7. Analogschalter.

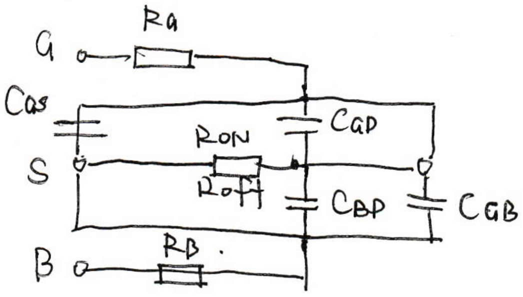
7.1 Schaltungtypen (SKRIPT)

7.2. MOSFETs im aktiven Bereich und im Sperrbereich

Active bereich，可变电阻区，~~饱~~（非饱和区）

—开位模型有很多个，较为精确的就属于SPICE模型（有很多关于工艺制造上的参数）

CMOS制造 PDF — 49页



Level 1

$\beta = u_0 C_{ox}'' \frac{W}{L}$

Level 2.

$u_s = U_0 \left[\frac{\varepsilon_{Si}}{\varepsilon_{ox}} \cdot \frac{UCRIT \cdot TOX}{(U_{GS}-U_{th})}\right]^{UEXP}$ (falls $u_c < u_0$)

UEXP = 0,5

UCRIT = $8 \times 10^4 \frac{V}{cm}$

TOX = 100nm

U0 = $580\,cm^2/Vs$

Level 3.（经验公式） $u_s = \frac{U_0}{1+THETA(U_{GS}-U_{th})}$，THETA 就是经验参数.

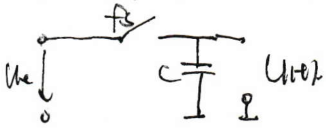
— 可变电阻区的直流电阻和交流电阻.

$I_{DN} = \beta_N (U_{GSN} - U_{th,N} - \frac{U_{DSN}}{2}) U_{DSN}$，$U_{DSN} = U_a - U_e$.

$R_{ON} = \frac{U_{DSN}}{I_{DN}} = \frac{1}{\beta_N (U_{GSN} - U_{th,N} - \frac{U_a - U_e}{2})}$，因为我们为了工作在~~饱和区~~ 可变电阻，~~使~~ 可以使 $U_{DSA}=0$. $U_G - U_S \geq U_{th}$ $U_G - U_D \geq U_{th}$

那么，$r_{ON} = \frac{\partial U_{DS}}{\partial I_D}\Big|_{U_{DSA}=0} = \frac{1}{\beta_N (U_{GSA} - U_{th,N})} = R_{ON,N}\Big|_{U_{DSA}=0}$

开关电路、系统.



$U_e = U_0$，$U(0)=0$、~~[illegible]~~ 闭合 开关 ← 充电. $\tau_{on} = CR_{ON}$.

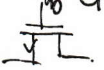
$U(t) = U_0 [1 - \exp(\frac{-t}{\tau})]$，$\varepsilon = \frac{U_0 - U(T_s/2)}{U_0}$

$\frac{U(\frac{T_s}{2})}{U_0} = 1 - \varepsilon = 1 - \exp(\frac{-T_s}{2\tau}) \Rightarrow \varepsilon = \exp(\frac{-T_s}{2\tau}) \Rightarrow R_{ON} = \frac{T_s}{2C\ln(1/\varepsilon)}$，例如 72 kΩ

~~U断开~~ 断开开关 放电：$U(0) = U_0$ $\frac{U(t)}{U_0} = \exp(\frac{-t}{\tau})$，$\varepsilon = \frac{U_0 - U(T_s/2)}{U_0} \Rightarrow R_{OFF} = \frac{T_s}{2C\varepsilon}$，100MΩ

解释说明：当为放电状态时，如果开关用 N MOS管代替，则会根据 U_0 的大小，进入不同的工作状态.

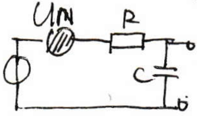
若 ~~$U_0 > U$~~ $U_{DD} - U_0 < U_{th}$，则为饱和区→可变电阻区. 若 $U_{DD} - U_0 > U_{th}$，只有可变电阻区



可变电阻区则可以使用上面的导通电阻. 那么这个电路就是一个采样电路

NMOS 而当 ~~Ue~~ 输入电压为 U_{DD} 时，即为 U_G 时则不能完美跟随

Rauschen in RC-Gliedern



$S_{UN} = 4kTR$.

$S_{UaN} = |G|^2 S_{UN}$.

输出的噪声与R无关

而减少噪声只能增大电容，而 $f_{3dB} = \frac{1}{2\pi RC}$

增加电容则会减小带宽.

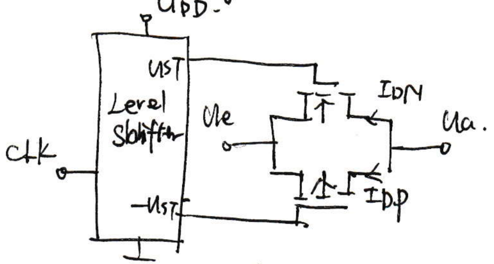
$G = \frac{1}{1+R\cdot sC}$

$\Rightarrow U^2_{an,eff} = 4kTR \int_0^\infty \left|\frac{1}{1+RC\cdot j\omega}\right|^2 d\omega$

$= 4kTR \cdot \int_0^\infty \frac{\sqrt{1+(RC)^2}}{1+RC\omega^2} d\omega = \frac{kT}{C}$.

$= \int \frac{dx}{x^2+1} = \tan^{-1} x$

7.3 Anwendungen



导通条件. NMOS, 可变电阻区.

$U_{ST} - U_e > U_{th,N}$,

$U_{ST} - U_a < U_{th,N}$.

PMOS, 可变电阻区

$-U_{ST} - U_e < U_{th,P}$

$-U_{ST} - U_a \ngtr U_{th,P}$

$G_{ON,N} = \frac{I_{DN}}{U_{DSN}} = \beta_N\left(U_{ST} - U_{th,N} - \frac{U_a - U_e}{2}\right)$

疑问 $\frac{U_a+U_e}{2} = U_{DS}$?

$G_{ON,P} = \beta_P\left(U_{ST} + U_{th,P} + \frac{U_a - U_e}{2}\right)$

根据SPICE模型. $R_{ON} = \frac{1}{G_{ON,N} + G_{ON,P}}$, mit $\beta = \beta_N = \beta_P$. $R_{ON} = \frac{1}{2\beta(U_{ST} - U_{th})} = r_{ON}$

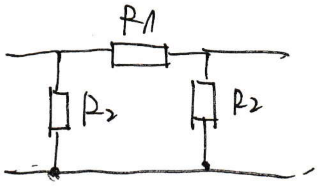
$(U_{DS} = 0)$

7.4. 衰减器.

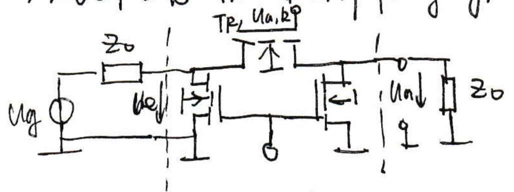
① 可以调整信号的大小.

② 可以改善阻抗匹配, 可以缓冲阻抗的变化.

VL7 中采用的是π型的衰减器.



MOSFETs im Dämpfungsgliedern.



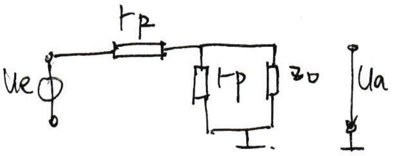
可以用近似模型计算.

(I) 计算特性阻抗.

$Z_0 = r_P // (r_R + r_P // Z_0)$

$\Rightarrow r_R = 2Z_0 \frac{r_P/Z_0}{(r_P/Z_0)^2 - 1}$

(II) 计算衰减系数. V, 即为通用 $N = \frac{U_a}{U_e}$.



$\Rightarrow$ 参考 Foto – Vorlesung 7

$V = \frac{r_P/Z_0 - 1}{r_P/Z_0 + 1} \Rightarrow \frac{r_P}{Z_0} = \frac{1+V}{1-V}$.

即 $R_2 = R_C \cdot \frac{N+1}{N-1}$

$R_1 = R_C \frac{N^2 - 1}{2N}$

AS-01.

工作在可变阻区.有 $r_{min} \Rightarrow U_{GS}=U_{GSmax}$, $U_{DS}=0$.

$I_D=\beta_N\left(U_{GSN}-U_{th,N}-\frac{U_{DSN}}{2}\right)U_{DSN}$

~~β~~ $R_{ON}=1/\frac{I_D}{U_{DSN}}=\frac{1}{\beta_N\left(U_{GSN}-U_{thN}-\frac{U_{DSN}}{2}\right)}$

$r_{ON,min}=r_{ON}|_{U_{DSN}=0}=\frac{1}{\beta_N(U_{GSN}-U_{thN})}$

$U_{GSN}=U_{GSmax}$.

$\Rightarrow \beta=\frac{1}{10(3-0.5)}=0.04$.

$\Rightarrow W/L=\beta/kp=4\times10^{-2}/2\times10^{-4}=2\times10^{2}=200$

$r_{on,max}=\frac{1}{\beta_N(U_{GS,min}-U_{th,N})}=\frac{1}{0.2\times0.04}=125\Omega$

$U_{a\,max}=U_e\cdot\frac{r_{on,max}}{r_{on,max}+R}$

$U_{a\,min}=U_e\frac{r_{on,min}}{r_{on,min}+R}$

$\Rightarrow \alpha=\frac{1+\frac{R}{r_{on,min}}}{1+\frac{R}{r_{on,max}}}=\frac{101}{9}\Rightarrow \alpha_{dB}=20\lg\alpha=21dB$.

AS-02.

$U_{GS1}=U_{GN1}-U_e=1.5V>0.6V$，导通.　　$U_{GN2}=0$，~~截~~ $U_{GS2}=$ ~~-0~~ $\overset{0}{U_{on}}$, ~~截~~, $U_{GD2}=0$

$U_{DS1}=U_{D1}-U_e=$ ~~U_{D1}~~ $U_a-U_e=-U_e$.

开始时. ~~U_{DS1} 对于~~

T1 处于 Aktive Bereich, T2. Sperrenbereich

T1 在预夹断点.

$U_{G1}-U_a=U_{th}\Rightarrow U_a=2.5-0.6=1.9>1$

所以 T1 处于 Aktive bereich, T2 Sperren.

1) 已经证毕.

2). $R_{ON}=\frac{1}{\beta_N\left(U_{GSN}-U_{thN}-\frac{U_{DS}}{2}\right)}$, $\beta=kp\cdot\frac{W_{N1}}{L}=160\times10^{-6}\times1.2\times10^{-6}\times\frac{1}{0.24}\times10^{6}=8\times10^{-4}$ A/V^2

am Anfang

$R_{ON}(0)=\frac{1}{\beta\left(U_{GSN}-U_{th,N}-\frac{U_a-U_e}{2}\right)}=\frac{1}{8\times10^{-4}\cdot\left(1.5-0.6+\frac{1}{2}\right)}=$ ~~3125~~ 892.8Ω

am End ~~R_{ON}~~:

$R_{ON}(1)=\frac{1}{\beta(U_{GSN}-U_{th,N})}=1389\Omega$

$\boxed{\begin{array}{l} fF=10^{-15}F \\ pF=10^{-12}F. \end{array}}$

$R_{ers}=\frac{R_{ON}(1)+R_{ON}(0)}{2}=1.14k\Omega$

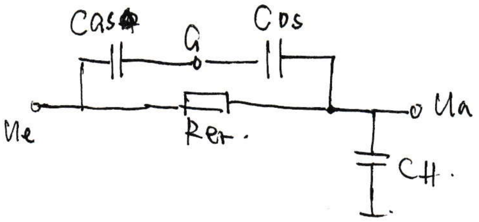
3) $U(t)=U_e\cdot\left[1-\exp\frac{-t}{R\cdot C}\right]$, $R\cdot C=R_{ers}\cdot C_H$

$\varepsilon=\frac{U_0-U(T_s/2)}{U_0}\Rightarrow U(T_s/2)=U_0(1-\varepsilon)\Rightarrow U_a=U(T_s/2)=U_0\left[1-\exp\frac{-\frac{T_s}{2}}{\tau}\right]=U_0(1-\varepsilon)$

$\Rightarrow \varepsilon=\exp\frac{-T_s/2}{\tau}$　　$T_s=-2\tau\ln\varepsilon\Rightarrow -2\cdot R_{er}\cdot C_H\cdot\ln\varepsilon=7.88\,ns\Rightarrow T_a=3.94\,ns$

4) 进入~~放电~~保持.

$C_{GSA}=C_{DS\cdot A}=C''_{ox}\cdot W\cdot L/2+C'_{GSO}\cdot W=1.14pF$　　$C_{GS\cdot Ns}=C_{GD\cdot N}=0.24pF$.



① 这里忽略了 Rers，因为太难算了. 而且电流也不大. 忽略省了简单。

② 要为null和是基座接地的非平衡状态.

③ 计算偏差和可以使用电荷守恒的定律计算.

一切推想TX.

Teil 1 是 CDS/Cas 电压变化. 电荷转移到 CH (2.5 - 1.6

Teil 2 是 人把那改完 1.1.6) . 结果为负

这题有病 !!!

am Anfang.

$U_{GS}(0) = 1.5V$

$U_{DS}(0) = 1.5V$

$U_a(0) = 1V$

Teil 1. im Aktivbereich, bis $U_G = U_{th} + U_e = 1.6V$.

$$\Delta U_{a1} = \frac{1}{j\omega C_H} \Big/ \left(\frac{1}{j\omega C_H} + \frac{1}{j\omega C_{GSN1.A}}\right) \cdot [U_{GS}(0) - U_{GS}(A-S)]$$

$= -2.052mV$.

Teil 2. im Sperrbereich.

$$\Delta U_{a2} = \frac{C_{GS\,N1.S}}{C_H}[U_{GN1(neu)} - U_{GN1(alt)}]$$

$= -0.768mV$.

$\Delta U_a = \Delta U_{a1} + \Delta U_{a2} = -2.82mV$

等效为 C_{GD1}

$\Uparrow$

5) 由于 T_2 管所用容都等于，所以可以将 Cas 和 Cap 并联. $\Rightarrow C_{GD1} = 2C_{D2} \Rightarrow W_{N,2} = \frac{W_{N,1}}{2}$

$= 0.6\mu m$.

As-03

1) für T_N. $U_{GN} - U_e \geq U_{th,N} \Rightarrow U_e \leq U_{GN} - U_{th,N} = 2V$

für T_P $U_e \geq U_{pN} - U_{th,P} = 0.5V$.

$0.5 \leq U_e \leq 2V$

2). $r_{ON}|_{U_{DS}} = \frac{1}{\beta(U_{GS} - U_{th})}$

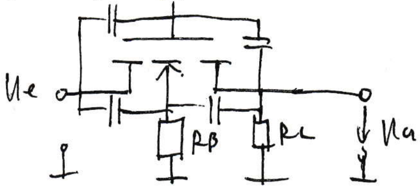
$r_{ON,N}|_{U_{DS}=0} = \frac{1}{\beta_N(U_{GS,N} - U_{th,N})}$, $r_{ON,P}|_{U_{DS}=0} = \frac{-1}{\beta_P(U_{GS,P} - U_{th,P})}$

$r_{ON} = \frac{r_{ON,P} \cdot r_{ON,N}}{r_{ON,P} + r_{ON,N}} = 250\Omega$

3. $\beta_{N,P} = \beta_{K,P}$, aus (2). können β berechnen.

$r_{on,n} = r_{on,p} = \left| \frac{1}{\beta(U_{GS} - U_{th} - U_{DS})} \right|$

As-04



变成器.