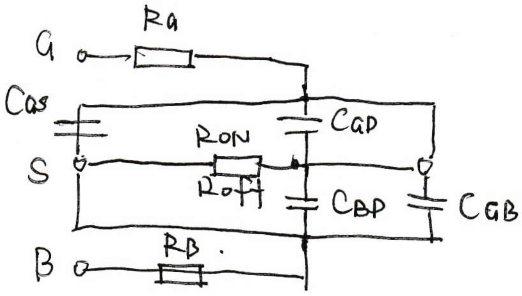
7. Analogschalter.

7.1 Schaltungstypen (SKRIPT)

7.2. MOSFETs im aktiven Bereich und im Sperrbereich

Activebereich，可变电阻区，(非饱和区)

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



Level 1

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

CMOS 制造 PDF — 49页

Level 2.

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

$UEXP = 0{,}5$

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

$T_{OX} = 100\,nm$

$U_0 = 580\,cm^2/Vs$

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

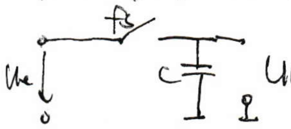
— 可变电阻区的直流电阻和交流电阻.

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

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

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.



$U_e = U_0$，$\boxed{U(0) = 0，闭合开关}$ ← 充电. $\tau_{on} = CR_{ON}$.

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

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

$\boxed{断开开关}$：放电 $U(0) = U_0$ $\frac{U(t)}{U_0} = \exp\left(\frac{-t}{\tau}\right)$，$\varepsilon = \frac{U_0 - U(T_s/2)}{U_0} \Rightarrow R_{OFF} = \frac{T_s}{2C\varepsilon}$，700 MΩ

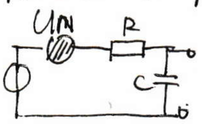
$\boxed{解释说明}$：当为放电状态时，如果开关用 NMOS 管代替，则会根据 U_0 的大小，进入不同的工作状态.

若 ~~$U_0 >$~~ $U_{DD} - U_0 \leq U_{th}$，则为饱和区 → 可变电阻区、若 $U_{DD} - U_0 \geq U_{th}$，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 而当输入电压为 U_{DD} 时，和为 U_G 时则不同能完美跟随

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 $f_{3dB} = \frac{1}{2\pi RC}$

增加电容则会影响带宽.

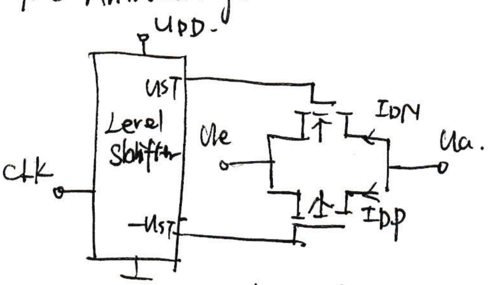
$G = \frac{1}{1 + R \cdot sC}$

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

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

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

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

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

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

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

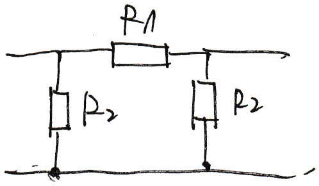
疑问 $\frac{U_a + U_e}{2} = U_{DS}$?

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

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.

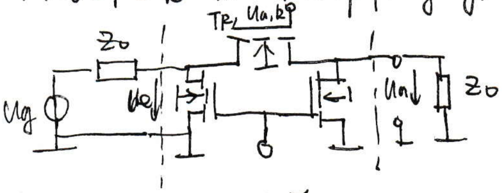


① 可以调整信号的大小.

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.



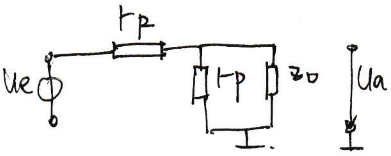
可以用近似模型计算.

(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 $N = \frac{U_a}{U_e}$.



⇒ 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.

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

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

$$\cancel{\beta}\ R_{ON} = 1 / \frac{I_D}{U_{DSN}} = \frac{1}{\beta_N (U_{GSN} - U_{thN} - \frac{U_{DSN}}{2})}$$

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

$U_{GSN} = U_{GS\,max}$.

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

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

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

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

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

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

AS-02.

$U_{GS1} = U_{GN1} - U_e = 1.5V > 0.6V$, 导通.　　$U_{GN_2} = 0$, $U_{GS2} = \cancel{0}\ 0$ ~~ohm~~, $U_{GD2} = 0$

$U_{DS1} = U_{D1} - U_e. = \cancel{U_{D1}}\ U_a - U_e = -U_e.$

开始时. ~~U_{DS1} 对于~~

T1 处于 Aktive Bereich, T2. Sperrenbereich

T1 会预夹断点.

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

所以 T1 处于 Aktive bereich, T2 Speren.

1) 已经证明.

2). $R_{ON} = \frac{1}{\beta_N (U_{GSN} - U_{thN} - \frac{U_{DS}}{2})}$, $\beta = kp \cdot \frac{W_{N1}}{L} = 160\times10^{-6} \times 1.2\times10^{-6} \times \frac{1}{0.24}\times10^{6} = 8\times10^{-4}$ A/V²

am Anfang

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

am End ~~R_{ON1}~~:

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

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

$\boxed{fF = 10^{-15} F \quad pF = 10^{-12} F.}$

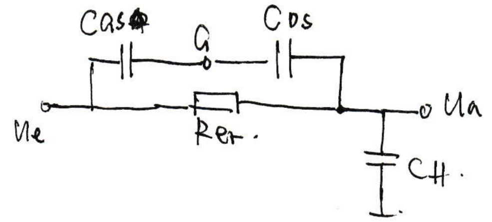
3) $U(t) = U_e \cdot [1 - \exp\frac{-t}{R\cdot C}]$, $R\cdot C = R_{ers} \cdot C_H$

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

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

4) 进入保持.

$$C_{GS\,A} = C_{DS\cdot A} = c''_{ox}\cdot W\cdot L/2 + C'_{GSO}\cdot W = 1.14\,pF \qquad C_{GS\cdot N_3} = C_{GD\cdot N} = 0.24\,pF.$$



① 这里忽略了 R_{BTs}，因为太难算了. 而且电流也不大. 忽略了简单。

② 第一步 null 都是考虑接地的非平衡状态.

③ 计算偏差都可以使用电荷守恒的定律计算.

- - - .

一切都想了.

am Anfang.

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

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

$U_a(0) = 1V$

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

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

$= -2.052 mV$.

Teil 2. im Sperrbereich.

$$\Delta U_{a2} = \frac{C_{GSN1.S}}{C_H}[U_{GN1(en)} - U_{GN1(alt)}]$$

$= -0.768 mV$.

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

等效为 C_{aD1}

5) 由于 T_2 管所用容都是一样, 所以可以将 C_{aS} 和 C_{aD} 并联. $\Rightarrow C_{GD1} = 2C_{DB2} \Rightarrow W_{N,2} = \frac{W_{N,1}}{2} = 0.6\mu m$.

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 $U_e \geq U_{PN} - U_{th,P} = 0.5V$.

$0.5 \leq U_e \leq 2V$

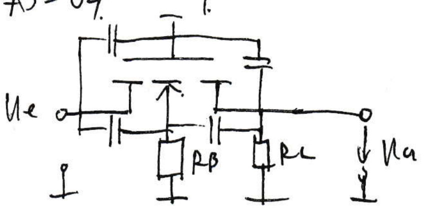
2). $r_{ON}|_{U_{DS}} = \frac{1}{\beta(U_{GS} - U_{th})}$

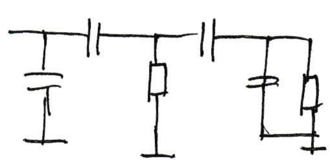
$r_{ON,N}|_{U_{DS}=0} = \frac{1}{\beta_N(U_{GS,N} - U_{th,N})}$, $r_{ON,P}|_{U_{DS}=0} = \frac{-1}{\beta_P(U_{GS,P} - U_{th,P})}$

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

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

$$r_{ON,N} = r_{ON,P} = \left|\frac{1}{\beta(U_{GS} - U_{th} - U_{DS})}\right|$$

As-04 



高通滤波器.