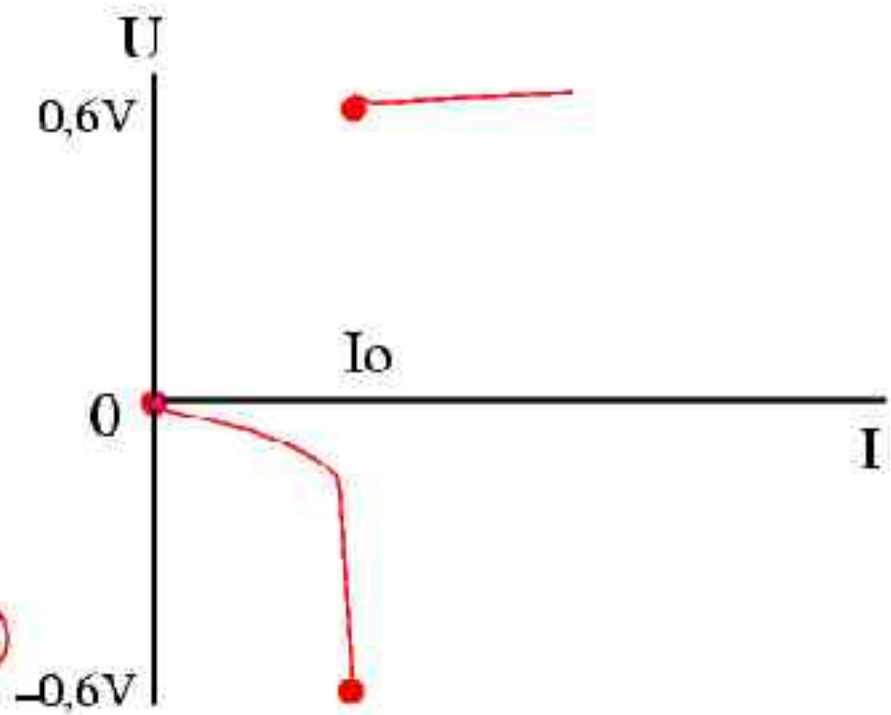
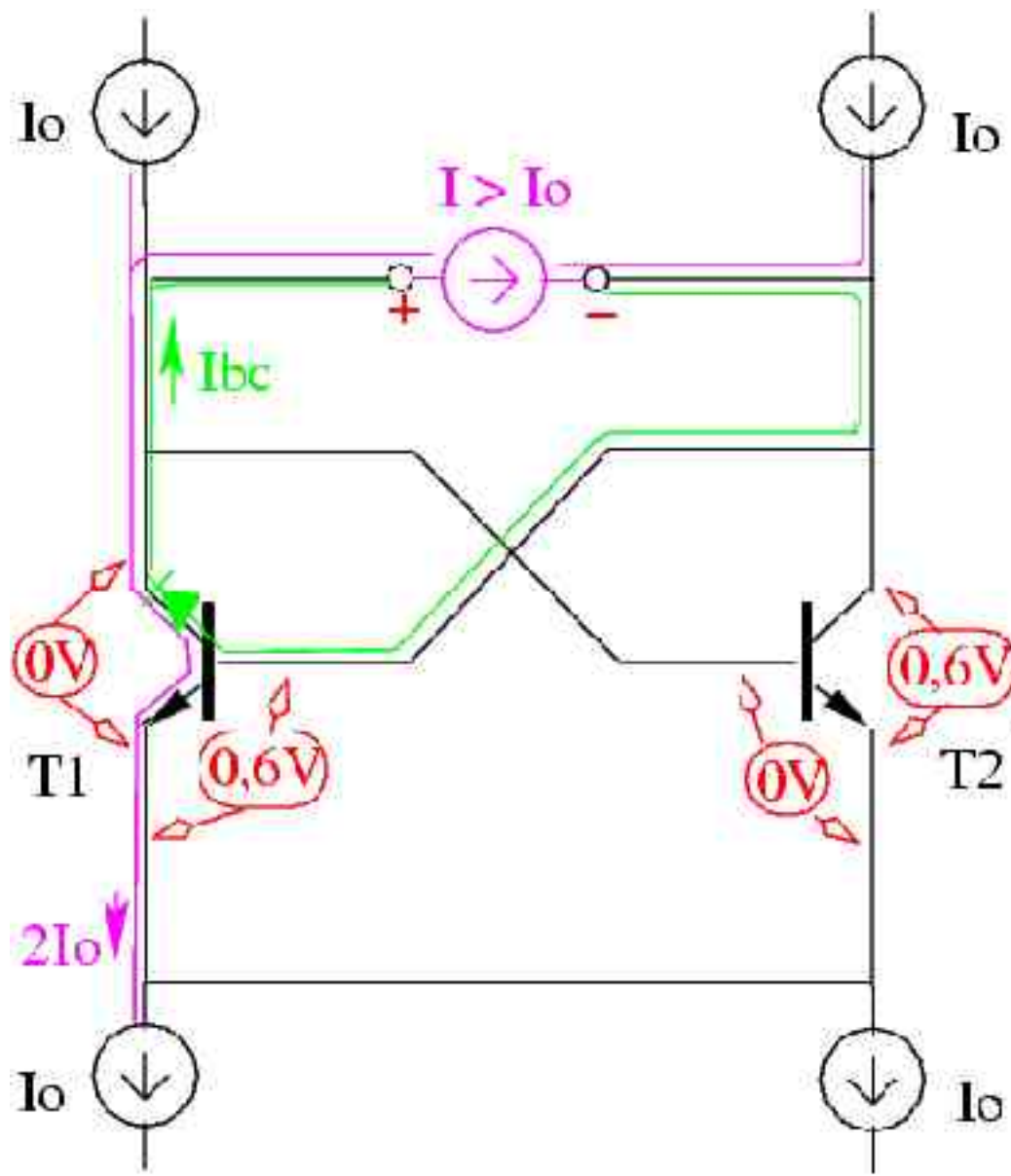


Balansschakeling: stroomgestuurd

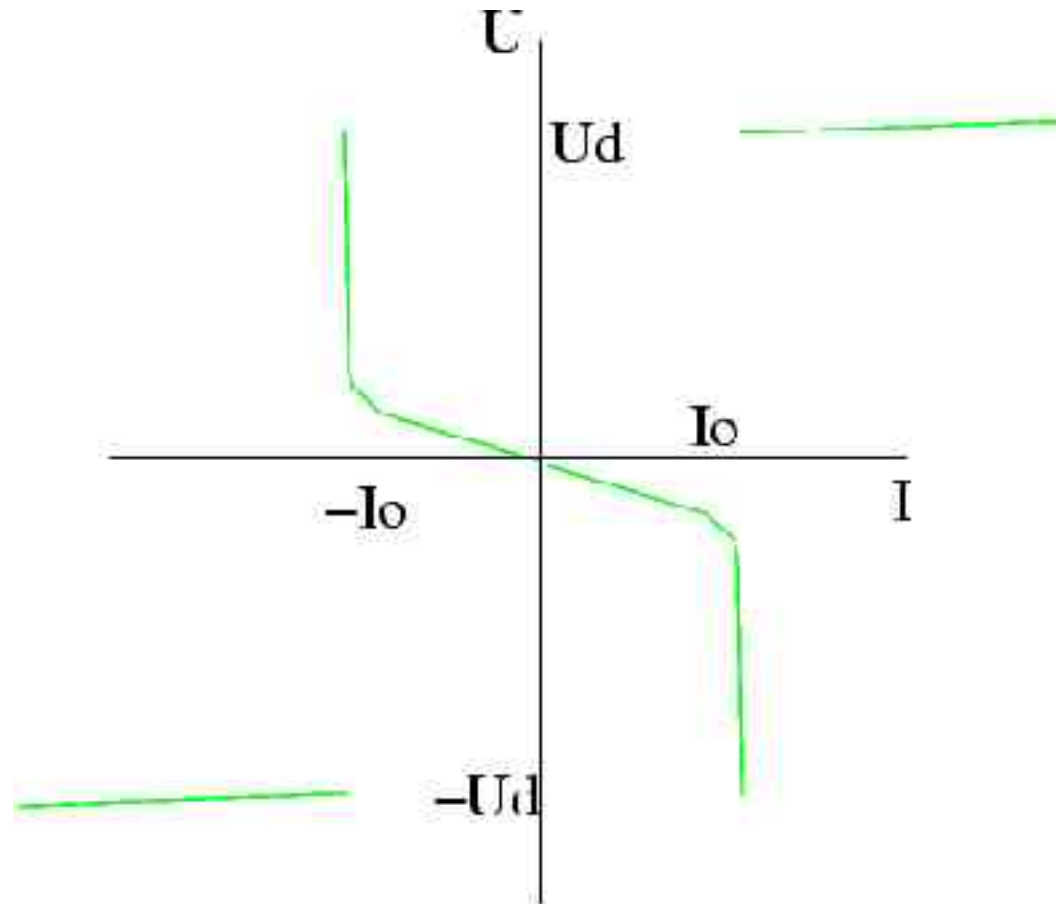
Welke karakteristiek krijgen we met een stroombron?



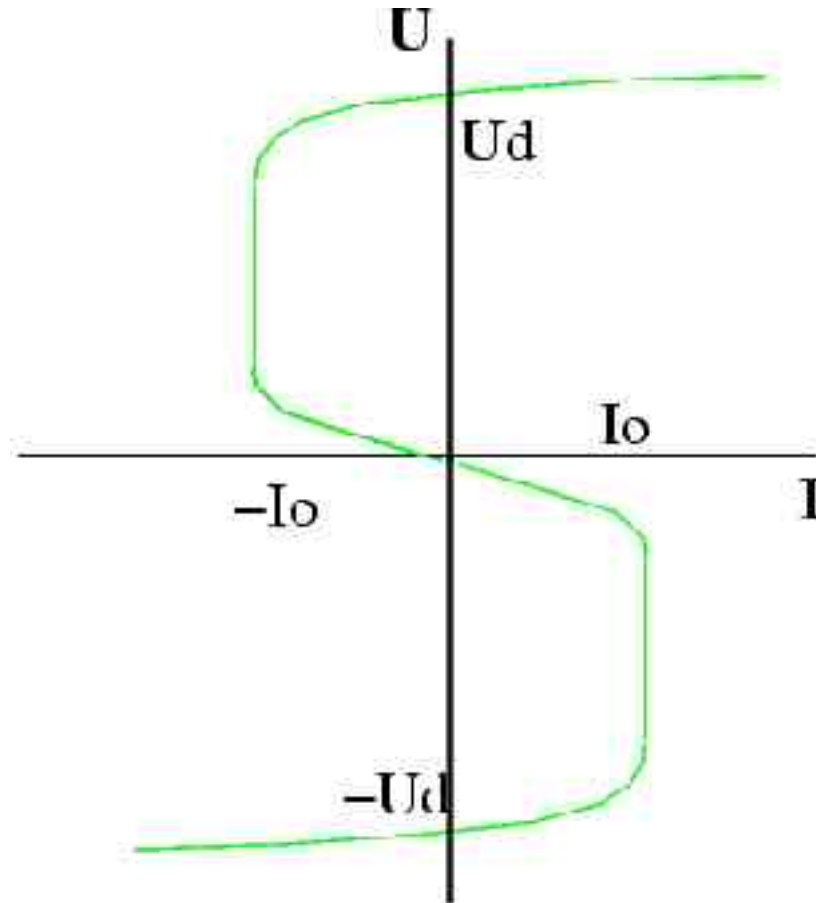




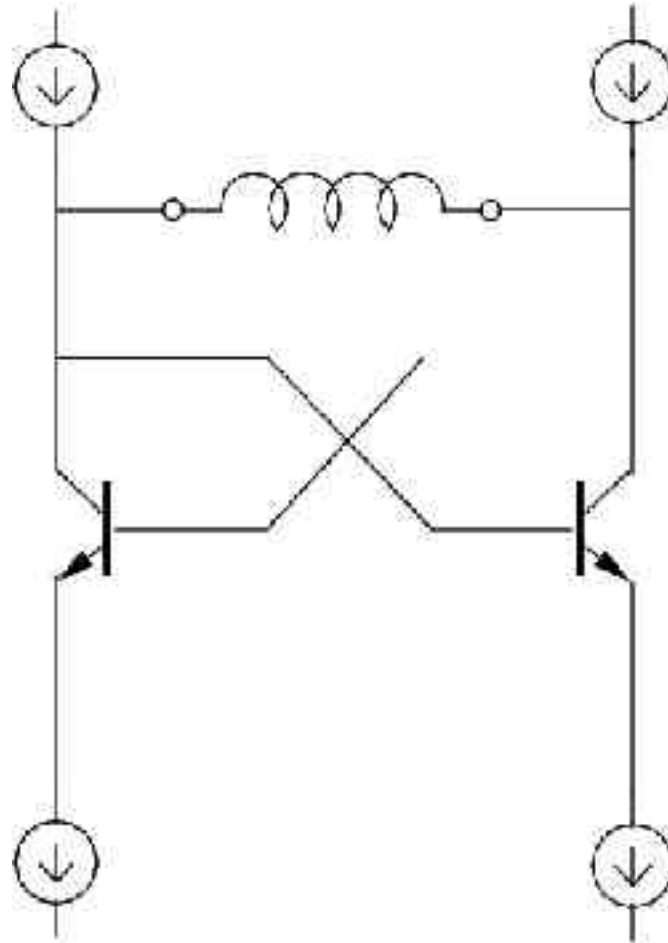
Balansschakeling IU grafiek

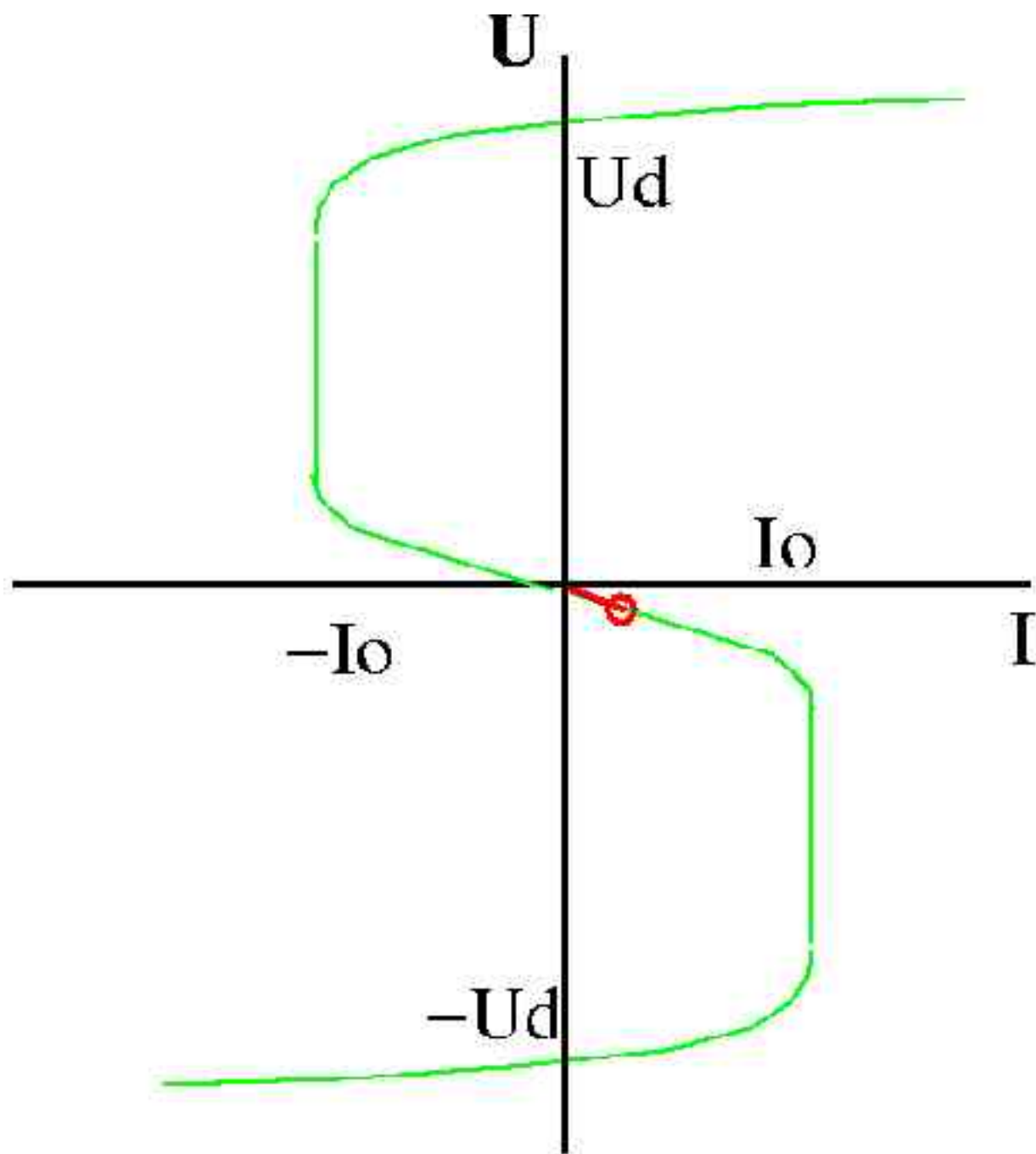


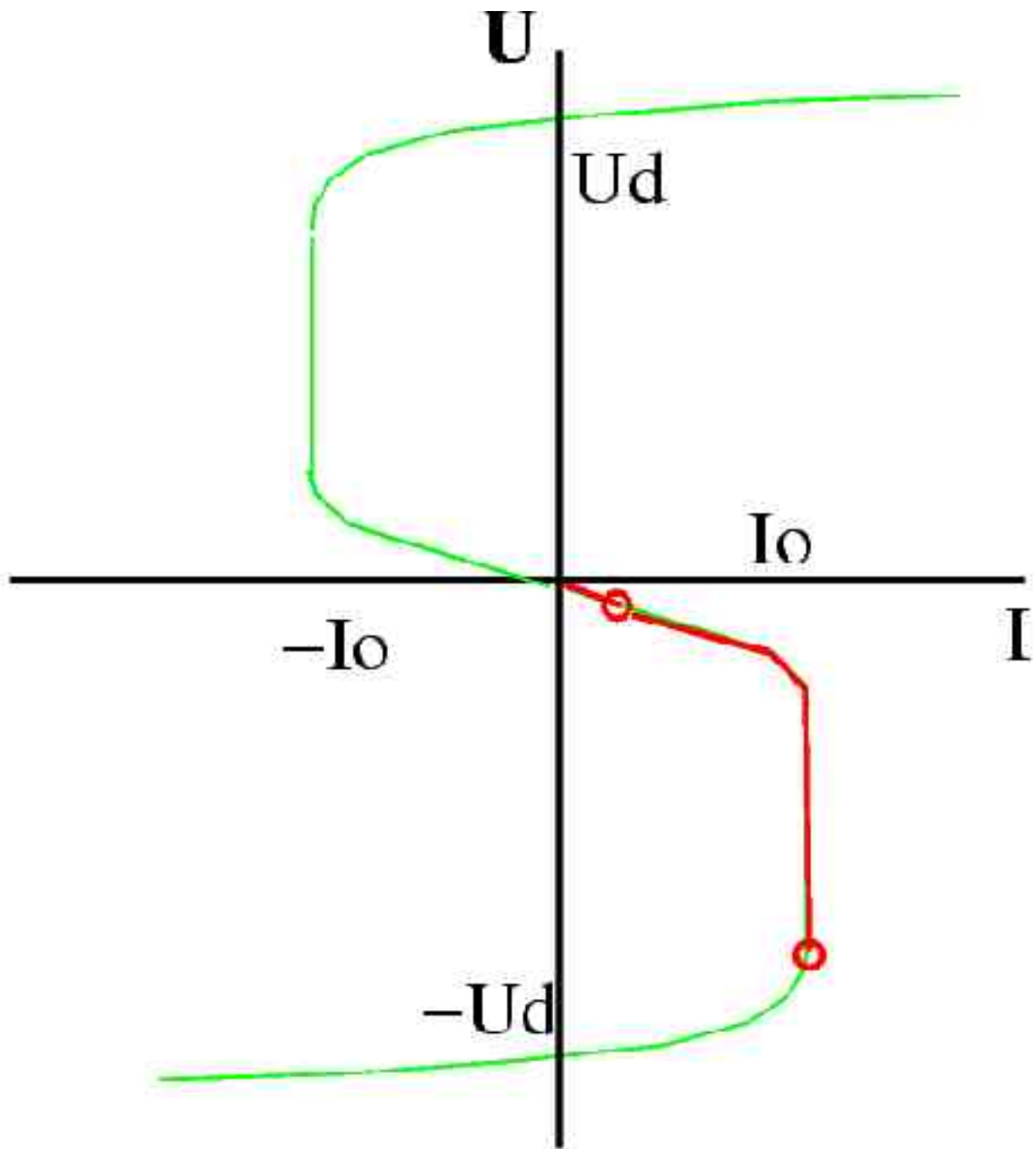
Balansschakeling IU grafiek

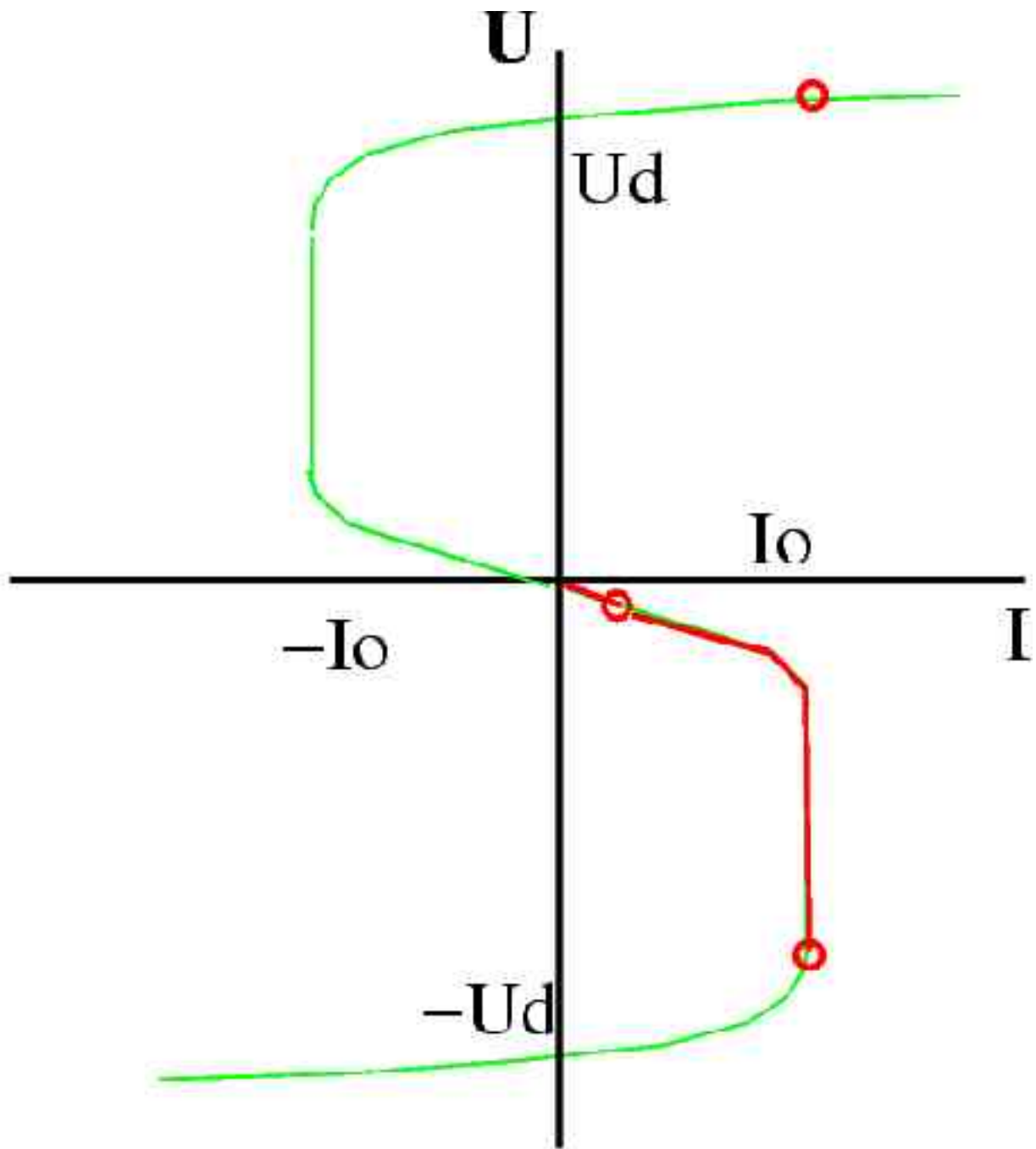


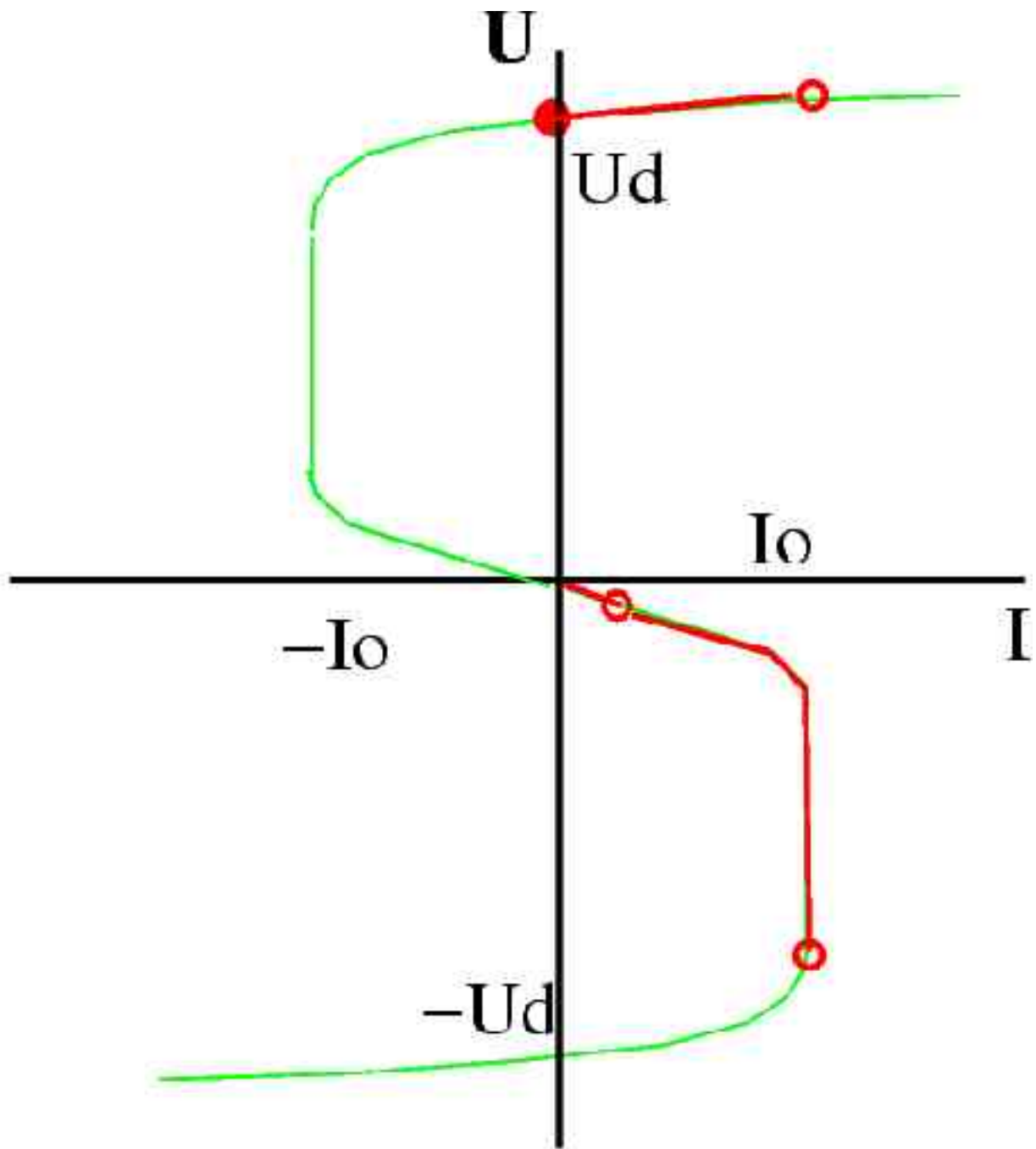
Koppeling spoel aan circuit

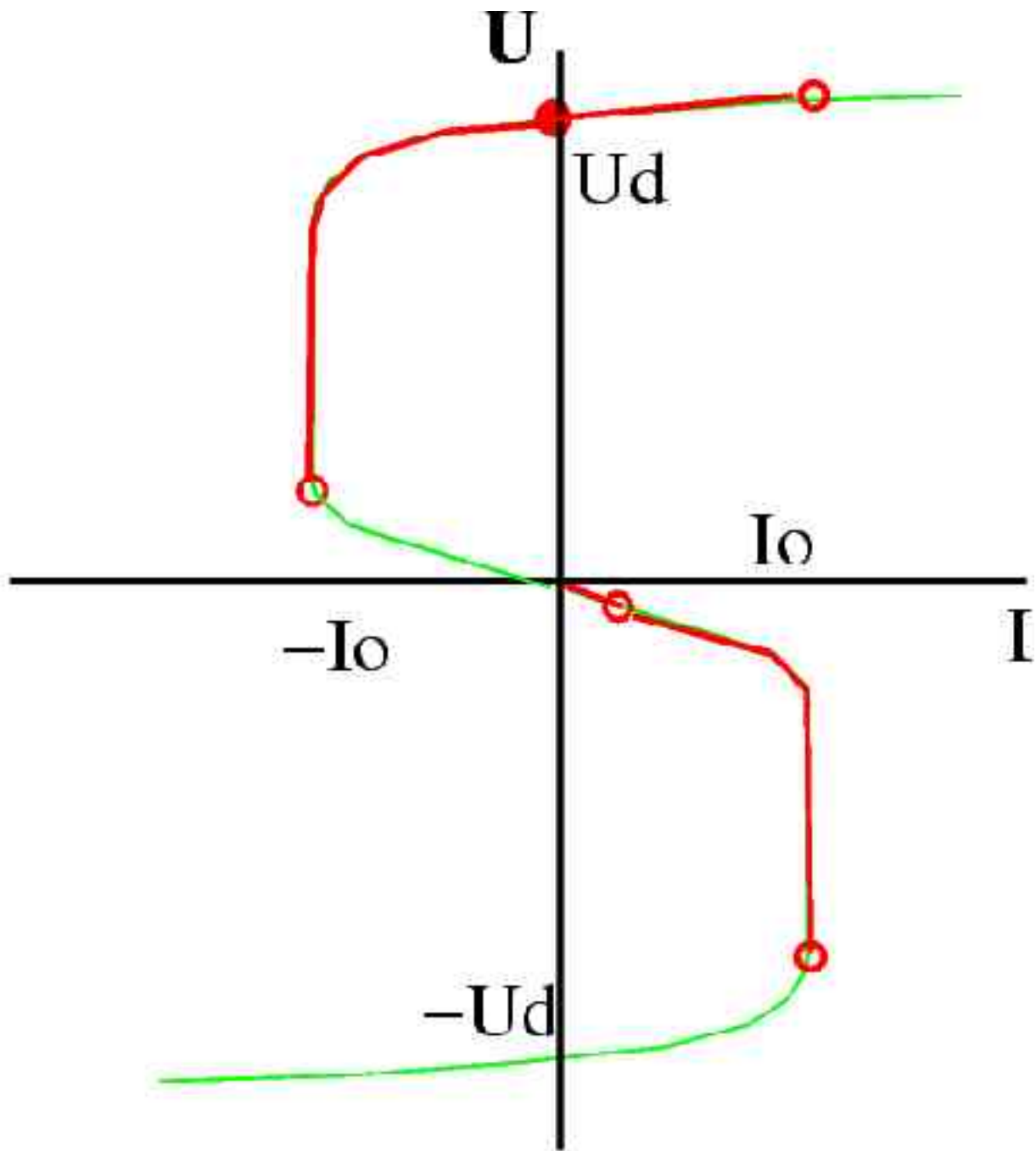


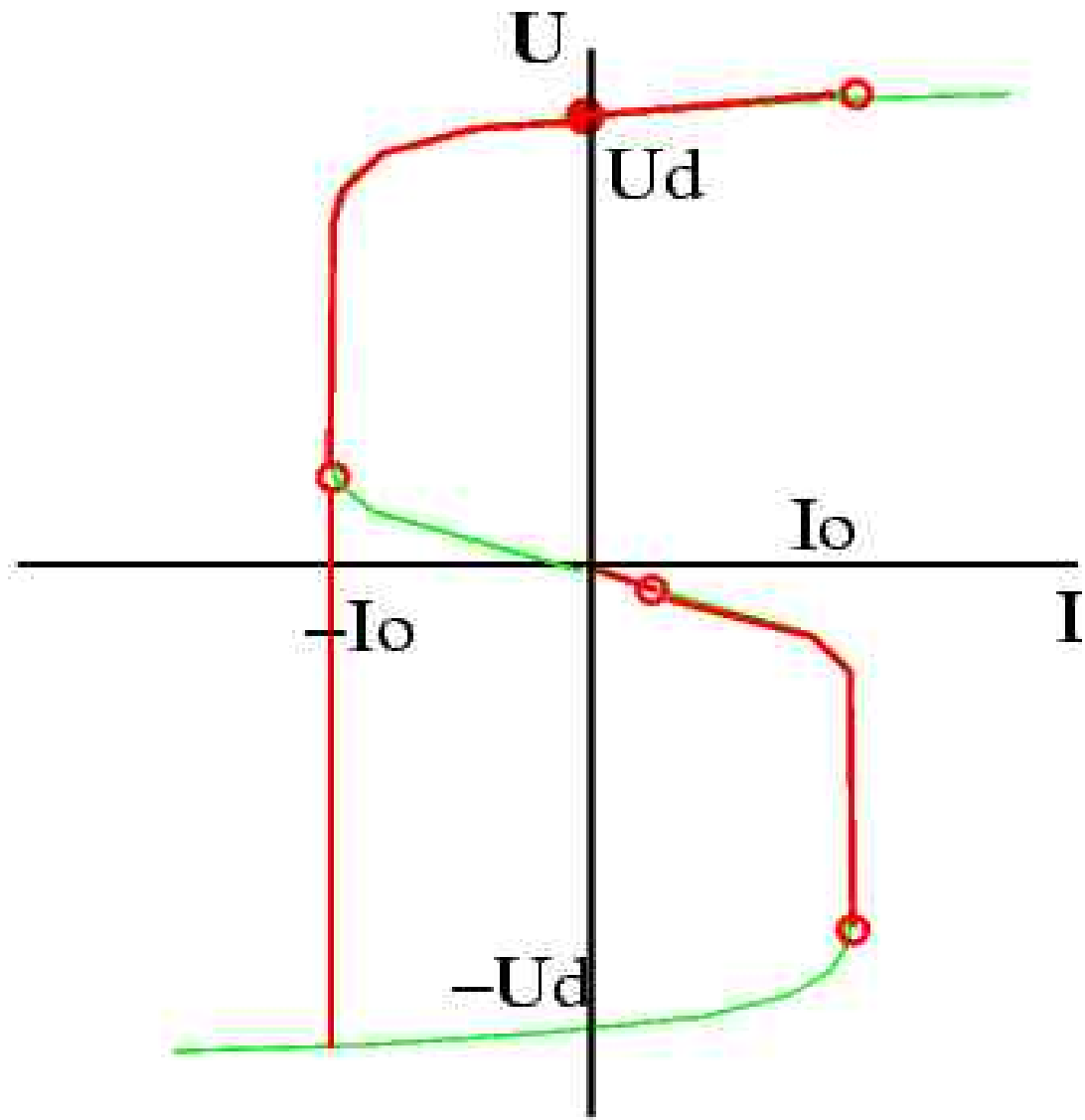


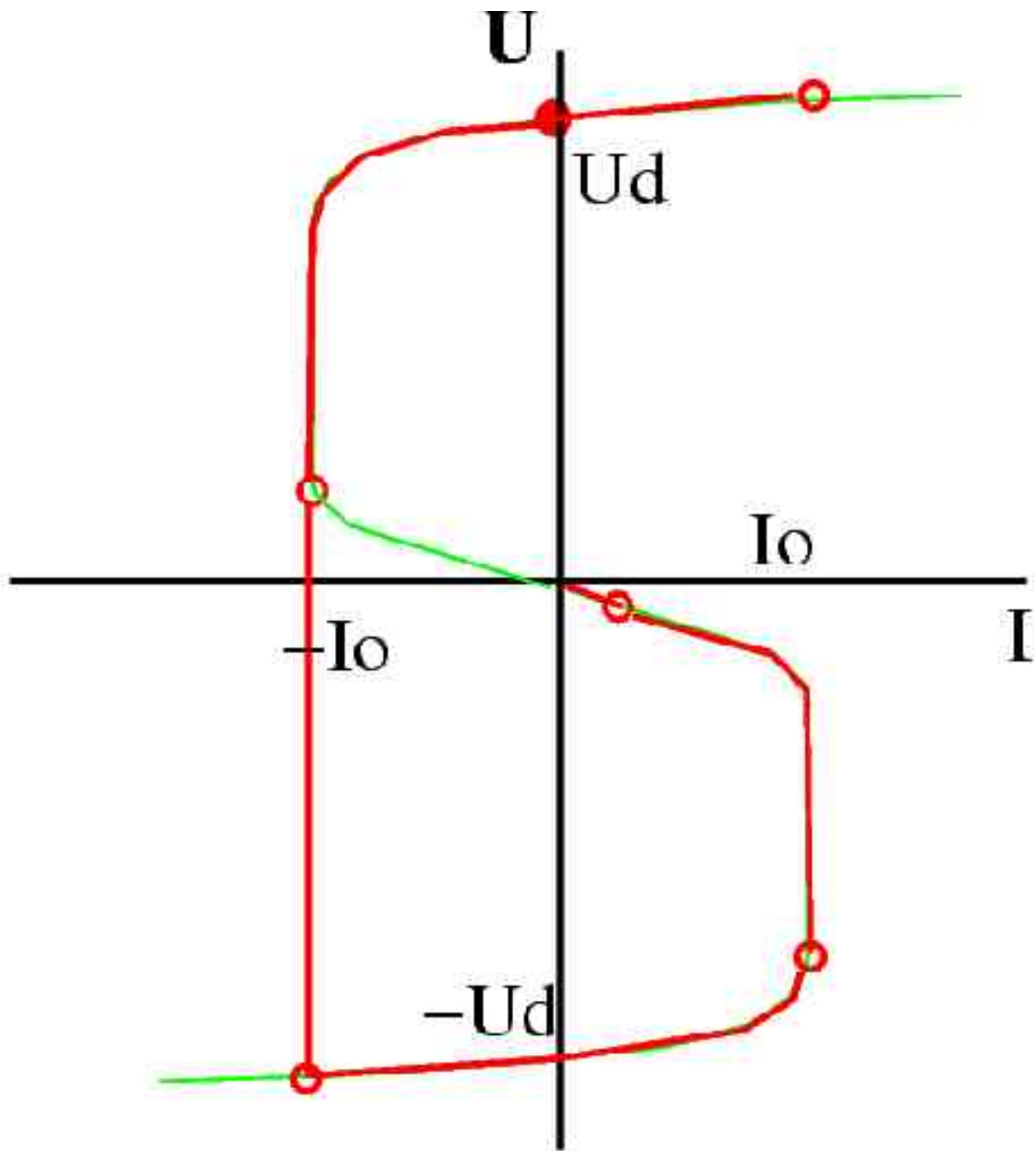












Simuleer schakeling met MATLAB

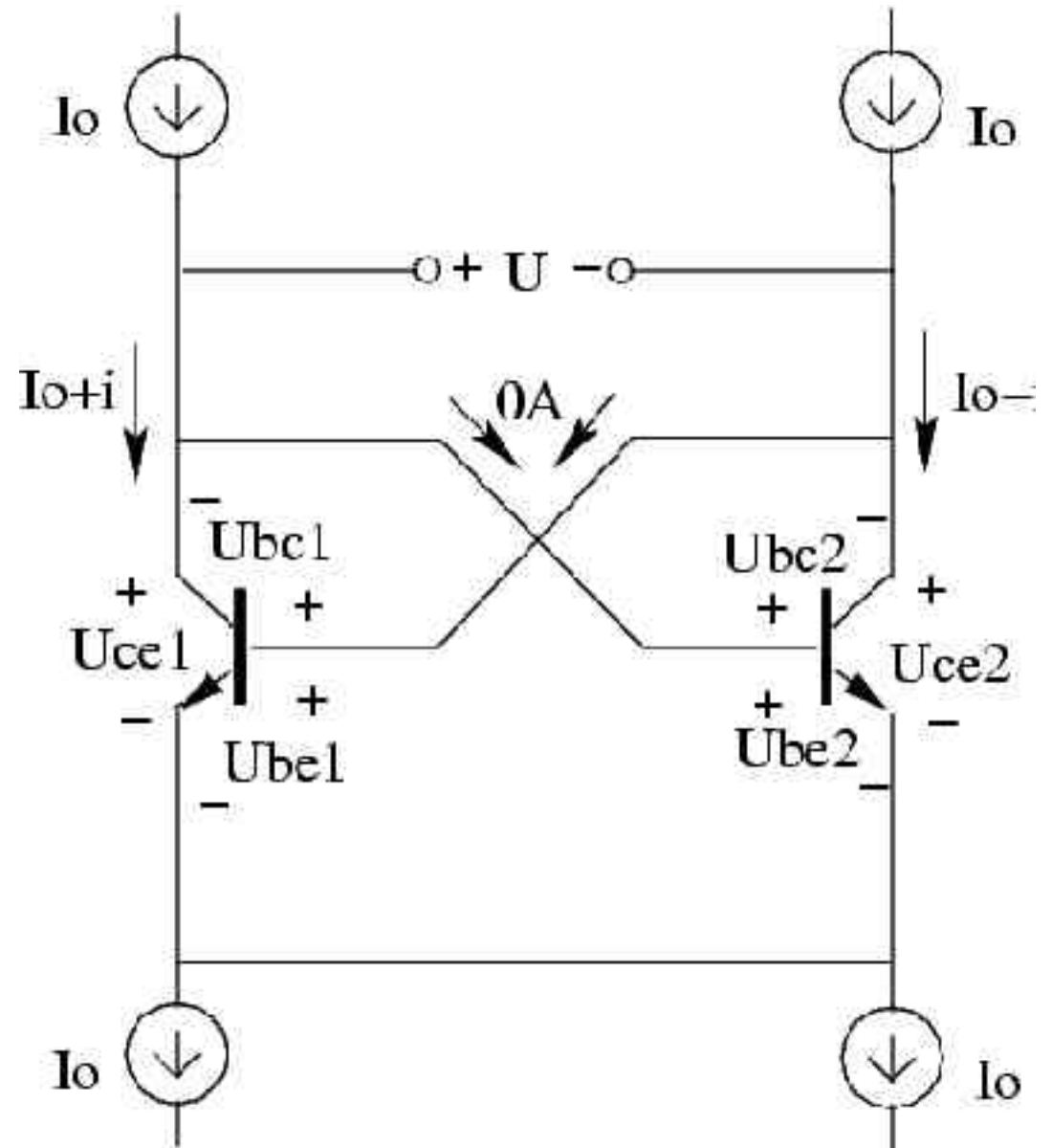
Mathematische Analyse met behulp van MATLAB

Transistormodel:

$$u_{bc} > -V_t :$$

$$I_{be} = 0,$$

$$I_{ce} = I_s e^{(40u_{be})}$$

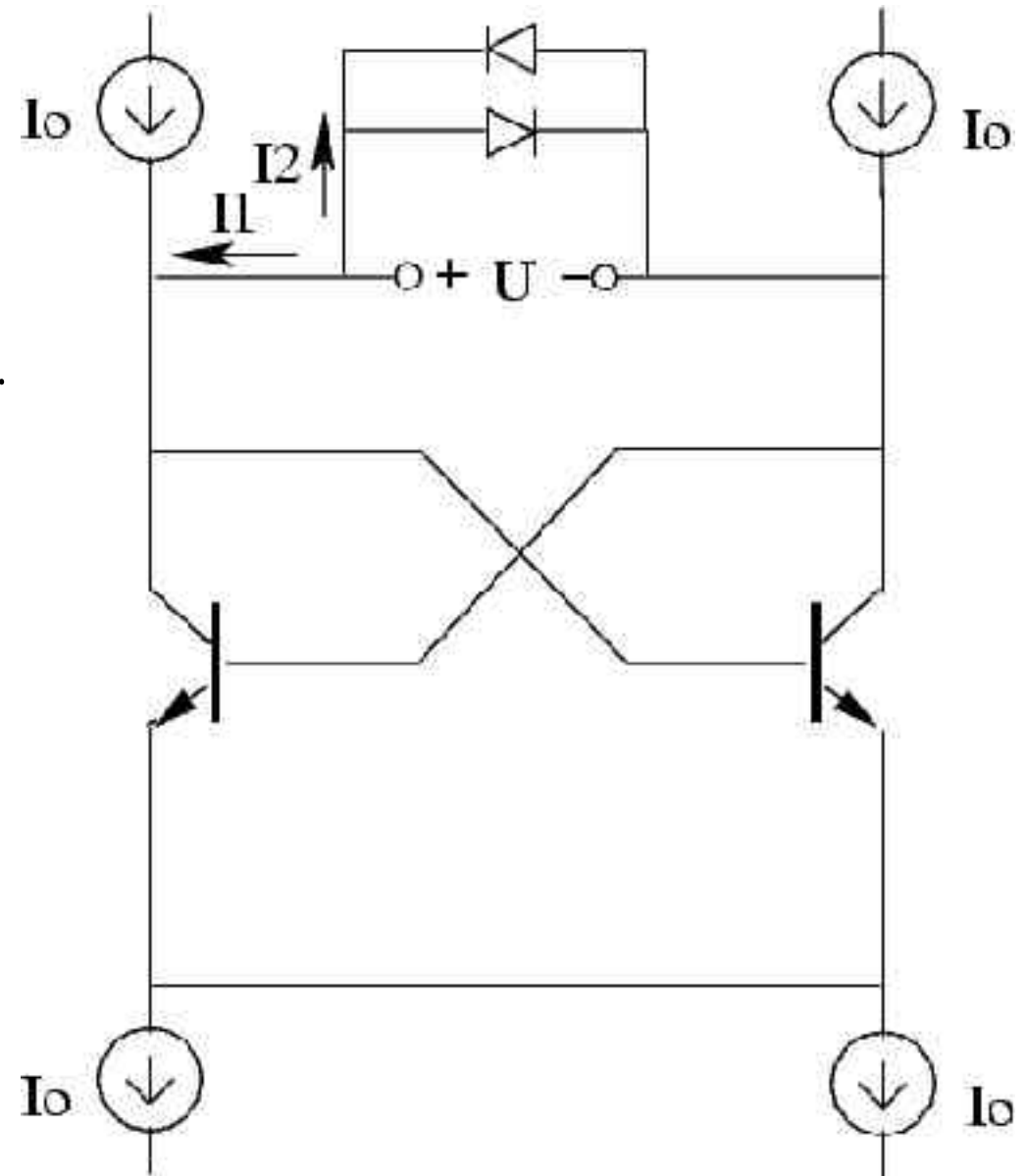


Transistormodel:

$$u_{bc} \leq -V_t :$$

extra diode parallell on base – collector

$$I_d = I_s e^{(40u_{be})} \quad I_{sd} = 10^{-16}$$



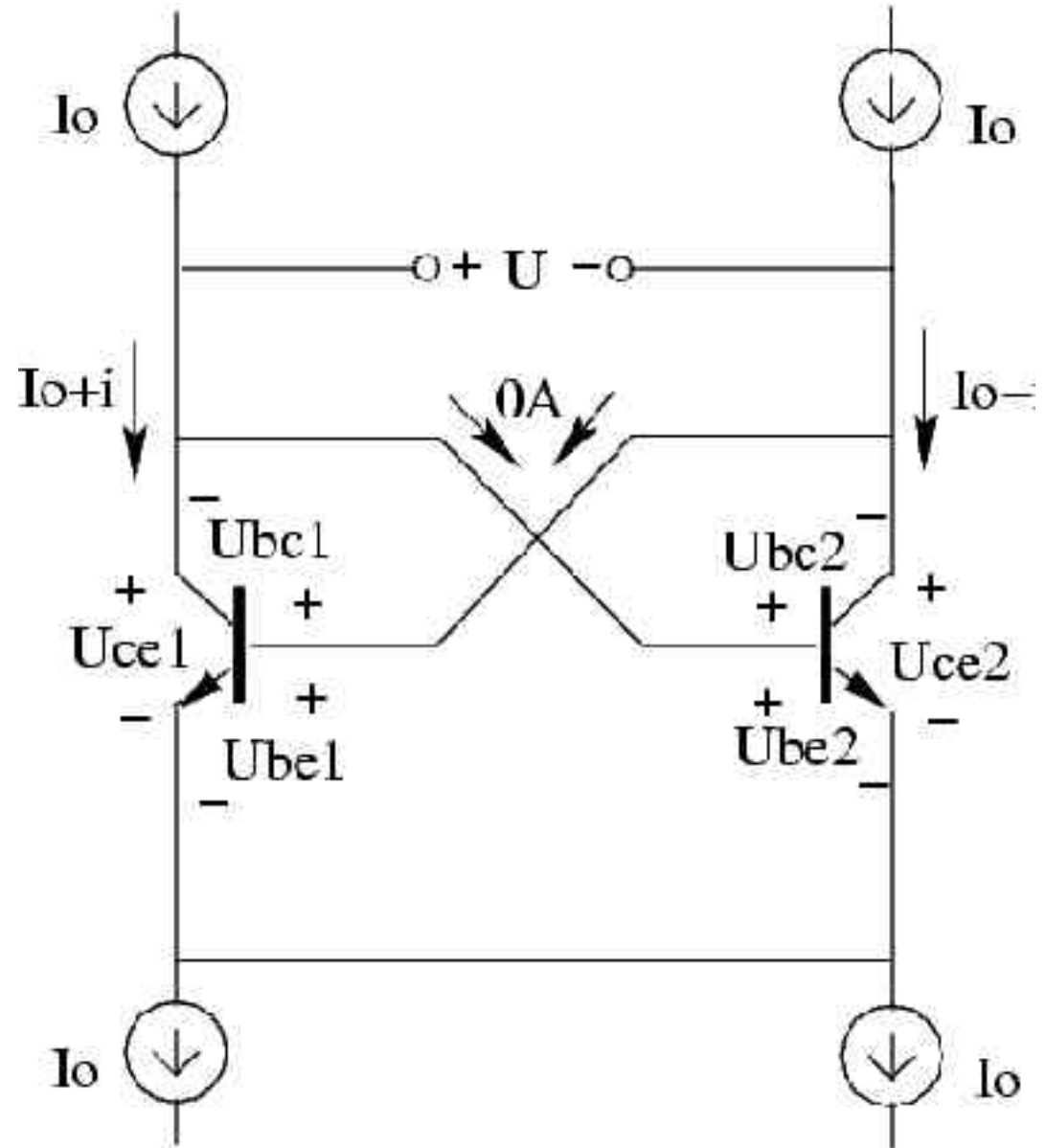
$$U_{bc} > -V_t$$

$$I_0 + i = I_s e^{40u_{be1}}$$

$$I_0 - i = I_s e^{40u_{be2}}$$

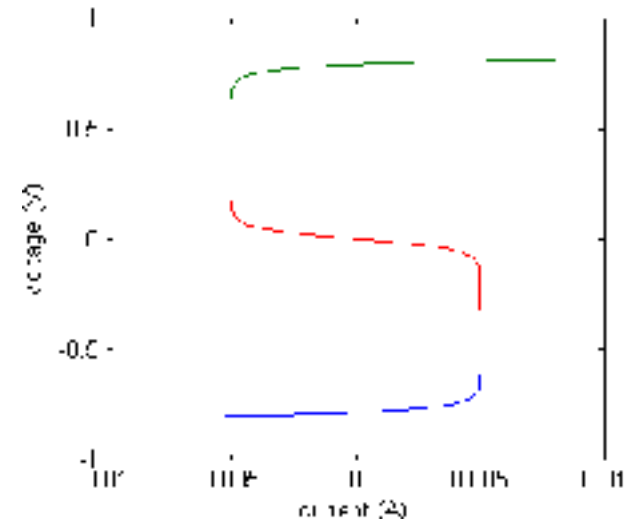
$$u_{be2} = u_{be1} + u$$

$$\Rightarrow u = \frac{1}{40} \ln \left(\frac{(I_0 - i)}{(i - I_0)} \right)$$



De drie vergelijkingen

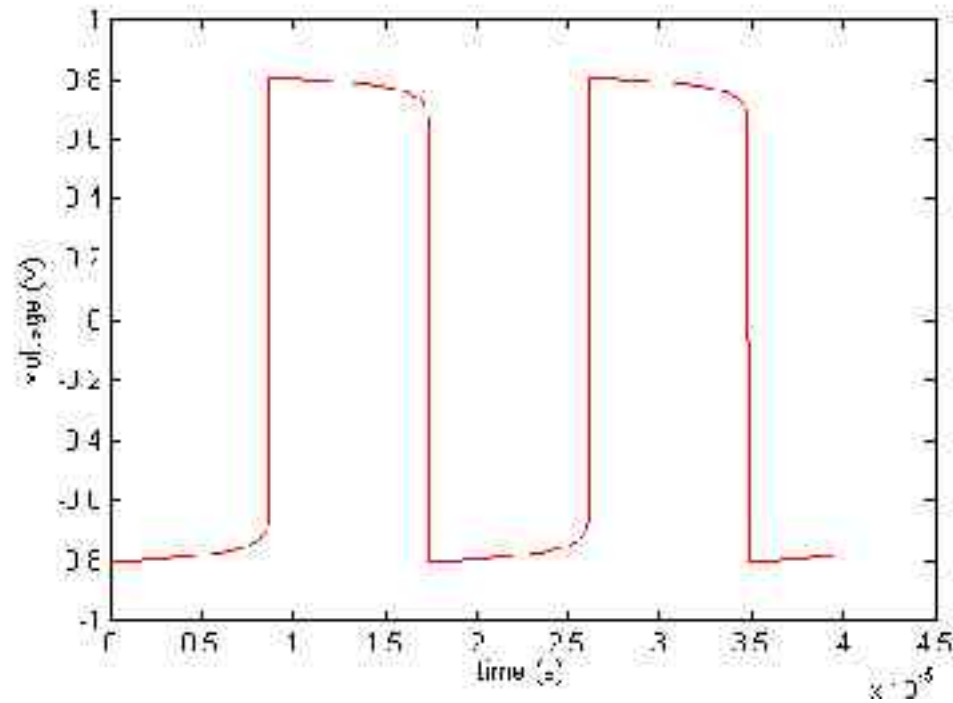
$$u = \left\{ \begin{array}{l} u \leq -V_t : u = -\frac{1}{40} \ln\left(\frac{(I_0 - i)}{I_{sd}}\right) \\ |u| < V_t : u = \frac{1}{40} \ln\left(\frac{(I_0 - i)}{(i - I_0)}\right) \\ u \geq V_t : u = \frac{1}{40} \ln\left(\frac{(i + I_0)}{I_{sd}}\right) \end{array} \right\}$$



Spoel aan circuit koppelen

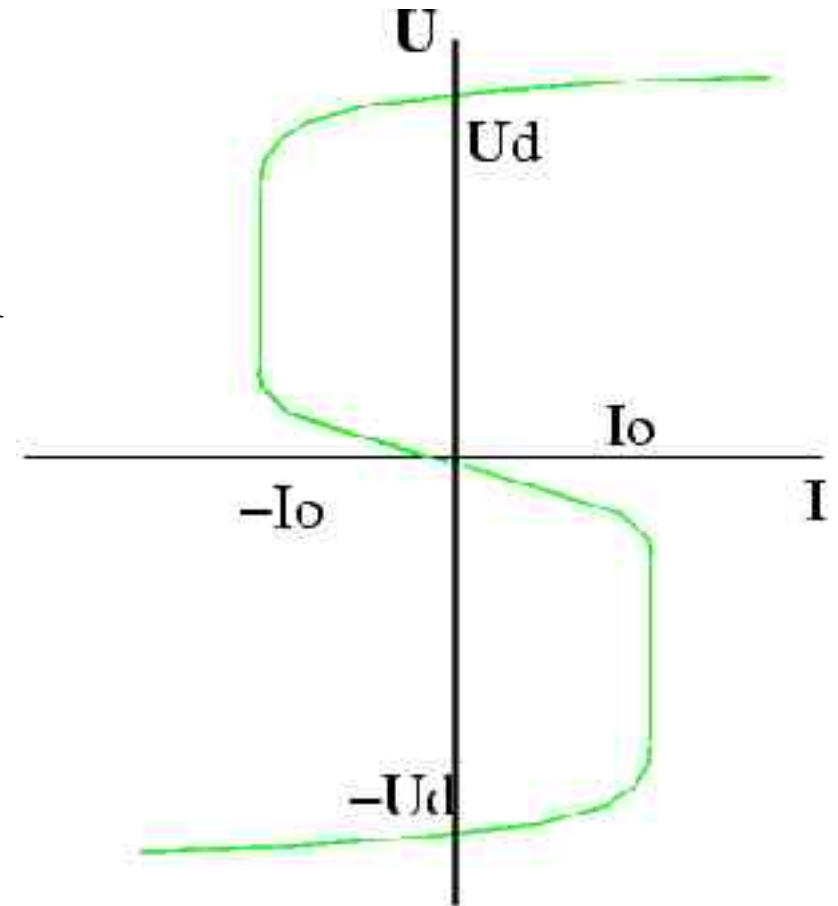
- Vergelijkingen vormen samen met spoelvergelijking $U = L di/dt$ de werking van het circuit
- Voor MATLAB omschrijven naar $di = -u dt/L$
- MATLAB script schrijven om voor elk tijdstip de stroom uit te rekenen, en bij I_0 en $-I_0$ om te klappen

Oscillatie: resultaat

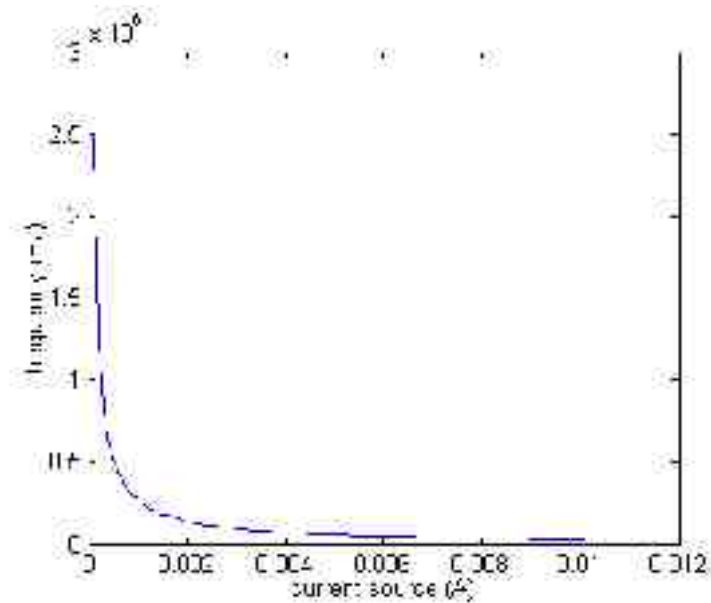


Effect I_o op oscillatie

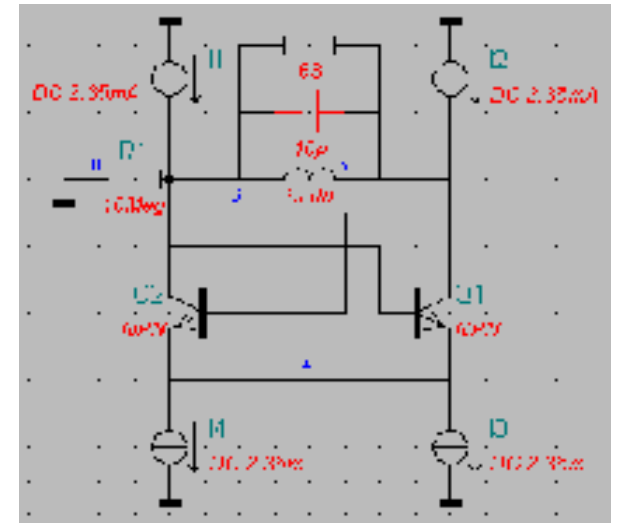
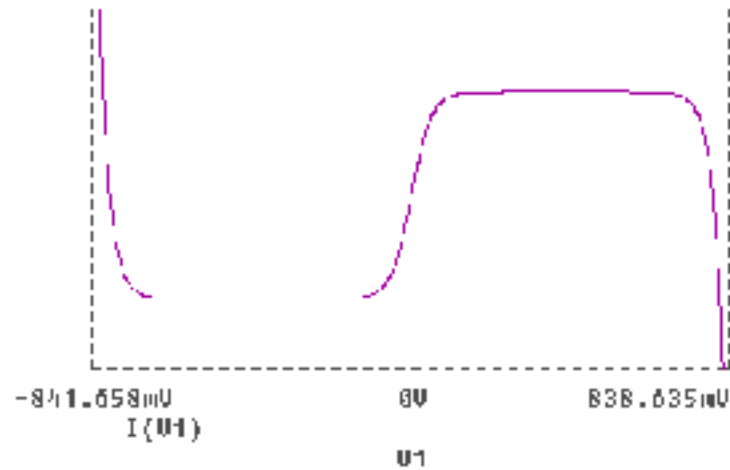
- Een grotere I_o : omklappunten verder uit elkaar
- Spanningen blijven bijna hetzelfde, dus langere oplaadtijd \rightarrow lagere frequentie



Effect I_0 op oscillatie



PSPICE simulaties



Resultaat

Met spoel van $680 \mu\text{H}$ en I_o 1mA: 250kHz

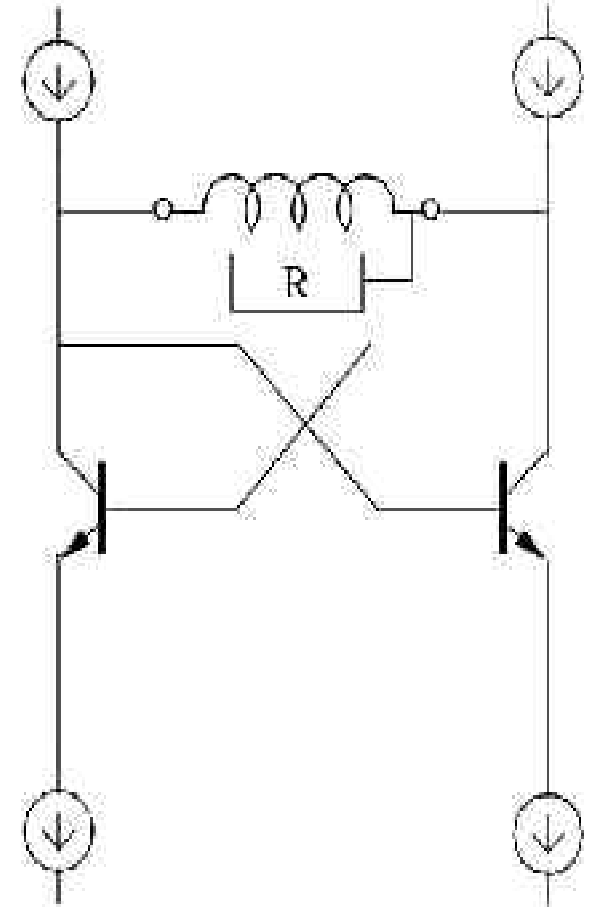
Voor 50kHz hebben we een I_o van 10mA nodig.

Optimalisatie

- Hoe kunnen we nog meer de frequentie naar 50kHz krijgen?
- De stroom verhogen betekent meer dissipatie
- Doel: de spoel moet minder snel 'leeglopen' zonder dat er extra stroom aan te pas komt

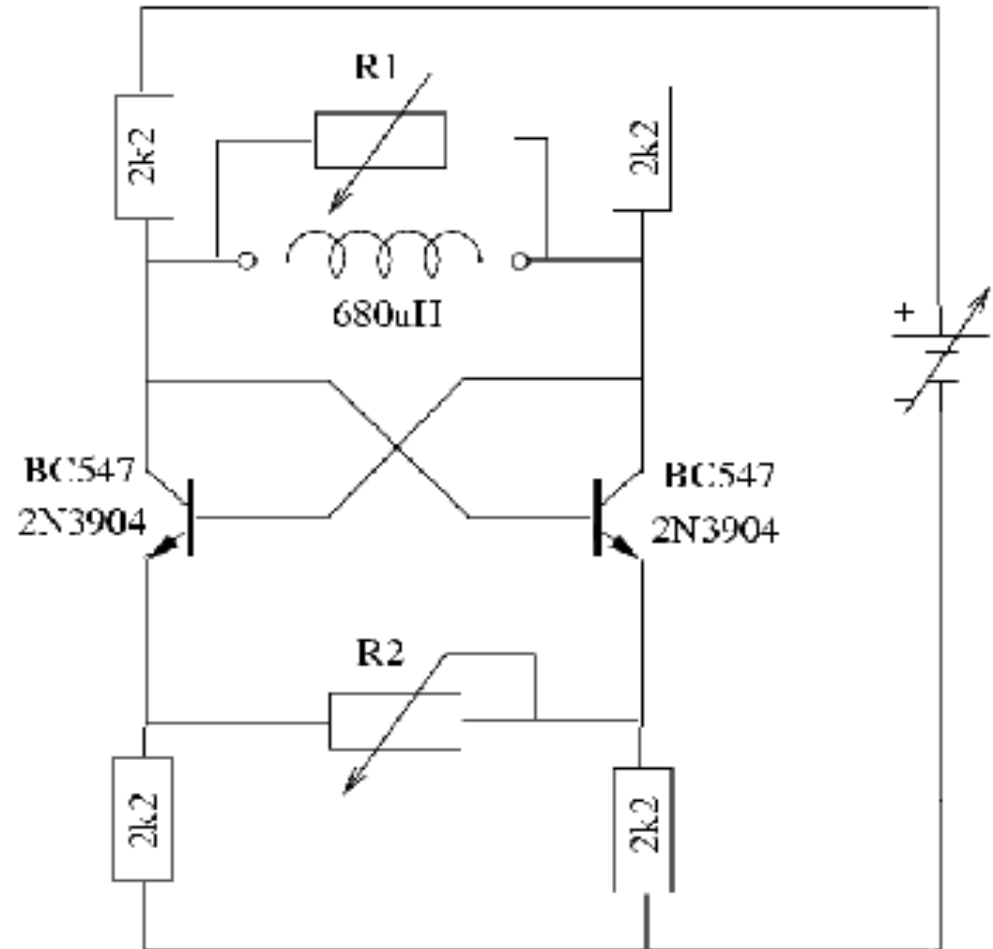
Optimalisatie

- Spoel minder snel leeg laten lopen: weerstand gekoppeld aan de spoel verlagen: minder ontlaadspanning bij dezelfde stroom
- Dus: extra parallelweerstand aan spoel koppelen



Optimalisatie

- Circuit bouwen en meten: bleek effectief
- Twee variabele weerstanden, I_o variëren met voedingspanning



Optimalisatie

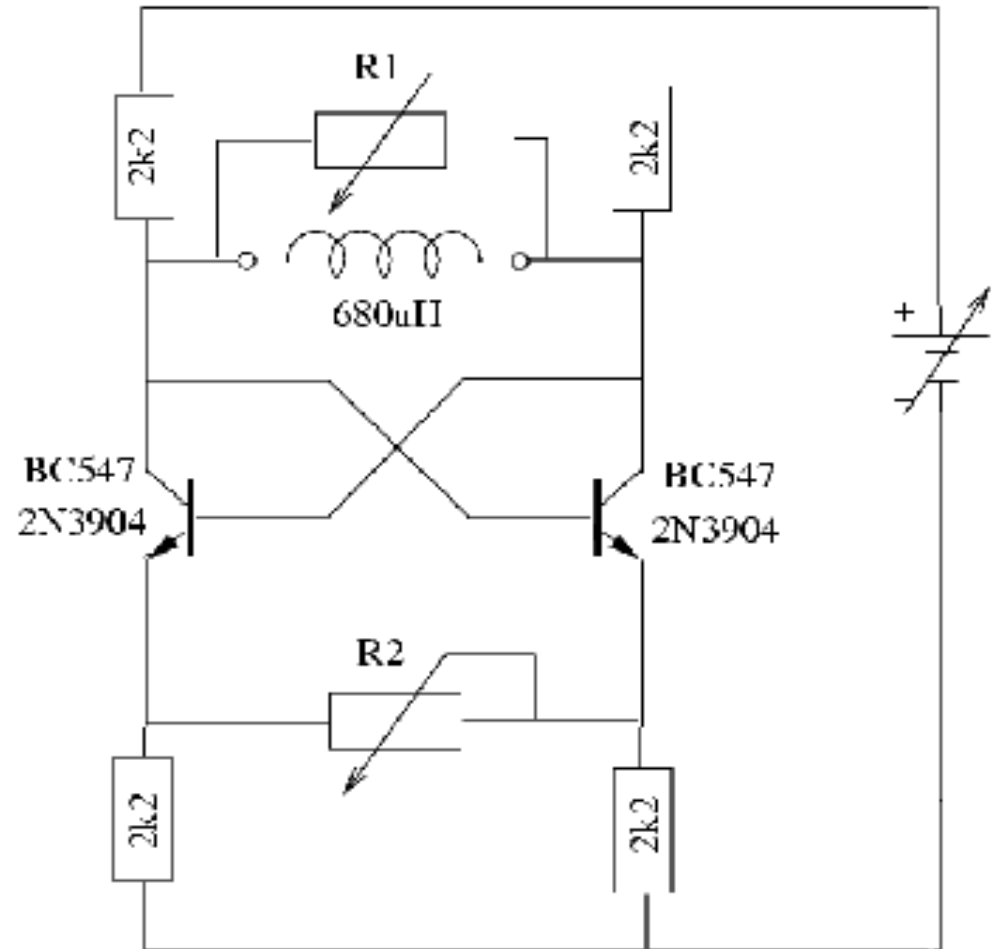
Resultaat:

R2 verslechtert eigenschappen: moet 0 blijven

R1 brengt frequentie omlaag maar verkleint amplitude. Maximaal resultaat R1: frequentie wordt gehalveerd.

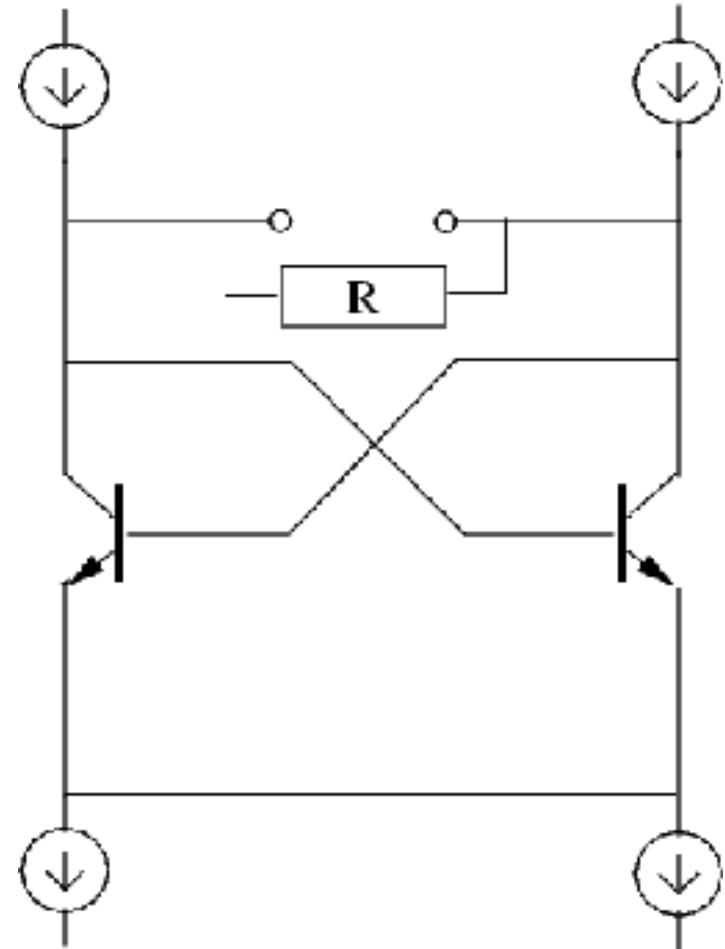
Waarden voor ons: R1 = 68 ohm bij I_o van 2,36mA, frequentie 50kHz.

Nadeel: R1 verlaagt de amplitude van de trilling en de vorm wordt raar.

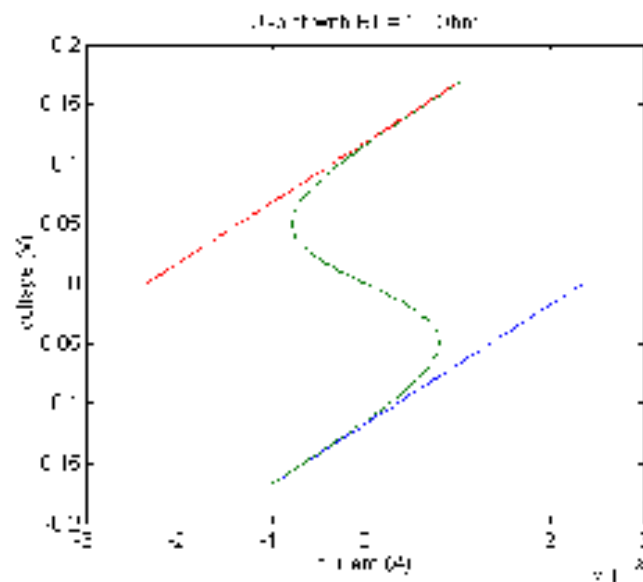
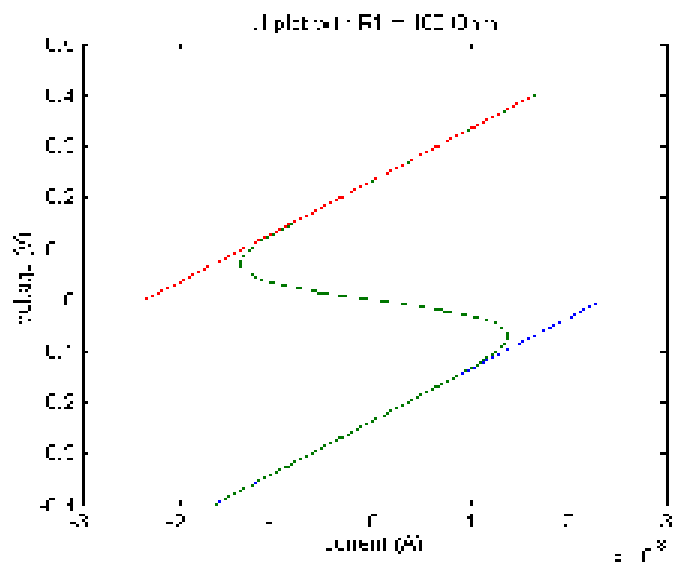
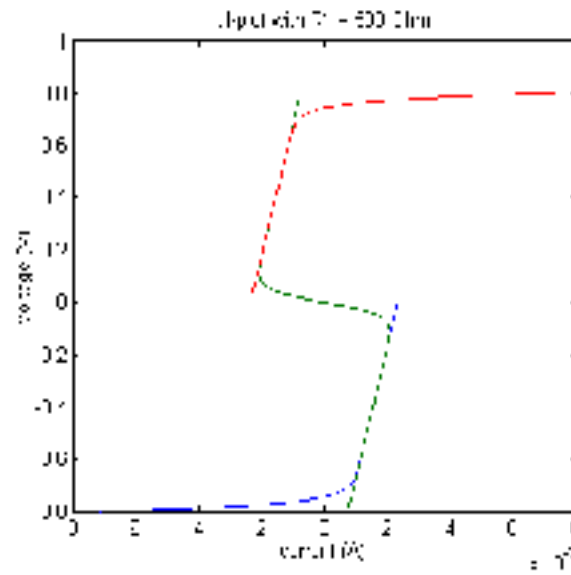
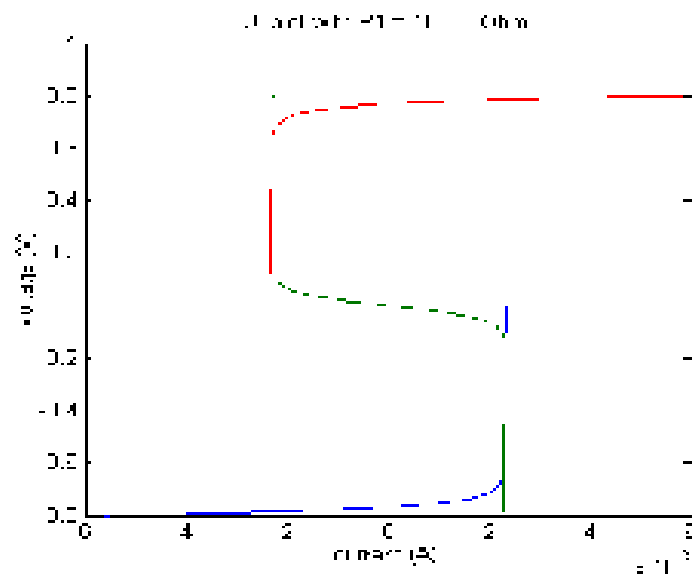


Circuit met weerstand

$$i = \left\{ \begin{array}{l} I_0 - I_{sd} e^{(-40u)} + u/R \\ I_0 \frac{1 - e^{(40u)}}{1 + e^{(40u)}} + u/R \\ I_{sd} e^{(40u)} - I_0 + u/R \end{array} \right\}$$



Circuit met weerstand



Circuit met weerstand

$$i = \left\{ \begin{array}{l} I_0 - I_{sd} e^{-40u} + u/R \\ I_0 \frac{1 - e^{40u}}{1 + e^{40u}} + u/R \\ I_{sd} e^{40u} - I_0 + u/R \end{array} \right\}$$

Omschrijven naar u als functie van i met de Lambert
functie

$$y = x e^x$$

$$W(y) = x$$

Circuit met weerstand

$$i = I_0 - I_{sd} e^{-40u} + u / R$$

$$(i - I_0)(-40R) = 40RI_{sd} e^{-40u} - 40u$$

$$e^{((i - I_0)(-40R))} = e^{(40RI_{sd} e^{-40u} - 40u)}$$

$$e^{((i - I_0)(-40R))} = e^{-40u} e^{(40RI_{sd} e^{-40u})}$$

$$40RI_{sd} e^{((i - I_0)(-40R))} = 40RI_{sd} e^{-40u} e^{(40RI_{sd} e^{-40u})}$$

$$W(40RI_{sd} e^{((i - I_0)(-40R))}) = 40RI_{sd} e^{-40u}$$

$$u = -1/40 \ln(1/(40RI_{sd}) W(40RI_{sd} e^{((i - I_0)(-40R))}))$$

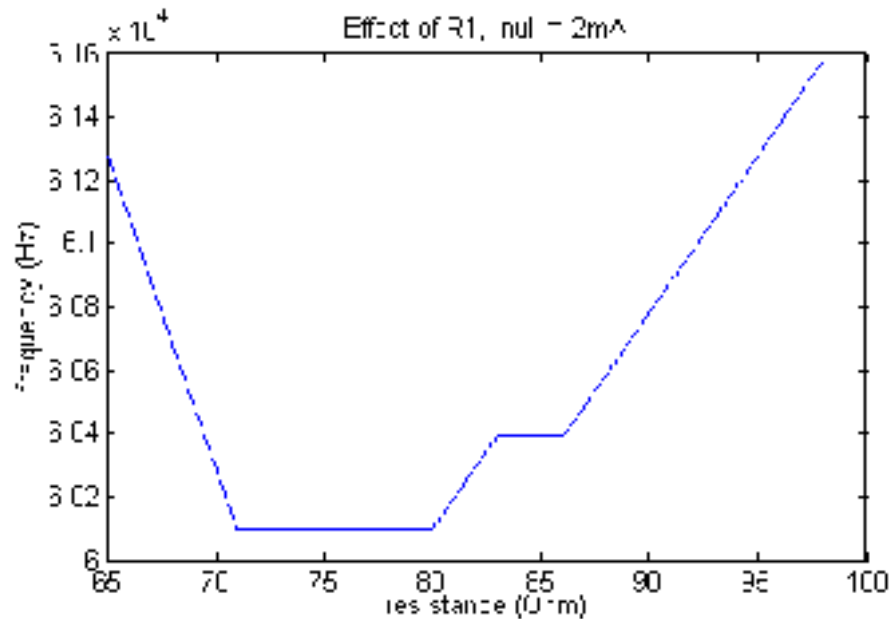
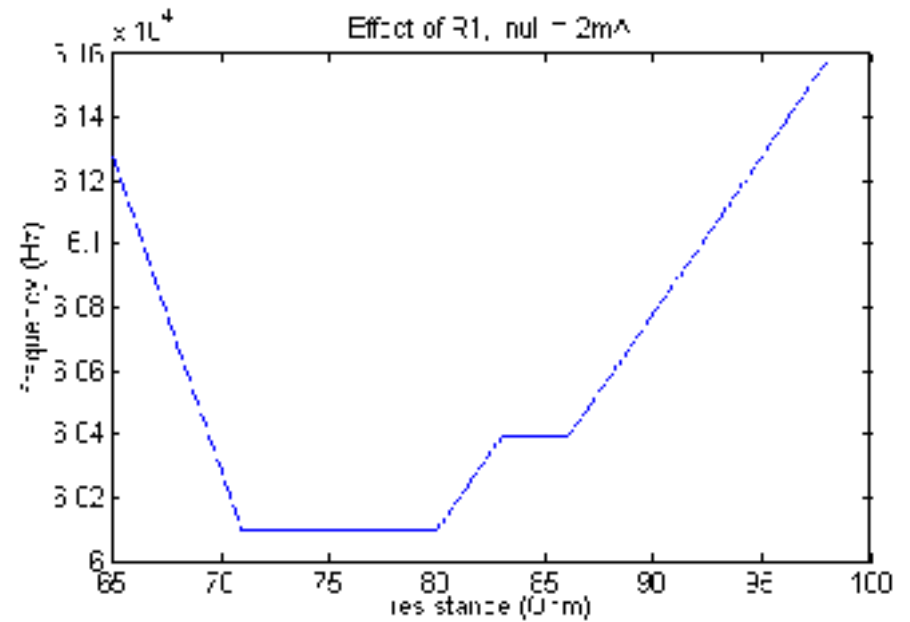
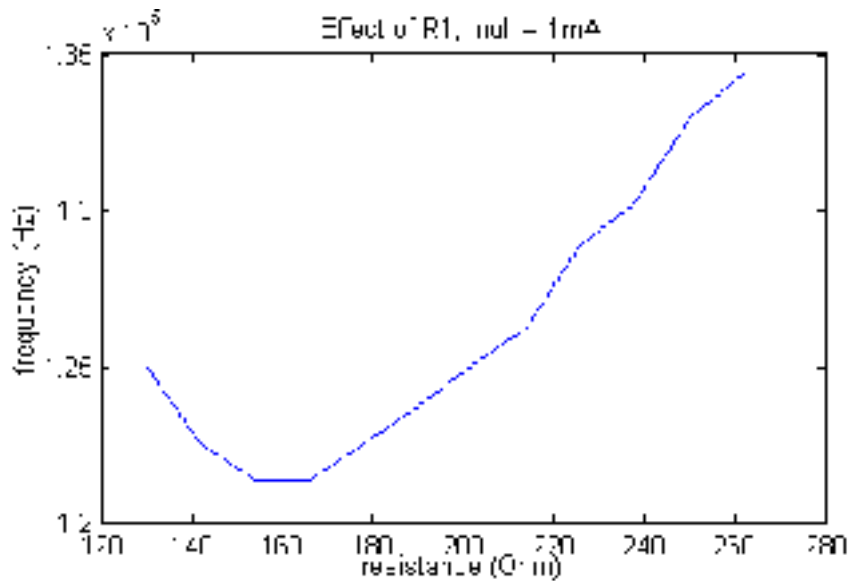
Voor MATLAB wordt dit dus:

$$u = 1/40 \ln(1/(40RI_{sd}) W(40RI_{sd} e^{((i + I_0)(40R))})) \quad (\text{voor omklappunt})$$

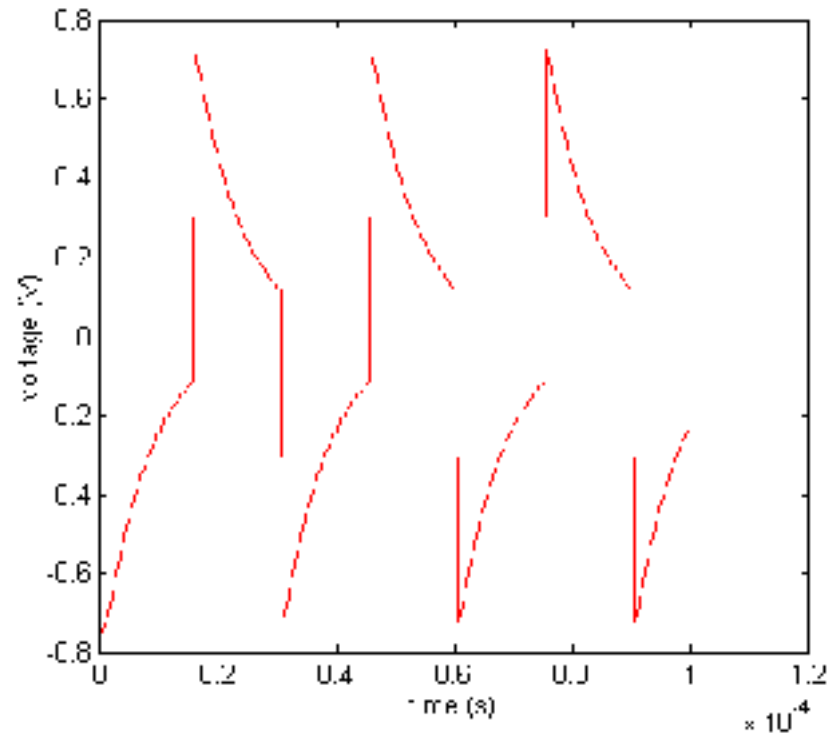
$$i = I_0 \frac{1 - e^{(40u)}}{1 + e^{(40u)}} + u / R \quad (\text{omklappunt})$$

$$u = -1/40 \ln(1/(40RI_{sd}) W(40RI_{sd} e^{((i - I_0)(-40R))})) \quad (\text{na omklappunt})$$

Circuit met weerstand

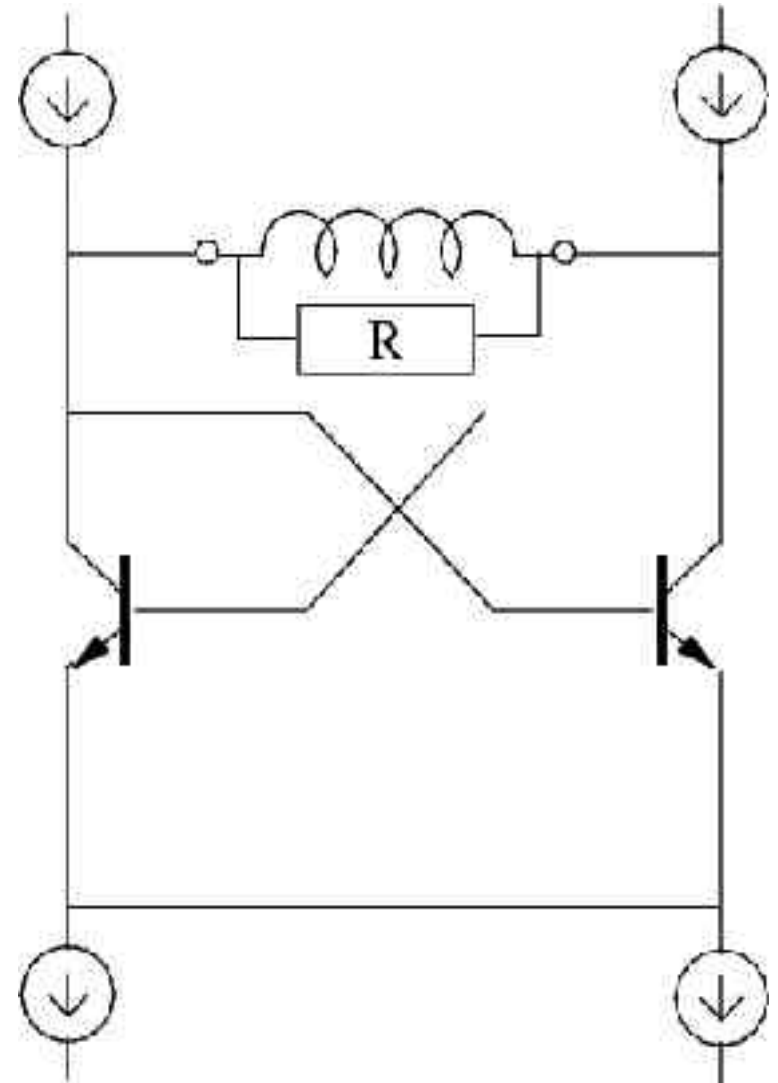


Circuit met weerstand



Uiteindelijk circuit

- Bovenste I_o (actieve) stroombronnen kunnen worden vervangen door weerstanden
- Onderste I_o (passieve) stroombronnen kunnen worden weggelaten, omdat de emitterspanning niet varieert



Uiteindelijk circuit

- Berekening weerstand:

U_{drop} circuit: gemiddeld 450mV
(helpt periode 0V, andere helft 700mV)

Blijft over voor weerstanden:

$$5V_{\text{dd}} - 450\text{mV} = 4,55\text{V}$$

$R = V/I_o$ dus $4.55\text{V}/2,35\text{mA} = 1,9\text{k}\Omega$,
afgerond 1k8

- Keuze transistor:

Klein-siginaaltransistor: 2N3904, of BC547

