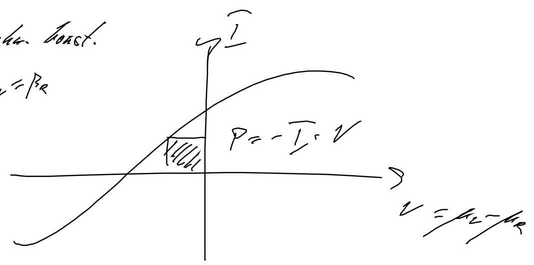
- stückw. konst.

$\beta_L = \beta_R$



→ scheinbare Verletzung von 2. HS → Entropie

- Ratengl. ohne fb

$$\dot P_a = \sum_\nu \sum_b W_{ab}^{(\nu)} \cdot P_b$$

- $W_{aa}^{(\nu)} = -\sum_{b\neq a} W_{ba}^{(\nu)}$
- $\frac{W_{ab}^{(\nu)}}{W_{ba}^{(\nu)}} = e^{-\beta_\nu[(E_b-E_a)-\mu_\nu(N_b-N_a)]}$

$$\longrightarrow S = -\sum_a P_a(t)\ln P_a(t) \quad \longrightarrow \dot S = \underbrace{\dot S_i}_{\geq 0} + \dot S_e \qquad \dot S_e = \sum_\nu \dot S_e^{(\nu)}$$

$$\dot S_e^{(\nu)} = \sum_{ij} W_{ij}^{(\nu)} P_j \ln\left(\frac{W_{ji}^{(\nu)}}{W_{ij}^{(\nu)}}\right) = \beta_\nu \underbrace{\left[I_E^{(\nu)} - \mu_\nu I_M^{(\nu)}\right]}_{\dot Q^{(\nu)}}$$

$$\mathcal{L}^{(\nu)} = \left(\begin{array}{c|c} W^{(\nu)} & 0 \\ \hline 0 & \dots \end{array}\right)$$

$$I_E^{(\nu)} = \mathrm{Tr}\{H_S(\mathcal{L}^{(\nu)}\rho)\} = \sum_i E_i(\mathcal{L}^{(\nu)}\rho)_{ii} \overset{BMS}{=} \sum_{ij} E_i W_{ij}^{(\nu)} \rho_{jj}$$

$$= \sum_{ij:\, i\neq j} E_i W_{ij}^{(\nu)} \rho_{jj} - \sum_{ij:\, i\neq j} E_i W_{ji}^{(\nu)} \rho_{ii} = \sum_{ij} (E_i - E_j) W_{ij}^{(\nu)} \underbrace{\rho_{jj}}_{P_j}$$

- mit feedback:

$$\frac{W_{ji}^{(i,\nu)}}{W_{ij}^{(j,\nu)}} = \underbrace{e^{\beta_\nu[E_i^{(i)} - E_j^{(j)} - \mu_\nu(N_i - N_j)]}}_{\text{LDB ohne fb}} \, e^{-\Delta_{ij}^{(\nu)}} \, e^{-\delta_{ij}^{(\nu)}}$$

Modifikationen ohne Energie-Änderung

mit Energie-Änderung

$$\dot S_i \geq 0$$

$$\dot S_i = \dot S - \sum_\nu \beta_\nu \dot Q^{(\nu)} + I_1 + I_2 \geq 0$$

$$\frac{d}{dt}E = \frac{d}{dt}\sum_i E_i^{(i)} P_i = \sum_\nu I_E^{(\nu)} + I_E^{fb}$$

$$I_E^{(\nu)} = \sum_{ij}\left(E_i^{(j)} - E_j^{(j)}\right) \cdot W_{ij}^{(j,\nu)} P_j$$

$$I_E^{fb} = \sum_\nu \sum_{ij}\left[E_i^{(i)} - E_i^{(j)}\right] W_{ij}^{(j,\nu)} P_j$$

7.1.4 Beispiel MD an SET

$$\mathcal{L}_{fb} = \sum_\nu \begin{pmatrix} -\Gamma_\nu^E f_\nu^E & \Gamma_\nu^F(1-f_\nu^F) \\ +\Gamma_\nu^E f_\nu^E & -\Gamma_\nu^F(1-f_\nu^F) \end{pmatrix} \qquad f_\nu^{E/F} = f_\nu(\varepsilon_{E/F})$$

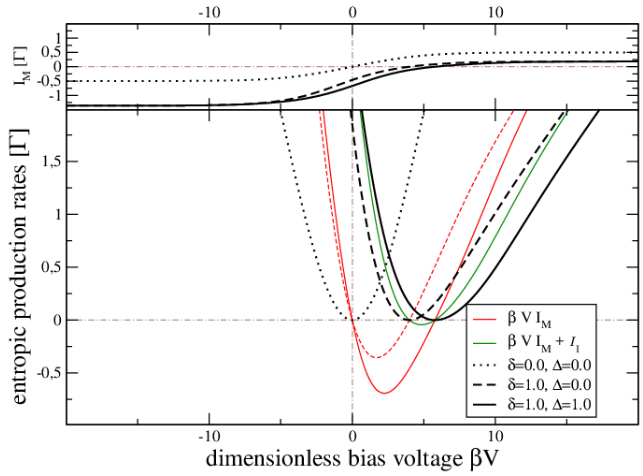
$$I_E^{(\nu)} = \varepsilon_E \Gamma_\nu^E f_\nu^E \cdot P_0 - \varepsilon_F \Gamma_\nu^F (1 - f_\nu^F) \cdot P_1$$

$$I_E^{fb} = (\varepsilon_F - \varepsilon_E) \sum_\nu Z_{fb}^{10,\nu} P_0$$

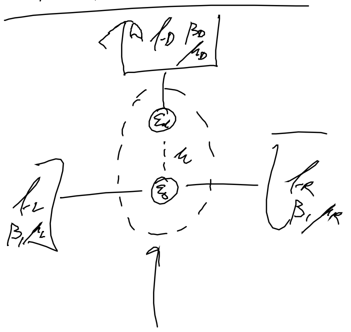
$$\frac{Z_{fb}^{01,\nu}}{Z_{fb}^{10,\nu}} = \frac{\Gamma_\nu^F}{\Gamma_\nu^E} \frac{1-f_\nu^F}{f_\nu^E} = \underbrace{\left(\frac{1-f_\nu^E}{f_\nu^E}\right)}_{e^{\beta_\nu(\varepsilon_E-\mu_\nu)}} \underbrace{\overbrace{\left[\frac{\Gamma_\nu^F}{\Gamma_\nu^E}\right]}^{e^{\delta_{01}^{(M)}}}}_{\text{Maxwell-Dämon fb}} \underbrace{\overbrace{\left\{\frac{1-f_\nu^F}{1-f_\nu^E}\right\}}^{e^{\Delta_{01}^{(M)}}}}_{\text{energet. feedback}}$$

$\rightsquigarrow I_1 / I_2$

$$\dot S_i \xrightarrow{t\to\infty,\ \beta_\nu=\beta_R} \underbrace{\beta(\mu_L-\mu_R) I_M + \beta \cdot I_E^{fb}}_{-\beta\sum_\nu \left[I_E^{(M)} - \mu_\nu I_M^{(M)}\right]} + I_1 + I_2 \geq 0$$



7.2. Autonomer Dämon



$$Z = Z_D + Z_L + Z_R$$

Sysst. $\{E, F\}$

Dämon $\{0, 1\}$

$$\rho \to \begin{pmatrix} P_{0E} \\ P_{1E} \\ P_{0F} \\ P_{1F} \end{pmatrix} \quad Z_D,\ Z_L/Z_R$$

$$Z_D = \begin{pmatrix} -\Gamma_D f_D & \Gamma_D(1-f_D) e^{+i\xi\varepsilon_d} & 0 & 0 \\ \Gamma_D f_D e^{-i\xi\varepsilon_d} & -\Gamma_D(1-f_D) & 0 & 0 \\ 0 & 0 & -\Gamma_D^u f_D^u & +\Gamma_D^u(1-f_D^u) \\ 0 & 0 & +\Gamma_D^u f_D^u & -\Gamma_D^u(1-f_D^u) \end{pmatrix}$$

$e^{+i\xi(\varepsilon_d+u)}$

$e^{-i\xi(\varepsilon_d+u)}$

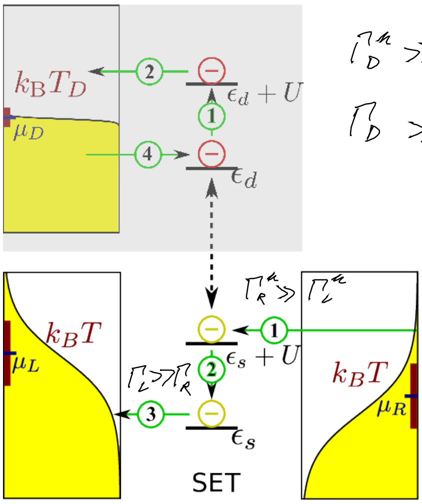
$$H_S = \varepsilon_s d_s^\dagger d_s + \varepsilon_d d_d^\dagger d_d + u\, d_s^\dagger d_s d_d^\dagger d_d$$

$$\Gamma_\nu = \Gamma_\nu(\varepsilon) \qquad \Gamma_\nu^u = \Gamma_\nu(\varepsilon+u)$$

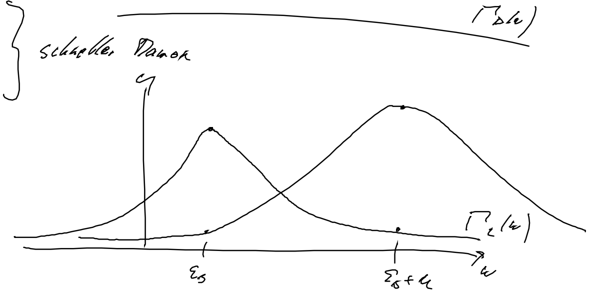
$$f_\nu = f_\nu(\varepsilon) \qquad f_\nu^u = f_\nu(\varepsilon+u)$$

3 Terminals $\longrightarrow$ 6 Zählfelder

i.z.SS $\quad I_E^{(L)} + I_E^{(R)} + I_E^{(D)} \to 0 \qquad I_M^{(D)} \to 0 \qquad I_M^{(L)} + I_M^{(R)} \to 0$



$$\Gamma_D^u \gg \Gamma_{L/R}^u$$
$$\Gamma_D \gg \Gamma_{L/R}$$
} schneller Dämon

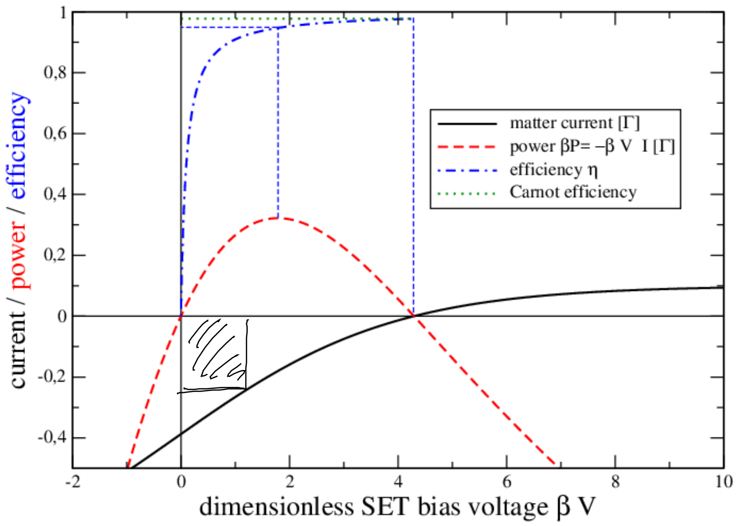


Energie-abhängige Tunnelraten

Umwandlung von Wärme in chem. Arbeit $\qquad P = -I_M(\mu_L - \mu_R)$

$$\eta = \frac{P}{\dot{Q}^{(L)} + \dot{Q}^{(R)}}$$

$$\dot{Q}^{(L)} + \dot{Q}^{(R)} = \underbrace{I_E^{(L)} + I_E^{(R)}}_{-I_E^{(D)} = \dot{Q}_{diss}^{(D)}} - \mu_L I_M^{(L)} - \mu_R \underbrace{I_M^{(R)}}_{-I_M^{(L)}} = \frac{P}{\dot{Q}_{diss}^{(D)} + P} \leq 1 - \frac{T_D}{T} = \eta_{Carnot}$$



→ Ausspeisen des Dämon-dots

$$\dot{P}_{ij} = \sum_{i'j'} \mathcal{L}_{ij,i'j'} P_{i'j'} \qquad P_i = \sum_j P_{ij}$$

System Dämon

$$\dot{P}_i = \sum_j \sum_{i'j'} \mathcal{L}_{(ij)(i'j')} P_{i'j'} = \sum_{i'} \left[\underbrace{\sum_{jj'} \mathcal{L}_{ij,i'j'}}_{\text{bekannt}} \underbrace{\frac{P_{i'j'}(t)}{P_{i'}(t)}}_{P_{j'|i'}} \right] P_{i'}(t) = \sum_{i'} \mathcal{L}_{ii'}(t) P_{i'}$$

bekannt $P_{j'|i'}$ kond. WS für Dämon in j' falls System in i'

genähert konstant

falls $\Gamma_D^{(u)} \gg \Gamma_{L/R}^{(u)}$

$$\bar{P}_{0|E} = \frac{\bar{P}_{E0}}{\bar{P}_E} = 1 - f_D \qquad \bar{P}_{1|E} = f_D$$

$$\bar{P}_{0|F} = 1 - f_D^u \qquad \bar{P}_{1|F} = f_D^u$$

$$\mathcal{L} = \begin{pmatrix} -\mathcal{L}_{FE} & +\mathcal{L}_{EF} \\ +\mathcal{L}_{FE} & -\mathcal{L}_{EF} \end{pmatrix}$$

$$\mathcal{L}_{EF} = \left[\underline{\Gamma_L(1-f_L)} + \Gamma_R(1-f_R)\right] \cdot (1 - f_D^u) + \left[\underline{\Gamma_L^u(1-f_L^u)} + \Gamma_R^u(1-f_R^u)\right] f_D^u$$

$$\mathcal{L}_{FE} = \left[\underline{\Gamma_L \cdot f_L} + \Gamma_R \cdot f_R\right] \cdot (1 - f_D) + \left[\underline{\Gamma_L^u f_L^u} + \Gamma_R^u f_R^u\right] f_D$$

$$\dot{S}_i = I_M^{(L)} \cdot \underbrace{\ln\left(\frac{\mathcal{L}_{EF}^{(L)} \cdot \mathcal{L}_{FE}^{(R)}}{\mathcal{L}_{FE}^{(L)} \mathcal{L}_{EF}^{(R)}}\right)}_{\mathcal{A}}$$

$$\mathcal{A} = \underbrace{\ln\left(\frac{\Gamma_L \Gamma_R^u}{\Gamma_L^u \Gamma_R}\right)}_{\text{Informations-fb}} + \underbrace{\ln\left(\frac{f_L f_R^u}{f_L^u \cdot f_R}\right)}_{\text{energetische fb}} + \mathcal{A}_0$$

ohne fb