13. Oszillatoren. 正弦波振荡器.

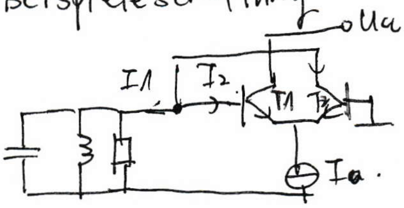
基本原理.

设开环放大倍数 $K(s)=\frac{U_o(s)}{U_i(s)}$，反馈系数 $F(s)=\frac{U_i'(s)}{U_o(s)}$，闭环 $K_u(s)=\frac{U_o(s)}{U_s(s)}$

$U_i(s)=U_s(s)+U_i'(s) \Rightarrow U_s(s)=U_i(s)-U_i'(s)$

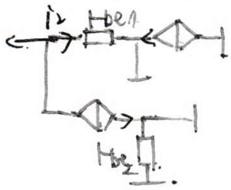
$K_u(s)=\frac{U_o}{U_i-U_i'(s)}=\frac{U_o/U_i}{1-\frac{U_i'(s)}{U_i(s)}}=\frac{K(s)}{1-F(s)\cdot K(s)}$ $\Rightarrow$ 自激振荡 $F(s)K(s)=1$，则没有输入电路也能稳定.

Beispieleschaltung



$I_1=-I_2 \Rightarrow I_1+I_2=0 \Rightarrow y_1+y_2=0$.

$y_1=\frac{1}{R}+j\omega C+\frac{1}{j\omega L}$　y_2 由于小信号分析.(线性等号)



$y_2=\frac{1}{H_{be1}}+g_{m2}$.

$i_2=\frac{u}{2}g_{m2}\cdot(-1)=-\frac{u}{2}\cdot g_{m2} \Rightarrow y_2=-\frac{g_{m2}}{2}=\frac{-I_0}{4U_T}$

$\Rightarrow \frac{1}{R}=\frac{I_0}{4U_T}$，$I_0=\frac{4U_T}{R}$，$j\omega C+\frac{1}{j\omega L}=0 \Rightarrow -\omega^2CL+1=0$　$f_c=\frac{1}{2\pi\sqrt{LC}}$

非线性分析. 电路方程.

$I_1=\frac{u}{R}+\frac{1}{L}\int u\,dt+C\frac{du}{dt}$　$I_2=\frac{I_0}{2}\left(1-\tanh\frac{u}{2U_T}\right)$

$\Rightarrow I_1+I_2=0$，$\frac{dI_1}{dt}+\frac{dI_2}{dt}=0$　$0=\frac{1}{R}\frac{du}{dt}+\frac{1}{L}u+C\frac{d^2u}{dt^2}-\frac{I_0}{4U_T}\left(1-\tanh^2\frac{u}{2U_T}\right)\frac{du}{dt}$

$\Rightarrow u+\frac{L}{R}\left[1-\frac{I_0R}{4U_T}\left(1-\tanh^2\left(\frac{u}{2U_T}\right)\right)\right]\frac{du}{dt}+LC\frac{d^2u}{dt^2}=0$

$\Rightarrow \frac{d^2u}{dt^2}+\frac{1}{RC}\left\{1-\frac{I_0R}{4U_T}\left[1-\tanh^2\left(\frac{u}{2U_T}\right)\right]\right\}\frac{du}{dt}+\frac{1}{LC}\cdot u=0$

产生正弦振荡. $A\cos\omega t$，$A\sin\omega t \Rightarrow c_1e^{j\alpha x}+c_2e^{-j\alpha x}$. 那么 $1-\frac{I_0R}{4U_T}\left[1-\tanh^2\left(\frac{u}{2U_T}\right)\right]=0$

$\begin{cases}0=\tanh^2\left(\frac{u}{2U_T}\right)\\ 1=\frac{I_0R}{4U_T}\end{cases} \Rightarrow \begin{cases}u=0\\ I_0=4U_T/R\end{cases}$　$\frac{du}{dt}$ 是阻尼项. 会使信号衰减.

$\Rightarrow u=\hat{u}_1\sin\omega t$，$f_1=\frac{1}{2\pi\sqrt{LC}}$

非线性近似. 傅里叶级数(一阶) ，$N(j\omega)$，非线性器件的跨导. G ~~线性器件~~的阻抗.

$I_2=F(u_e)=-\frac{I_0}{2}\left(1-\tanh\frac{\hat{u}_1\sin\omega t}{2U_T}\right)$，$a_1=0$　$b_1=-\frac{I_0}{2\pi}\int_0^{2\pi}\left(1-\tanh\frac{\hat{u}_1\sin\omega t}{2U_T}\right)\sin\omega t\,dt$

$N(j\omega)=\frac{b_1}{\hat{u}_1}$，$G(j\omega)=R+\frac{1}{j\omega C}+j\omega L \Rightarrow \frac{1}{j\omega C}+j\omega L=0 \Rightarrow f=\frac{1}{2\pi\sqrt{LC}}$

$\Rightarrow \frac{b_1}{\hat{u}_1}\cdot R=1 \Rightarrow b_1=\frac{\hat{u}_1}{R}=\frac{I_0}{2\pi}\int_0^{2\pi}\tanh\frac{\hat{u}_1\sin\omega t}{2U_T}\sin\omega t\,dt$.

$1=\frac{I_0}{\hat{u}_1}\mathrm{I}_1\left(\frac{\hat{u}_1}{2U_T}\right)=\frac{I_0}{2U_T}\cdot\frac{2U_T}{\hat{u}_1}\mathrm{I}_1\left(\frac{\hat{u}_1}{2U_T}\right)$

$$\sin^n x=\begin{cases}\frac{(2m-1)!!}{(2m)!!}\cdot\frac{1}{2}\cdot 2\pi & n=2m\\ 0, & n=2m+1\end{cases}$$

$\boxed{\text{奇次 }m-2}$

$\rightarrow \frac{x}{y}\cdot\frac{1}{\pi}\int_0^{2\pi}[\tanh(y\sin a)]\sin a\,da-1=0$. 其中，$y=\frac{\hat{u}_1}{2U_T}$，$x=\frac{I_0R}{4U_T}$.

① tanh 一阶近似　$\tanh(x)\approx x \Rightarrow \frac{x}{y}\cdot\frac{1}{\pi}\cdot y\cdot\frac{1}{2}\cdot 2\pi-1=0$，$x=1$，y muss kleine sein.

② tanh 三阶.　$\tanh(x)\approx x-\frac{x^3}{3} \Rightarrow \frac{x}{y}\cdot\frac{1}{\pi}\int_0^{2\pi}\left[y\sin^2a-\frac{y^3\sin a^4}{3}\right]da=\frac{x}{y}\cdot\frac{1}{\pi}\cdot\left(y\cdot\pi+y^3\cdot\frac{3}{4}\pi\right)-1=0$

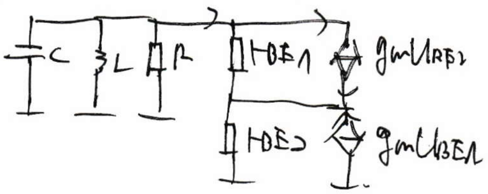
$\rightarrow y=\sqrt{1-\frac{1}{x}}$　$\hat{u}_1=4U_T\sqrt{1-\frac{4U_T}{I_0R}}$，$I_0\geq\frac{4U_T}{R}$.

③ tanh 三阶　$\tanh(x)\approx x-\frac{x^3}{3}+\frac{2x^5}{15}$，$x+xy^2\cdot\frac{3}{4}-\frac{2}{15}\cdot y^4\cdot\frac{15}{24}-1=0 \Rightarrow x>1$，$x<\frac{16}{13}$

$I_0>\frac{4U_T}{R}$，$\hat{u}_1=0$，$I_0<\frac{64U_T}{13R}=42.2\,mA$　$\frac{x}{4}-12\left(1-\frac{1}{x}\right)>0$　$\hat{u}_1=63.4\,mV$.

大信号　$\tanh(x)=\pm1 \Rightarrow \hat{u}_1=\frac{2}{\pi}RI_0$

OZ-01

1) 

$g_m = \frac{I_0}{2U_T}$ $\quad U_{BE1} = \frac{u}{2}$ $\quad U_{BE2} = -\frac{u}{2}$

$r = \frac{u}{i_2} = \frac{u}{\frac{u}{2}\cdot\frac{I_0}{2U_T}} = \frac{4U_T}{I_0}$, $|R| = |r|$, $I_0 = \frac{4U_T}{R} = 34.7\mu A$.

$g_m = 0.67 mS$

2) $f_1 = \frac{1}{2\pi\sqrt{LC}} \Rightarrow C = 2.533 nF$.

OZ-02.

1) $Z = \frac{1}{j\omega C_p + \frac{1}{j\omega L + \frac{1}{j\omega C} + R}}$, Cp vernachlässigt $Z = j\omega L + \frac{1}{j\omega C} + R$. Cp一般起微调作用 Q.品质因数.

$f_0 = \frac{1}{2\pi}\frac{1}{\sqrt{LC}} = 100.32 kHz$. $\quad Q = \frac{\omega_0 L}{r} = \frac{1}{\omega_0 C r} = \frac{L}{\sqrt{LC}\cdot r} = \frac{1}{r}\cdot\sqrt{\frac{L}{C}} = 99.91$. $\quad \omega_0 = \frac{1}{LC}\left(1-\frac{1}{Q^2}\right)$ 并联

2) $U_a = i_D \cdot R_D + U_{Ref}$

$i_D = |u_2 - i_D \cdot R_S \,//\, Z\,| g_m$ $\quad Z_S = \frac{1}{\frac{1}{R_S} + \frac{1}{j\omega L + \frac{1}{j\omega C} + R}}$, $Z_S \to V_1 = R_S$, $Z_S \to V_2 = \frac{R_S \cdot R}{R_S + R}$.

$\Rightarrow u_2 = \frac{i_D(g_m Z_S + 1)}{g_m}$ $\quad U_a = u_2 \frac{g_m R_D}{g_m Z_S + 1} + U_{Ref}$. $\Rightarrow V \frac{g_m R_D}{g_m Z_S + 1} + \boxed{\frac{U_{Ref}}{u_2}}$

1. Fall $V_1 = 0.367$ $\quad$ 2. Fall , $V_2 = 2.55$

3) $K = \frac{u_2}{u_a} = \frac{R_2}{R_1 + R_2} = \frac{1}{1 + \frac{R_1}{R_2}}$

~~$V_2 = g_m$~~ $\quad V_2 \cdot K = 1$ $\quad \frac{R_1}{R_2} + 1 = V_2$ $\quad \frac{R_1}{R_2} = V_2 - 1 = 1.55$.

4). $\boxed{U_a = V_2 \cdot \frac{1}{1+\frac{R_1}{R_2}} \cdot U_a + U_{Ref}}$

$U_{Ref} =$ $\quad I_D \cdot R_S = U_a \frac{R_1}{R_1 + R_2} \Rightarrow U_a = I_D \cdot R_S \cdot \left(1 + \frac{R_2}{R_1}\right) = U_a = I_D \cdot R_S \cdot V_1$. 375

$= 6.42 V$

$U_a - U_{Ref} = I_D \cdot R_D \Rightarrow U_{Ref} = U_a - I_D \cdot R_D = 5.42$ 375.

[注]. 无论Uref会影响放大倍数. 且UGSA与之很奇怪.

OZ-03.

1). $Y_1 = \frac{1}{R} + j\omega C + \frac{1}{j\omega L}$ $\quad f_1 = \frac{1}{2\pi\sqrt{LC}} = 1MHz$, (1000958.554 Hz)

2). $G(j\omega_1) = R$. $\quad N(j\omega) = \frac{\hat{I}_{2,1}}{\hat{u}} = \frac{-I_0}{2\pi \hat{u}_1} \int_0^{2\pi} \tanh\left(\frac{\hat{u}_1}{2U_T}\cdot \sin\omega_1 t\right) \sin\omega_1 t \, d\omega_1 t$

$|G(j\omega_1)| \cdot |N(j\omega_1)| = 1$.

3). aus Vorlesung. $\quad \int_0^{2\pi} \sin^n x = \begin{cases} \frac{2m-1}{2m}\cdot\frac{2m-3}{2m-1}\cdots\frac{1}{2}\cdot 2\pi \\ 0 , \; n = 2m-1 \end{cases}$

3.1) . $I_0 = \frac{4U_T}{R} = 34.7\mu A$

3.2) $\hat{u}_1 = \frac{4U_T}{\cdot}\sqrt{1 - \frac{4U_T}{R I_0}} = 38 mV$

3.3) pos. Halbwelle. T_2 sperrt. $I_2 = 0$ $\quad \boxed{\frac{I_0}{2} \Rightarrow I_0}$ $\;$ b1 扩大倍数. ×2.

neg. Halbwelle. T_1 sperrt. $I_2 = I_0$

$2\cdot\frac{x}{y}\cdot\frac{1}{\pi}\int_0^{\pi} \sin a - 1 = 0$ $\quad y = \frac{2}{\pi}x$

$2\cdot\frac{x}{y}\cdot\frac{2}{\pi} - 1 = 0$ $\quad x = \frac{I_0 R}{4U_T}$ $\quad y = \frac{\hat{u}_1}{2U_T}$ $\quad \hat{u}_1 = 2U_T \cdot \frac{4}{\pi}\frac{I_0 R}{4U_T} = \frac{2 I_0 R}{\pi} = 191 mV$