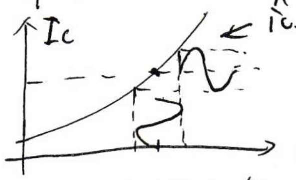
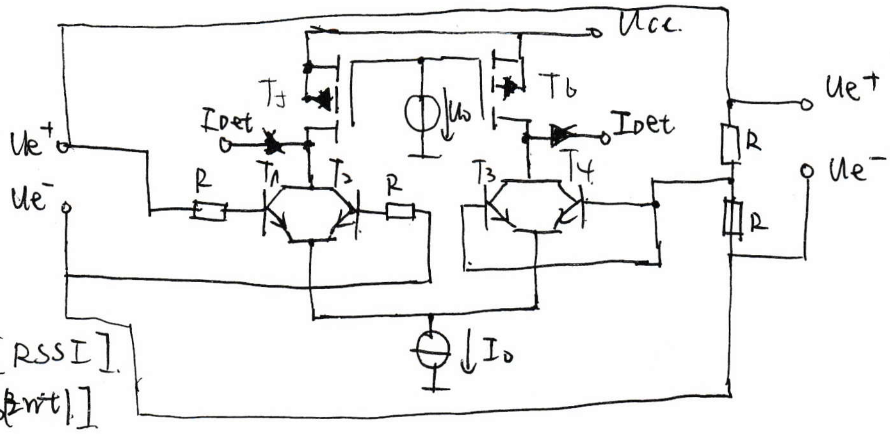
12. Funktionsschaltungen.

12.0 Grundsätze.

非线性元器件中.





12.1 功率检测器, Leistungsdetektor [RSSI].

$P = \frac{1}{2}\hat{u}^2$, $(\hat{u}\cos\omega t)^2 = \frac{1}{2}[\hat{u}^2 + \hat{u}^2\cos 2\omega t]$

对于 T1, T2.

$$I_{Det} + \frac{I_0}{2} = I_S\left[\exp\left(\frac{\frac{U_{diff}}{2} + U_{gl}}{U_T}\right) + \exp\left(\frac{\frac{U_{diff}}{2} + U_{gl}}{U_T}\right)\right] = \frac{2I_S}{} \exp\left(\frac{U_{gl}}{U_T}\right)\cosh\left(\frac{U_{diff}/2}{U_T}\right)$$

对于 T3, T4

$$-I_{Det} + \frac{I_0}{2} = 2I_S \left[\exp\left(\frac{U_{diff}/2}{U_T}\right)\right] \exp\left(\frac{U_{gl}}{U_T}\right)$$ ，约去共模信号(包含了静态工作点)

$$\frac{\frac{I_0}{2} - I_{Det}}{2I_S\left[\exp\left(\frac{U_{diff}/2}{U_T}\right)\right]} = \frac{\frac{I_0}{2} + I_{Det}}{2I_S\cosh\left(\frac{U_{diff}/2}{U_T}\right)} = \exp\left(\frac{U_{gl}}{U_T}\right)$$, $U_{diff}/2 \Rightarrow \hat{u}$

$$\Rightarrow \frac{\frac{I_0}{2} + I_{Det}}{\frac{I_0}{2} - I_{Det}} = \cosh\left(\frac{U_{diff}/2}{U_T}\right)$$

$$\Rightarrow \frac{I_0}{2} + I_{Det} = \frac{I_0}{2}\cosh\left(\frac{U_{diff}/2}{U_T}\right) - I_{Det}\cosh\left(\frac{U_{diff}}{U_T}\right)$$

$$I_{Det} = \frac{I_0}{2}\cdot\frac{\cosh\left(\frac{U_{diff}/2}{U_T}\right) - 1}{\cosh\left(\frac{U_{diff}/2}{U_T}\right) + 1}$$

$$= \frac{I_0}{2}\frac{(e^{\frac{x}{2}} - e^{-\frac{x}{2}})^2}{(e^{\frac{x}{2}} + e^{-\frac{x}{2}})^2} = \text{左边}!!$$

$$\Rightarrow \frac{I_0}{2}\tanh^2\left(\frac{U_{diff}}{4U_T}\right)$$ $x \ll 1$ 即 $\hat{u} \ll 4U_T$, $i_{Det} = \frac{I_0}{32}\left(\frac{U_{diff}}{U_T}\right)^2$

$U_{diff} = 2\hat{u}\cos\omega t$，通过低通滤波器后积分，由于后面仍然线性化。可以用跨导直接尝试

$I_{Det} + \frac{I_0}{2} = 2g_m U_{gl}$

$-I_{Det} + \frac{I_0}{2} = 2g_m\left[U_{gl} + \frac{U_{diff}}{2}\right]$

$-I_{Det} + \frac{I_0}{2} = I_{Det} + \frac{I_0}{2} - \frac{U_{diff}}{2}2g_m \Rightarrow 2I_{Det} = g_m U_{diff} \Rightarrow$

平方器件用线性计算不成功。两个差分则有可能变成两阶。

$\Rightarrow I_{Det} = \frac{I_0}{2U_T}U_{diff}$，可以发现不行。

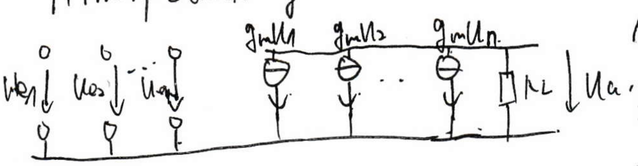
12.2. Summier-Schaltungen，应用(MIMO)

无源的电压难以实现.

方法. 被动
1. Transformator
2. RLC-Netzwerk
3. $\lambda/4$-Leitung

主动
1. Emitterstufe.
2. Basisstufe
3. Kaskode.

Prinzipschaltung



关于 Übung 中，数控加法器，大概分析(不一定对)(见思路)

1. T3, 线性区，T1 线性区或非线性，T2 线性或非线性.

2. 高电平，N管通，低电平 P管通.

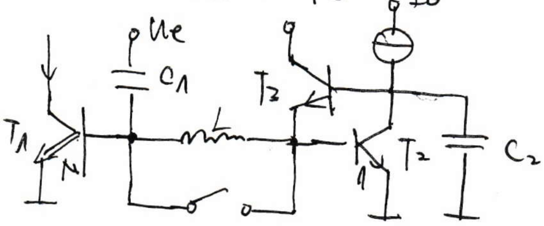
3. 就认为是个共源共栅放大.

4. 每个管子宽度不同，需要计算.

5. 栅电压控制电流

12.3 Programmierbare Stromquelle. 即为 Übung 中/上述的可控电流器件.

12.4 Emitterstufe



Fall 1，断开
Fall 2，连接

Fall 1: 电感呈理想态. 对于信号 (Leerlauf), 屏蔽了电容.

$U_{BE1} = U_{BEA} + \hat{U}_e \sin\omega t$, $U_{BE2} = U_{BEA}$.

$I_{C1} = I_{S1} \exp \frac{U_{BEA}}{U_T} \exp \frac{\hat{U}_e \sin\omega t}{U_T} = I_{C1} \exp\left(\frac{\hat{U}_e}{U_T} \sin\omega t\right)$

$\overline{I_{C1}} = I_{C1A} \cdot \frac{1}{2\pi} \int_0^{2\pi} \exp\left(\frac{\hat{U}_e}{U_T} \sin\omega t\right) d\omega t$

Normierung: $x = \frac{\hat{U}_e}{U_T}$ $y_1 = \frac{\overline{I_{C1}}}{I_{CA}}$ $y_1 = \frac{1}{2\pi} \int_0^{2\pi} \exp(x \sin\omega t) d\omega t = I_0(x) \geq 1$.

$\overline{U_{BE}} = U_{BEA}$.

Fall 2. Kurzschluss anstatt L. , 平均值是正了么. 平输入则不是了.

$U_{BE1} = U_{BE2}$. $\overline{I_{C2}} = I_{C2A} = I_0$ $\overline{U_{BE}} = U_{BEA} - \Delta U_{BE}$.

$I_{C2} = I_{C2A} \exp\left(\frac{-\Delta U_{BE}}{U_T}\right) \exp\left(\frac{\hat{U}_e}{U_T} \sin\omega t\right)$

$\overline{I_{C2}} = I_{C2A} = I_{C2A} \exp\left(\frac{-\Delta U_{BE}}{U_T}\right) \cdot \frac{1}{2\pi} \int_0^{2\pi} \left(\frac{\hat{U}_e}{U_T} \sin\omega t\right) d\omega t$

$1 = \exp\left(\frac{-\Delta U_{BE}}{U_T}\right) \frac{1}{2\pi} \int_0^{2\pi} \left(\frac{\hat{U}_e}{U_T} \sin\omega t\right) d\omega t$, 设 $x = \frac{\hat{U}_e}{U_T}$, $y_2 = -\frac{\Delta U_{BE}}{U_T}$.

$y_2 = -\ln[I_0(x)] < 0$ $\Delta U_{BE} > 0$

对于小信号.

$I_0(x)$, $I_1(x)$ 为贝塞尔函数.

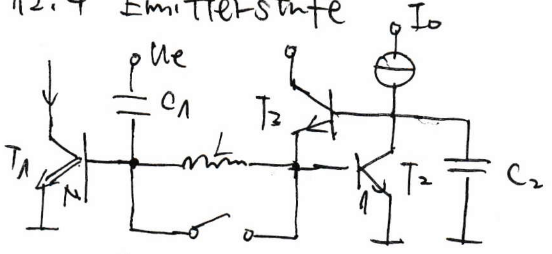
Kleinsignal, Fall 1.

$\hat{I}_{C1,1} = I_{C1A} \cdot \frac{1}{\pi} \int_0^{2\pi} \exp\left(\frac{\hat{U}_e}{U_T} \sin\omega t\right) \sin\omega t \, d\omega t$, 傅里叶级数.

$\hat{I}_{C1,1} = 2 I_{C1A} I_1(x) \longrightarrow g_{m1,1} = \frac{\hat{I}_{C1,1}}{\hat{U}_e} = 2 \frac{I_{C1A}}{U_T} \cdot \frac{I_1(x)}{x}$ $g_{m1} = \frac{I_{C1,A}}{U_T}$.

$\frac{g_{m1,1}}{g_{m1}} = 2 \frac{I_1(x)}{x} > 1$.

12.4 Emitterstufe



Fall 1，断开.
Fall 2，连接

Fall 1: 电感呈理想态. 对于信号 (Leerlauf)，屏蔽了电容.

$U_{BE1} = U_{BEA} + \hat{u}_e \sin\omega t$, $U_{BE2} = U_{BEA}$.

$I_{C1} = I_{S1} \exp\frac{U_{BEA}}{U_T} \exp\frac{\hat{u}_e \sin\omega t}{U_T} = I_{C1}\exp\left(\frac{\hat{u}_e}{U_T}\sin\omega t\right)$

$\bar{I}_{C1} = I_{C1A}\cdot\frac{1}{2\pi}\int_0^{2\pi}\exp\left(\frac{\hat{u}_e}{U_T}\sin\omega t\right)d\omega t$

Normierung: $x = \frac{\hat{u}_e}{U_T}$ $\quad y_1 = \frac{\bar{I}_{C1}}{I_{CA}}$ $\quad y_1 = \frac{1}{2\pi}\int_0^{2\pi}\exp(x\sin\omega t)\,d\omega t$
$= I_0(x) \geq 1.$

$\bar{U}_{BE} = U_{BEA}$.

Fall 2. Kurzschluss anstatt L.，输出仍是正弦. 输入则不是了.

$U_{BE1} = U_{BE2}$. $\quad \bar{I}_{C2} = I_{C2A} = I_0 \quad \bar{U}_{BE} = U_{BEA} - \Delta U_{BE}$.

$I_{C2} = I_{C2A}\exp\left(\frac{-\Delta U_{BE}}{U_T}\right)\exp\left(\frac{\hat{u}_e}{U_T}\sin\omega t\right)$

$\bar{I}_{C2} = I_{C2A} = I_{C2A}\exp\left(\frac{-\Delta U_{BE}}{U_T}\right)\cdot\frac{1}{2\pi}\int_0^{2\pi}\left(\frac{\hat{u}_e}{U_T}\sin\omega t\right)d\omega t$

$1 = \exp\left(\frac{-\Delta U_{BE}}{U_T}\right)\frac{1}{2\pi}\int_0^{2\pi}\left(\frac{\hat{u}_e}{U_T}\sin\omega t\right)d\omega t$ ，设 $x = \frac{\hat{u}_e}{U_T}$， $y_2 = -\frac{\Delta U_{BE}}{U_T}$.

$y_2 = -\ln[I_0(x)] < 0 \quad \Delta U_{BE} > 0$

对于大信号.

$I_0(x)$
$I_1(x)$ 为贝塞尔函数.

Kleinsignal，Fall 1.

$\hat{I}_{C1,1} = I_{C1A}\cdot\frac{1}{\pi}\int_0^{2\pi}\exp\left(\frac{\hat{u}_e}{U_T}\sin\omega t\right)\sin\omega t\,d\omega t$ ，傅里叶级数.

$\hat{I}_{C1,1} = 2 I_{C1A} I_1(x) \longrightarrow g_{m1,1} = \frac{\hat{I}_{C1,1}}{U_T} = 2\frac{I_{C1A}}{U_T}\cdot I_1(x) \qquad g_{m1} = \frac{I_{C1,A}}{\hat{u}_e\cdot U_T}$

$\frac{g_{m1,1}}{g_{m1}} = 2\frac{I_1(x)}{x} > 1.$

FS-01

1). für T_1, T_2 limit I_B. für T_3, T_4. ~~NUR Differen~~ ~~Udifferenz~~ $U = \frac{U_e^+ \mp U_e^-}{2} = \frac{U_{diff}}{2} + U_{gl} + U_A$.

$I_{Det} \sim P_e \sim U_e^2 \sim U^2_{diff}$

2). $U_{DD} - U_0 < U_{th0}$. ..

3). $i_{Det}(U_{diff})$ aus Vorlesung $i_{Det}(U_{diff}) = \frac{I_0}{2} \tanh^2\left(\frac{U_{diff}}{4U_T}\right)$

4). $\tanh\left(\frac{U_{diff}}{4U_T}\right) \approx \frac{U_{diff}}{4U_T}$ für $U_{diff} \ll 4U_T$. $i_{Det,N}(U_{diff}^2) = \frac{I_0}{32}\left(\frac{U_{diff}}{U_T}\right)^2$

5). ~~$i_{Det} = \frac{I_0}{2}$~~. $\left|\frac{i_{Det}(U_{diff,10}) - i_{Det,N}(U_{diff,10})}{i_{Det,N}(U_{diff,10})}\right| = 0.1$

$i_{Det} < i_{Det,N}$.

$\Rightarrow \frac{i_{Det}(U_{diff,10})}{i_{Det,N}(U_{diff,10})} - 1 = -0.1$. $\Rightarrow U_{diff,10} = \pm 40.8mV$.

FS-02. 这个电路没有在Vorlesung解决!!!

$I_{D3} = I_{Ref1} = 10mA$. $U_{DS3} = U_{GS3}$, T_3 饱和.

$U_{GS3} = \sqrt{\frac{2I_{Ref1}}{\beta}} + U_{th} = \sqrt{\frac{2I_{Ref1}}{\frac{W_3}{L}k_p}} = 0.665$. $U_{GS1} = U_{GS2} = \sqrt{\frac{2I_{Ref2}}{\frac{W_{1,2}}{L} \cdot k_p}} + U_{th} = 0.782V$. ↙ 假设线性区. 因为这是我们想要的区域

$U_{DS1} = U_{GS3} - U_{GS1,2}$, $U_{DS2} = U_{GS1,2} - U_{DS1} = U_{GS1,2} - (U_{GS3} - U_{GS1,2}) = 2U_{GS1,2} - U_{GS3}$

$\Rightarrow U_{DS1} = 0.253V$, $U_{DS2} = 0.459V$. $U_{DS sat\,1,2} = U_{GS1,2}\, U_{th} = 0.112V$;

$\Rightarrow T_1, T_2, T_3$ im Abschnürbereich

$I_{b0} = \frac{W_0}{W_{1,2}} I_{Ref2} = \frac{I_{Ref2}}{4} = 2.5mA$. $I_{b0} = \frac{2}{16} \cdot I_{Ref2} = 1.25mA$.

$I_{b1} = 2I_{b0} = 2.5mA$ $I_{b2} = 5mA$ $I_{b3} = 10mA$.

$I_e = I_0 + I_{bn} = \begin{cases} 2.5mA & 1.25mA \\ \cdots & 21.25mA \end{cases}$ h

Fs-03.

1). $I_{CA} = 50mA$ $I_{BA} = \frac{I_{CA}}{B_F} = 250mA$. $U_{BEA} = U_T \ln\left(\frac{I_{CA}}{I_S}\right) = 760.25mA$.

$\overline{U_{BE}} = U_{BEA} - \Delta U_{BE}$.

$\overline{I_{CA}} = I_{CA} = \frac{1}{2\pi}\int_0^{2\pi} I_S \exp\left(\frac{U_{BEA} + \hat{u}\sin\omega t}{U_T}\right)$ ~~$= \int I_{CA} \exp$~~ $\sin\omega t\, dt$

$= I_{CA} \cdot \frac{1}{2\pi}\int_0^{2\pi} \exp\left(\frac{\hat{u}\sin\omega t}{U_T}\right) dt \cdot \exp\left(\frac{\Delta U_{BE}}{U_T}\right) \Rightarrow$

$\exp\left(\frac{\Delta U_{BE}}{U_T}\right) = I_0\left(\frac{\hat{u}}{U_T}\right)$, nach Bronstein Interpolation

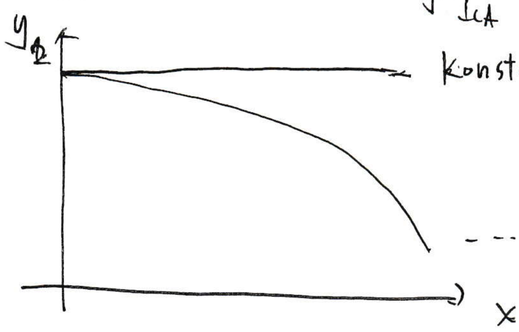
$\Delta U_{BE} = U_T \ln I_0\left(\frac{\hat{u}}{U_T}\right) > 0$. $\overline{U_{BE}} = U_{BEA} + \Delta U_{BE} = 746.68mV$.

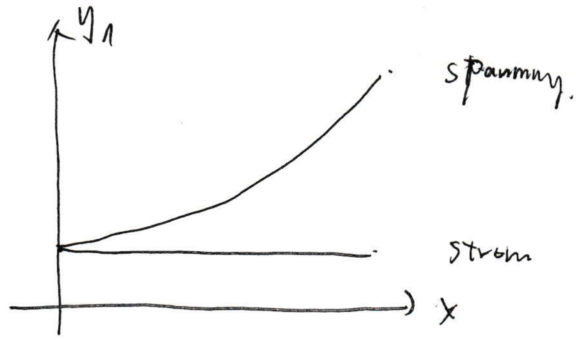
2) $\overline{I_C} = I_{CA} \cdot I_0\left(\frac{\hat{u}_e}{U_T}\right) = 84.26mA$ $U_B = U_{BEA} = 760.25mA$.

3) $\overline{I_C} =$ ~~$I_{C\,U_{BS}} I_0\left(\frac{\hat{u}_e}{U_T}\right) = 2I_{CA}$~~ $\Rightarrow 2I_{CA} = I_C \cdot \exp\left(\frac{-\Delta U_{BS}}{U_T}\right) \cdot I_0\left(\frac{\hat{u}}{U_T}\right)$

$\Rightarrow \Delta U_{BE} = U_T \ln\frac{I_0\left(\frac{\hat{u}}{U_T}\right)}{2} \Rightarrow U_{BS} = 754.1mV$.

(4) y_1, y_2. $y = \frac{\bar{I}_c}{I_{cA}}$ $x = \frac{\hat{u}_e}{u_T}$





(5) ① konstant strom.

$\hat{I}_{c1} = I_{cA} \exp\left(\frac{-\Delta U_{BE}}{U_T}\right) \cdot 2 \cdot \frac{1}{2\pi} \int_0^{2\pi} \exp\left(\frac{\hat{u}_e \sin\omega t}{U_T}\right) \sin\omega t \, d\omega t.$

$\exp\left(\frac{\Delta U_{BE}}{U_T}\right) = I_0\left(\frac{\hat{u}_e}{u_T}\right) \Rightarrow$ ~~$\Delta U_{BE} = U_T \ln 2 I_1(\frac{\hat{u}_e}{u_T})$~~

$g_{m1} = \frac{\hat{I}_{c1}}{\hat{u}_e} = \frac{2 I_1(\frac{\hat{u}_e}{u_T})}{\hat{u}_e I_0(\frac{\hat{u}_e}{u_T})} \cdot I_{cA} = 1.5145$, $k = 2 I_{cA}$

② konstantspannung.

$\hat{I}_1 = 2 I_{cA} \cdot I_1\left(\frac{\hat{u}_e}{u_T}\right)$ $k = 2 I_{cA} \cdot I_0\left(\frac{\hat{u}_e}{u_T}\right)$

$= 102.04 mA$. $g_{m2} = 2.5515$

③ Eingestellt.

$\hat{I}_1 = 2 \cdot \frac{1}{2\pi} \int_0^{2\pi} \exp(\ldots) \ldots d\omega t \cdot \exp\left(\frac{U_{BE}}{u_T}\right)$

$= \frac{2 I_{cA}}{I_0(\frac{\hat{u}_e}{u_T})} \cdot 2 \cdot I_1\left(\frac{\hat{u}_e}{u_T}\right)$

$= 2Z I_{cA} \cdot \frac{I_1(\frac{\hat{u}_e}{u_T})}{I_0(\frac{\hat{u}_e}{u_T})}$ ~~200mA~~ $g_{m3} = 2.01S$ $k = 2Z I_{cA}$.