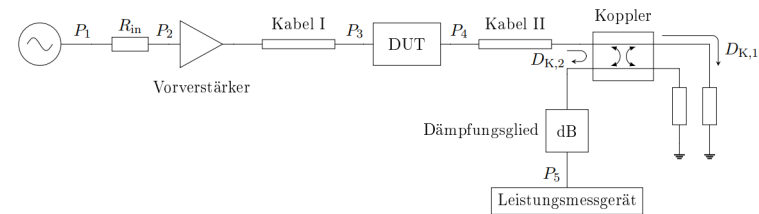


Name: [REDACTED]	Vorname: [REDACTED]	Anfangsbuchstabe: [REDACTED]	Nummer:
Matrikelnummer: [REDACTED]			

Bewertung – wird vom Institut ausgefüllt

[REDACTED] (3)	[REDACTED] (2)	[REDACTED] (3)	[REDACTED] (3)	[REDACTED] (2)	[REDACTED] (3)	[REDACTED] (2)	[REDACTED] (18)
[REDACTED] (2)	[REDACTED] (7)	[REDACTED] (6)	[REDACTED] (4)	[REDACTED] (3)	[REDACTED] (+1)		[REDACTED] (22 + 1)
[REDACTED] (6)	[REDACTED] (7)	[REDACTED] (9)	[REDACTED] (4)				[REDACTED] (26)
[REDACTED] (66 + 1)				[REDACTED] +/0/-			

Aufgabe 17



max. Leistung des Signalgenerators	$P_{1,max} = 10 \text{ mW}$
Verstärkung des Vorverstärkers	$G_{VV} = 1000$
max. Eingangsleistung des Vorverstärkers	$P_{2,max} = 20 \text{ mW}$
Vorwärtsdämpfung des Kopplers	$D_{K,1} = 1 \text{ dB}$
Koppeldämpfung des Kopplers	$D_{K,2} = 20 \text{ dB}$
Dämpfung des Dämpfungsglieds	$D_{DG} = 23 \text{ dB}$
max. Leistung am Leistungsmessgerät	$P_{5,max} = 50 \text{ mW}$
Verstärkung des DUTs	$G = 10 \dots 40$

a) Leistung P : $P[\text{mW}] \rightarrow P[\text{dBm}]$

$$P[\text{dBm}] = 10 \lg \left(\frac{P[\text{mW}]}{1 \text{ mW}} \right)$$

Verstärkung G : $G[\text{dB}] \rightarrow G[\text{dB}]$

$$G[\text{dB}] = 10 \lg (G[\text{dB}])$$

b) geg : $Z_{in} = R_{in} + j X_{in} = R_{in}$; $X_{in} = 0$
 $Z_{in}^* = R_{in} - j X_{in} = R_{in}$
 ges : $Z_{in} = R_{in} + j X_{in}$

$$|I| = \frac{|U|}{|Z|} = \frac{U_q}{\sqrt{(R_{in} + R_{in}')^2 + (X_{in} + X_{in}')^2}}$$

$$P_{2,max} = |I|^2 \cdot R_{in}' = \frac{U_q^2 R_{in}'}{(R_{in} + R_{in}')^2 + (X_{in} + X_{in}')^2}$$

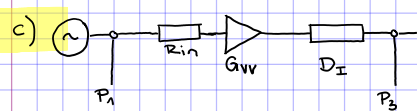
Annahme : $R_{in} \wedge R_{in}'$ feste Werte : $\rightarrow X_{in}' = -X_{in}$

$$P_{2,max} = \frac{U_q^2 R_{in}'}{(R_{in} + R_{in}')^2} \quad \frac{dP}{dR_{in}'} = \frac{(R_{in} + R_{in}')^2 - 2 R_{in}' (R_{in} + R_{in}')}{(R_{in} + R_{in}')^4} \stackrel{!}{=} 0 \rightarrow R_{in}' = R_{in}$$

$$\rightarrow Z_{in}' = Z_{in}^* = R_{in}$$

$$G_{2,1} = 10 \cdot \lg \left(\frac{P_2 \cdot 0,5}{P_1} \right) = -3,0103 \text{ dB} = -D_{2,1}$$

neg. Verstärkung = Dämpfung



$$P_1 = 10 \cdot 10^{-6} \text{ W}$$

$$P_3 = 4,68 \cdot 10^{-3} \text{ W}$$

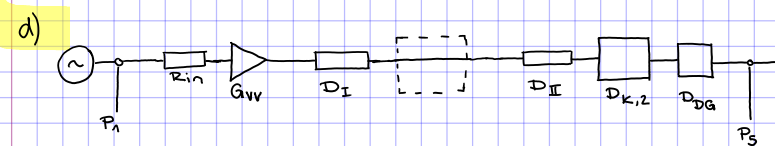
ges : D_I

$$G_{3,1} = 10 \cdot \lg (P_3/P_1)$$

$$= G_{2,1} + G_{VV} - D_I$$

$$G_{3,1} = 468$$

$$D_I = 0,2872 \text{ dB}$$



$$G_{5,1} = 10 \cdot \lg (P_5/P_1)$$

$$= G_{2,1} + G_{VV} - D_I - D_{II} - D_{K,2} - D_{DG}$$

$$= G_{3,1} - D_{5,4}$$

$$D_{II} = 0,2 \text{ dB}$$

geg : $P_1 = 10 \cdot 10^{-6} \text{ W}$
 $P_5 = 224 \cdot 10^{-9} \text{ W}$

ges : D_{II}

$$D_{5,4} = 45,2 \text{ dB}$$

e) geg : $P_3 = 1 \text{ W}$
 ges : P_1 in mW & dBm
 $\frac{P_3}{P_1} = G_{3,1}$
 $P_1 = 2,1368 \text{ mW}$
 $= 3,2975 \text{ dBm}$

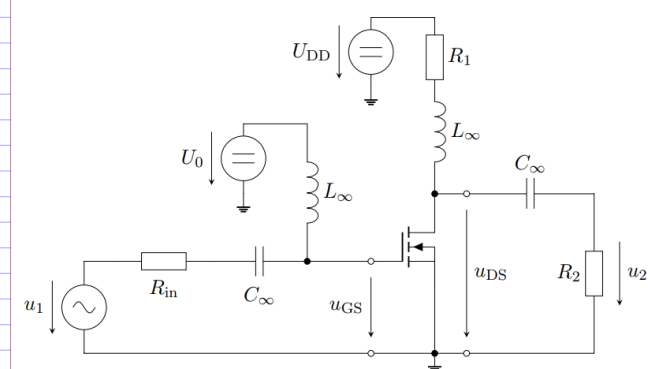
f) geg : $P_5 = 0,8 \text{ dBm}$ $P_3 = 1 \text{ W} = 30 \text{ dBm}$
 ges : P_4
 $P_4 - D_{5,4} = P_5$
 $P_4 = 44 \text{ dBm}$
 $P_3 + G_{4,3} = P_4$
 $G_{4,3} = 14 \text{ dB}$
 $= 10^{\frac{G_{4,3}[\text{dB}]}{10}} = 25,12 \hat{=} G_{DUT}$

g)

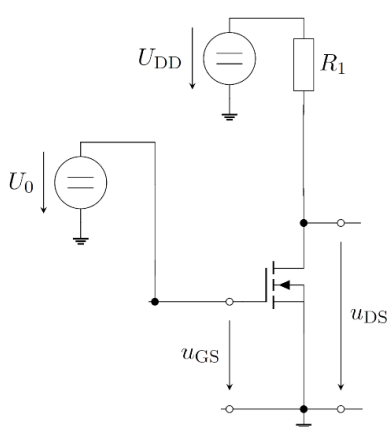
i) $P_{5,max}$ Leistungsmessgerät $< P_4$ Ausgangspg. DUT

ii) P_3 Eingangspg. DUT $> P_1$ Ausgangspg. Signalgenerator

Aufgabe 18 A:



a)



C_{∞} Leerlauf Kurzschluss
 L_{∞} Kurzschluss Leerlauf
 $= \sim$

$$U_0 = U_{GS}$$

$$U_{DD} = U_{R1} + U_{DS} = I_D \cdot R_1 + U_{DS}$$

$$U_{DS} = U_{DD} - I_D \cdot R_1$$

b) ges: $U_{DS}(U_{GS})$

$$i(u_{GS}, u_{DS}) = \begin{cases} 0, & u_{GS} < U_{th} \quad (\text{Sperrbetrieb}), \\ \beta \left((u_{GS} - U_{th}) u_{DS} - \frac{1}{2} u_{DS}^2 \right), & u_{GS} - U_{th} > u_{DS} \quad (\text{linearer Betrieb}), \\ \frac{\beta}{2} (u_{GS} - U_{th})^2, & u_{GS} - U_{th} \leq u_{DS} \quad (\text{Sättigungsbetrieb}). \end{cases}$$

$$U_{DD} = 7V, \quad \beta = 50 \text{ mA/V}^2, \quad U_{th} = 0,5V, \quad R_1 = 50\Omega, \quad R_2 = 1k\Omega.$$

- Sperrbetrieb:

$$U_{DS} = U_{DD} - I_D \cdot R_1 = U_{DD} - 0 \cdot R_1 = U_{DD} = 7V$$

- linearer Betrieb:

$$U_{DS} = U_{DD} - I_D \cdot R_1 = U_{DD} - \beta \left[(u_{GS} - u_{th}) u_{DS} - \frac{1}{2} u_{DS}^2 \right] \cdot R_1$$

$$0 = U_{DD} - U_{DS} - \beta R_1 (u_{GS} - u_{th}) u_{DS} + \frac{1}{2} \beta R_1 u_{DS}^2$$

$$0 = U_{DD} + \left[(-1) - \beta R_1 (u_{GS} - u_{th}) \right] u_{DS} + \frac{1}{2} \beta R_1 u_{DS}^2$$

$$U_{DS_{1,2}} = \frac{1 + \beta R_1 (u_{GS} - u_{th}) \pm \sqrt{[1 + \beta R_1 (u_{GS} - u_{th})]^2 - 2 \beta R_1 U_{DD}}}{\beta R_1}$$

$$= \frac{1 + 2,5V^{-1} (u_{GS} - 0,5V) \pm \sqrt{[1 + 2,5V^{-1} (u_{GS} - 0,5V)]^2 - 35}}{2,5V^{-1}}$$

- Sättigungsbetrieb

$$U_{DS} = U_{DD} - I_D \cdot R_1 = U_{DD} - \frac{\beta}{2} (u_{GS} - u_{th})^2 R_1 = 7V - 25 \frac{\text{mA}}{\text{V}^2} (u_{GS} - 0,5V)^2 \cdot 1\Omega$$

- Übergang:

Sperr-Sättigung $U_{0,1}$

$$0 = \frac{\beta}{2} (u_{0,1} - u_{th})^2$$

$$u_{0,1} = 0,5V$$

Sättigung-Linear $U_{0,2}$

$$\frac{\beta}{2} (u_{0,2} - u_{th})^2 = \beta \left[(u_{0,2} - u_{th}) u_{DS} - \frac{1}{2} u_{DS}^2 \right]$$

$$\frac{\beta}{2} (u_{0,2} - u_{th})^2 = \beta \left[(u_{0,2} - u_{th}) (U_{DD} - I_D \cdot R_1) - \frac{1}{2} (U_{DD} - I_D \cdot R_1)^2 \right]$$

$$\frac{\beta}{2} (u_{0,2} - u_{th})^2 = \beta \left[(u_{0,2} - u_{th}) (U_{DD} - \frac{\beta}{2} (u_{0,2} - u_{th})^2 R_1) - \frac{1}{2} (U_{DD} - \frac{\beta}{2} (u_{0,2} - u_{th})^2 R_1)^2 \right]$$

$$u_{0,21} = 2,5V$$

$$u_{0,22} = -2,3V$$

$$u_{0,2} - u_{th} = u_{DS} > 0$$

$$u_{0,2} = 2,5V$$

c) geg: $U_0 = 2,2V$

$$U_{DS}(U_{GS}) = U_{DD} - \beta \frac{R_1}{2} (u_{GS} - u_{th})^2$$

$$U'_{DS}(U_{GS}) = -\beta R_1 \cdot (u_{GS} - u_{th})$$

$$U''_{DS}(U_{GS}) = -\beta R_1$$

→ Sättigungsbetrieb $U_0 < U_{0,2}$
 $U_0 > U_{0,1}$

$$T_2(x) = U_{DS}(U_0) + \frac{U'_{DS}(U_0)}{1!} (x - U_0) + \frac{U''_{DS}(U_0)}{2!} (x - U_0)^2$$

$$= U_{DD} - \beta \frac{R_1}{2} (U_0 - u_{th})^2 - \beta R_1 \cdot (U_0 - u_{th}) (x - U_0) - \frac{\beta R_1}{2} (x - U_0)^2$$

$$= 3,3875V - 4,25 (x - 2,2V) - 1,25 V^{-1} (x - 2,2V)^2$$

d) geg: $u_1 = 0,3V \cos(\omega_1 t)$

$$\cos^2(x) = \frac{1 + \cos(2x)}{2}$$

ges: u_2

$$2\omega_1 = \omega_2$$

$$u_{GS} = u_1 + U_0 = 0,3V \cos(\omega_1 t) + 2,2V$$

$$T_2(u_{GS}) = 3,3875V - 4,25 \cdot 0,3V \cos(\omega_1 t) - 1,25V^{-1} (0,3V \cos(\omega_1 t))^2$$

$$= 3,3875V - 1,275V \cos(\omega_1 t) - 0,1125V \left(\frac{1 + \cos(2\omega_1 t)}{2} \right)$$

$$= 3,3875V - 1,275V \cos(\omega_1 t) - 0,05625V - 0,05625V \cos(2\omega_1 t)$$

$$= 3,3313V - 1,275V \cos(\omega_1 t) - 0,05625V \cos(2\omega_1 t)$$

$$\rightarrow u_2(t) = -1,275V \cos(\omega_1 t) - 0,05625V \cos(2\omega_1 t)$$

e) $\frac{\hat{u}_{w_2}}{\hat{u}_{w_1}} = \frac{0,05625V}{1,275V} = 0,0441$

$$20 \cdot \lg\left(\frac{\hat{u}_{w_2}}{\hat{u}_{w_1}}\right) = -27,1078 \text{ dBc}$$

f) geg: $u_1 = 0,3V \cos(\omega_1 t)$

$$\cos^2(x) = \frac{1 + \cos(2x)}{2}$$

ges: u_2

$$2\omega_1 = \omega_2$$

$$u_{GS} = u_1 + U_0 = 0,3V \cos(\omega_1 t) + 5V$$

$$T_2(u_{GS}) = 3,3875V - 4,25 (0,3V \cos(\omega_1 t) + 5V - 2,2V) - 1,25 V^{-1} (0,3V \cos(\omega_1 t) + 5V - 2,2V)^2$$

$$= 3,3875V - 1,275V \cos(\omega_1 t) + 12,6V - 1,25V^{-1} \left(0,3^2 \left(\frac{1 + \cos(2\omega_1 t)}{2} \right) + 1,63 \cos(\omega_1 t) + 7,84V^2 \right)$$

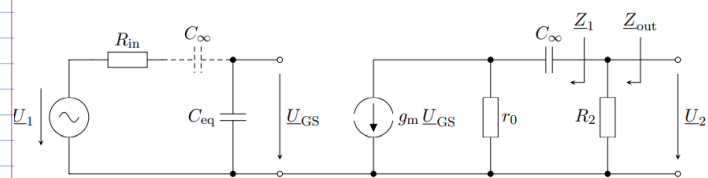
$$u_2(t) = \left[-1,275 \cos(\omega_1 t) - 0,05625 \cos(2\omega_1 t) - 2,1 \cos(\omega_1 t) \right] V$$

$$= \left[-3,375 \cos(\omega_1 t) - 0,05625 \cos(2\omega_1 t) \right] V$$

$$\frac{\hat{u}_{w_2}}{\hat{u}_{w_1}} = 0,0167$$

$$20 \cdot \lg\left(\frac{\hat{u}_{w_2}}{\hat{u}_{w_1}}\right) = -37,3412 \text{ dBc}$$

Aufgabe 18 B:



$$C_{\infty} = 2 \mu F$$

$$R_{in} = 40 \Omega$$

$$C_{eq} = 2,5 pF$$

$$g_m = 10 \frac{mA}{V}$$

$$r_o = 5 k\Omega$$

$$R_z = 1 k\Omega$$

g) $\underline{U}_1 = (R_{in} \cdot j\omega C_{eq} + 1) \cdot \underline{U}_{GS}$

$$g_m \underline{U}_{GS} \cdot \frac{r_o \cdot [\frac{1}{j\omega C_{\infty}} + R_z]}{r_o + \frac{1}{j\omega C_{\infty}} + R_z} = \underline{I}_z \cdot [\frac{1}{j\omega C_{\infty}} + R_z]$$

$$\frac{g_m \underline{U}_{GS} \cdot r_o \cdot C_{\infty} \cdot j\omega}{j\omega C_{\infty} (r_o + R_z) + 1} = \underline{I}_z$$

$$\underline{U}_z = \underline{I}_z \cdot R_z = g_m \cdot r_o \cdot C_{\infty} \cdot R_z \cdot j\omega \frac{1}{j\omega C_{\infty} (r_o + R_z) + 1} \cdot \underline{U}_{GS}$$

$$\underline{F}(j\omega) = \frac{\underline{U}_z}{\underline{U}_1} = g_m \cdot r_o \cdot C_{\infty} \cdot R_z \cdot j\omega \frac{1}{[j\omega C_{\infty} (r_o + R_z) + 1]} \cdot \frac{1}{[j\omega C_{eq} R_{in} + 1]}$$

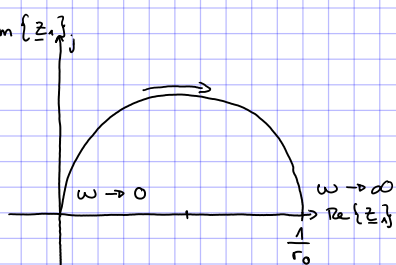
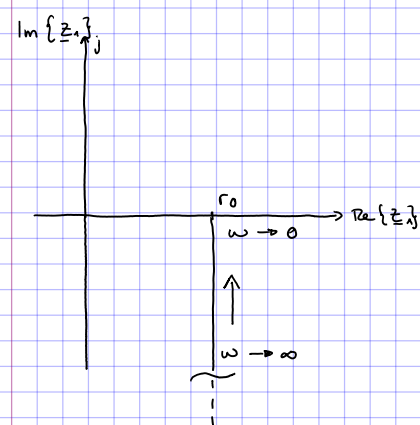
$$= K \cdot j \frac{\omega}{\omega_0} \cdot \frac{1}{j \frac{\omega}{\omega_1} + 1} \cdot \frac{1}{j \frac{\omega}{\omega_2} + 1}$$

$$K = 1 \quad \omega_1 = \frac{1}{C_{\infty} (r_o + R_z)} \quad \omega_0 = \frac{1}{C_{\infty} r_o g_m R_z} \quad \omega_2 = \frac{1}{C_{eq} R_{in}}$$

h)

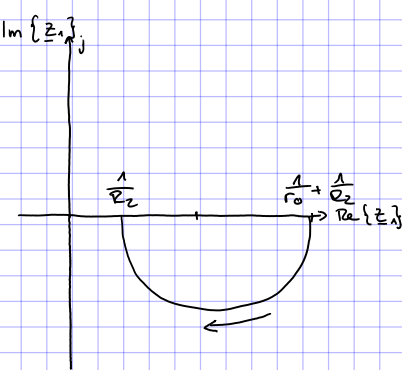
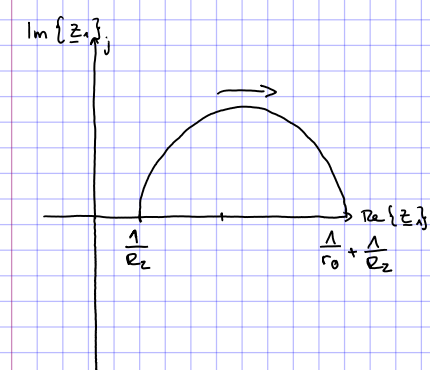
$$\underline{z}_1 = r_o + \frac{1}{j\omega C_{\infty}} = r_o - \frac{j}{\omega C_{\infty}} \quad \omega \rightarrow \infty \quad \text{Im}\{\underline{z}_1\} \rightarrow 0 \quad \text{Re}\{\underline{z}_1\} = r_o$$

$$\underline{y}_1 = \frac{1}{\underline{z}_1} = \frac{1}{r_o - \frac{j}{\omega C_{\infty}}} = \frac{r_o + \frac{j}{\omega C_{\infty}}}{r_o^2 + \frac{1}{(\omega C_{\infty})^2}} \quad \omega \rightarrow \infty \quad \text{Im}\{\underline{y}_1\} \rightarrow 0 \quad \text{Re}\{\underline{y}_1\} \rightarrow \frac{1}{r_o}$$



$$\underline{y}_{out} = \frac{1}{\underline{z}_{out}} = \frac{R_z + \underline{z}_1}{R_z \cdot \underline{z}_1} = \frac{R_z + \frac{1}{\underline{y}_1}}{R_z \cdot \frac{1}{\underline{y}_1}} = \frac{R_z \cdot \underline{y}_1 + 1}{R_z} = \underline{y}_1 + \frac{1}{R_z} \rightarrow \text{Verschiebung nach r. um } \frac{1}{R_z}$$

$$\underline{z}_{out} = \frac{R_z \cdot \underline{z}_1}{R_z + \underline{z}_1} = \frac{1}{\underline{y}_{out}} = \frac{1}{\underline{y}_1 + \frac{1}{R_z}} \rightarrow \text{Spiegelung, da } \frac{1}{a+jb} = \frac{a-jb}{a^2+b^2}$$



ij) $\underline{F}(j\omega) = K \cdot j \frac{\omega}{\omega_0} \cdot \frac{1}{j \frac{\omega}{\omega_1} + 1} \cdot \frac{1}{j \frac{\omega}{\omega_2} + 1}$

$$K = 1 \quad \omega_1 = \frac{1}{C_{\infty} (r_o + R_z)} = 10^2$$

$$\omega_0 = \frac{1}{C_{\infty} r_o g_m R_z} = 10^1 \quad \omega_2 = \frac{1}{C_{eq} R_{in}} = 10^{10}$$

$$|F(j\omega)| = 20 \lg(K) + 20 \lg\left(\frac{\omega}{\omega_0}\right) - 20 \lg\left(\sqrt{\left(\frac{\omega}{\omega_1}\right)^2 + 1}\right) - 20 \lg\left(\sqrt{\left(\frac{\omega}{\omega_2}\right)^2 + 1}\right)$$

$$+ 20 \frac{dB}{dek} - 20 \frac{dB}{dek} - 20 \frac{dB}{dek}$$

$$\varphi(\omega) = \angle K + \angle j \frac{\omega}{\omega_0} - \angle j \frac{\omega}{\omega_1} + 1 - \angle j \frac{\omega}{\omega_2} + 1$$

$$0^\circ + 90^\circ - \arctan\left(\frac{\omega}{\omega_1}\right) - \arctan\left(\frac{\omega}{\omega_2}\right)$$

$$0 + \frac{\pi}{2} - \frac{\pi}{2} - \frac{\pi}{2} = -\frac{\pi}{2}$$

