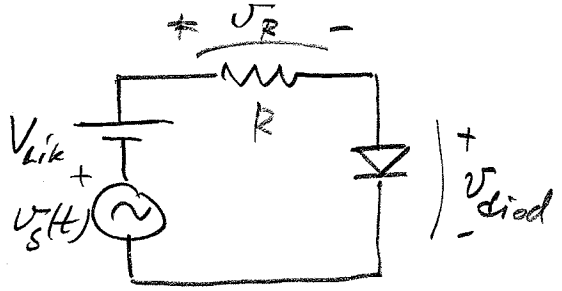
Svar till tenta i Elektronik 5p, E2, T2, D3, 26/10-03

A1. $A_V = \frac{R_1+R_2}{R_1} = \frac{100+20}{20} = 6gr$

$\Rightarrow A_V = \frac{U_{OUT,max}}{U_{IN,max}} \Rightarrow U_{IN,max} = \frac{\pm 12V}{6} = \underline{\pm 2V}$

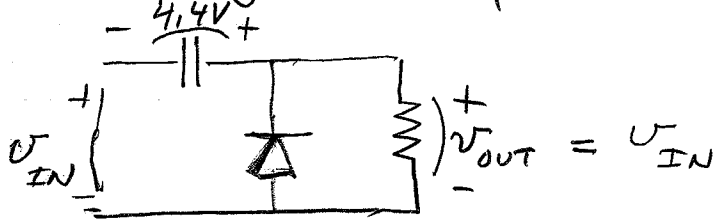
A2.



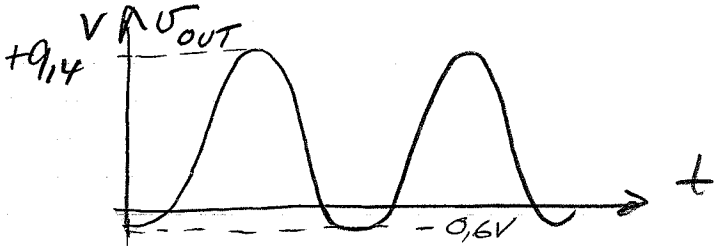
Man mäter signalspänningarna över diod och motstånd R

$r_d = \frac{U_{diod}}{\frac{U_R}{R}} = \frac{R \cdot U_{diod}}{U_R}$

A3. Kondensatorn laddas till $5-0{,}6 = 4{,}4\,V$ under 1:a negativa halvperioden.



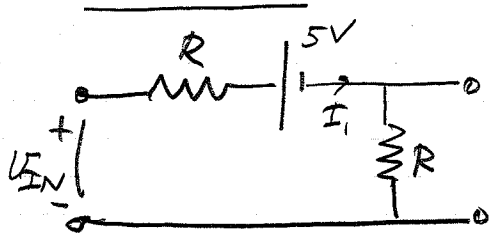
$U_{OUT} = U_{IN} + 4{,}4\,V$



A4. $C = \frac{I_L \cdot T}{V_r} = \frac{\frac{20V}{100\Omega} \cdot 20ms}{4V} = 1mF = \underline{1000\mu F}$

A5.

$\underline{U_{IN} > 5V}$



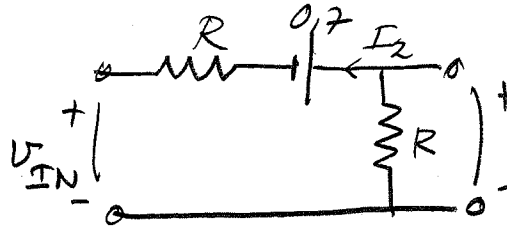
$U_{OUT} = I_1 \cdot R = \frac{U_{IN}-5V}{2R} \cdot R =$

$= \frac{U_{IN}-5V}{2}$

$U_{OUT,max} = \frac{10-5}{2} = 2{,}5\,V$

forts
45.

$U_{IN} = < -0{,}7V$

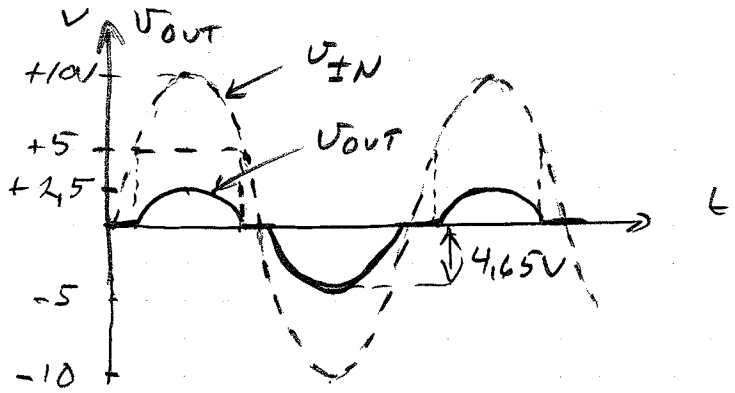


$U_{OUT} = -I_2 \cdot R = \frac{U_{IN}+0{,}7V}{2R} \cdot R =$

$= \frac{U_{IN}+0{,}7}{2}$

$U_{OUT,min} = \frac{-10+0{,}7}{2} = -4{,}65V$

$\therefore U_{OUT} = 0$ då $-0{,}7V < U_{IN} < 5V$



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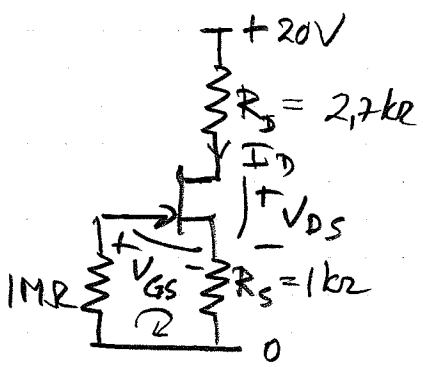

Kirch. spän.lag ger

$V_{GS} + I_D \cdot R_S = 0$

$\Rightarrow V_{GS} = -I_D \cdot 1k\Omega$

Ritas in i diagrammet

Skärningen med kurvan ger

$I_{DQ} \approx 3{,}7mA$ $(V_{GSQ} = -3{,}7V)$

Arbetslinjens ekv. ger

$20V = V_{DS} + I_D \cdot (R_D + R_S) \Rightarrow V_{DSQ} = 20 - 3{,}7 \cdot 3{,}7 = 6{,}3V$

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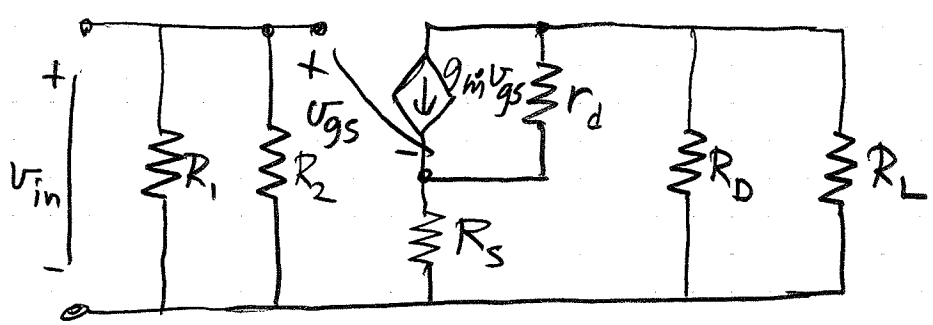
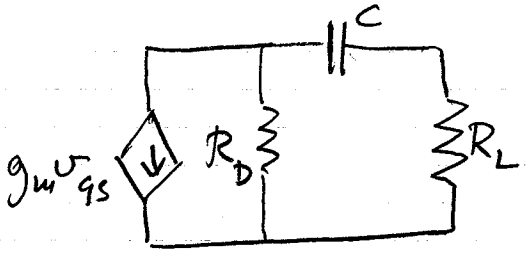
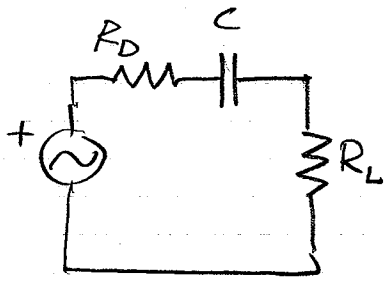


A8. Förstärkarstegets utgång

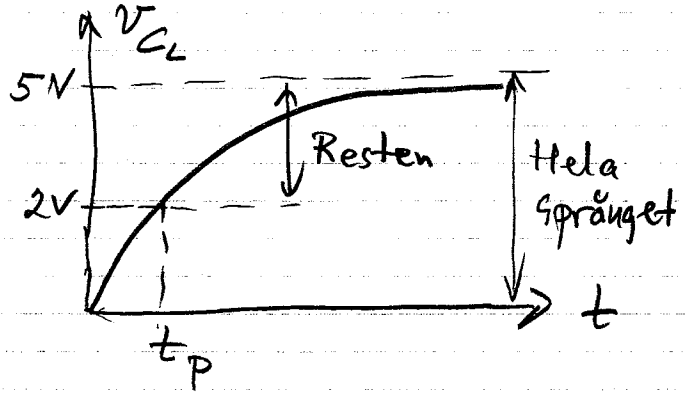


⇒ Tvåpol-sats



$$f_{ng} = \frac{1}{2\pi(R_D+R_L)\cdot C} = \frac{1}{2\pi\cdot(2+5)\cdot 10^3\cdot 10^{-5}} = \underline{2{,}3\,Hz}$$

A9.



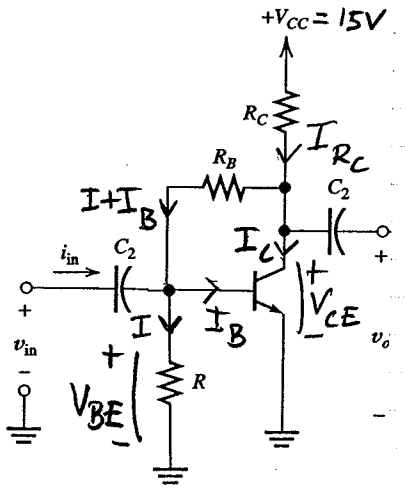
$$t_p = \tau \ln \frac{\text{Hela språnget}}{\text{Resten}} =$$

$$= R_D C_L \ln \frac{5\,V}{3\,V} =$$

$$= \underline{0{,}245\,\mu s}$$

A10. NOR-grind ⇒ $X = \overline{A+B+C} = (A \vee B \vee C)'$

B1.



Kirch. strömlag ger

$$I_{R_C} = I_C + I + I_B =$$

$$= I + I_B(1+\beta)$$

Ohms lag

$$I = \frac{V_{BE}}{R} = \frac{0{,}7\,V}{15\,k\Omega} = 46{,}7\,\mu A$$

Kirch. spän. lag ger

$$\begin{cases} V_{CE} = (I+I_B)\cdot R_B + V_{BE} & \text{---} \ (1) \\ V_{CC} = I_{R_C}\cdot R_C + V_{CE} & \text{---} \ (2) \end{cases}$$

$$\Rightarrow V_{CC} = I_{R_C}\cdot R_C + (I+I_B)R_B + V_{BE} =$$

$$= (I + I_B(1+\beta))\cdot R_C + IR_B + I_B R_B + V_{BE}$$

forts. B1/

$$\Rightarrow V_{CC} - IR_C - IR_B - V_{BE} = I_B\left((1+\beta)\cdot R_C + R_B\right)$$

$$15V - 46{,}7\mu A \cdot (3{,}3+54)k\Omega - 0{,}7V = I_B\left(126\cdot 3{,}3k\Omega + 54k\Omega\right)$$

$$\Rightarrow I_B = \frac{11{,}63V}{469{,}8k\Omega} = 24{,}75\mu A$$

$$I_{CQ} = \beta \cdot I_{BQ} = 125 \cdot 24{,}75\mu A = \underline{3{,}09mA}$$

$$V_{CE} = (I+I_B)\cdot R_B + V_{BE} = (46{,}7+24{,}75)\mu A \cdot 54k\Omega + 0{,}7V = \underline{\underline{4{,}56V}}$$

B2/

Arbetslinjens ekv.

$$V_{CC} = V_{CE} + I_C(R_C+R_E) \Rightarrow I_C = \frac{V_{CC}-V_{CE}}{R_C+R_E} =$$

$$= \frac{15V-5{,}6V}{(4{,}7+0{,}2)k\Omega} = 1{,}92mA$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{1{,}92mA}{0{,}026V} = 73{,}8mA/V$$

$$r_\pi = \frac{\beta}{g_m} = \frac{200}{73{,}8}k\Omega = 2{,}71k\Omega$$

$$R_{in} = R_1 \| R_2 \| r_\pi = 50 \| 3{,}9 \| 2{,}71k\Omega =$$

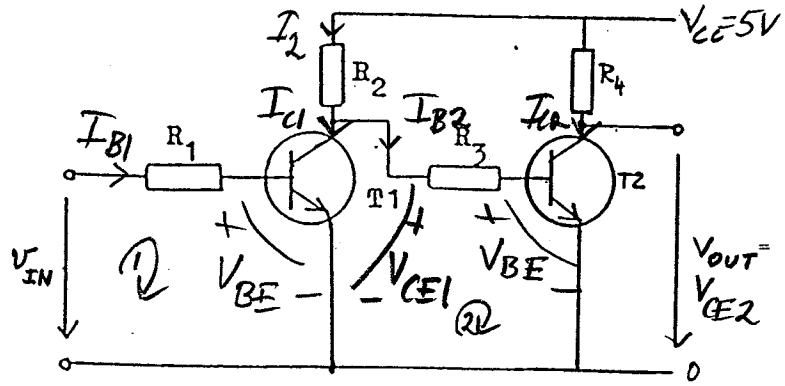
$$= \underline{\underline{1{,}54k\Omega}}$$

$$R_{out} = r_o \| R_C = 100 \| 4{,}7k\Omega = \underline{\underline{4{,}49k\Omega}}$$

$$A_V = -g_m \cdot (r_o \| R_C \| R_L) = -73{,}8 \cdot 3{,}098 =$$

$$= -228{,}6 \approx \underline{\underline{-229 \text{ ggr}}}$$

B3.



T2 bottnar då $V_{CE2} \approx 0{,}2\,V \Rightarrow I_{C2} = \frac{(5-0{,}2)V}{R_4} =$

$= 4{,}8\,mA$ dvs $I_{B2} \geq \frac{I_{C2}}{\beta} = \frac{4{,}8mA}{60} = 80\mu A$

krävs för att bottna T2

Kirch. spän. lag ger

(2) $V_{CE1} = I_{B2} \cdot R_3 + V_{BE} = 80\mu A \cdot 20k\Omega +$

$+ 0{,}7V = 2{,}3V$

Kirch. strömlag

$I_{C1} = I_2 - I_{B2} = \frac{V_{CC} - V_{CE1}}{R_2} - I_{B2} = 2{,}62\,mA$

$\Rightarrow I_{B1} = \frac{I_{C1}}{\beta} = \frac{2{,}62}{60}\,mA = 43{,}7\mu A$

Kirch. spän. lag ger

(1) $U_{IN} = I_{B1} \cdot R_1 + V_{BE} = 43{,}7 \cdot 20mV + 0{,}7V =$

$= 1{,}57V$ ∴ $U_{IN} \leq 1{,}57V \Rightarrow$ T2 bottnar

T2 strypt då $I_{B2} = 0$ dvs $V_{CE1} \approx 0{,}7V$

$\Rightarrow I_{C1} = \frac{5V - 0{,}7V}{R_2} = 4{,}3\,mA \Rightarrow I_{B1} = \frac{I_{C1}}{\beta} =$

$= \frac{4{,}3mA}{60} = 71{,}67\mu A$

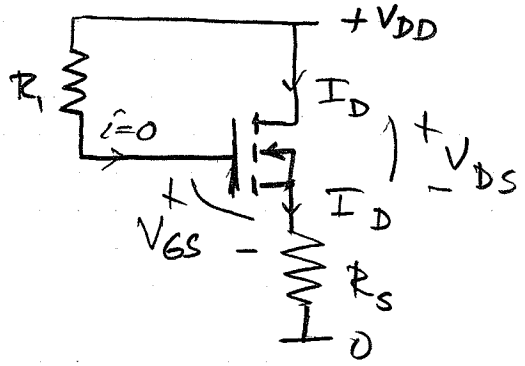
Kirch. spän. lag ger

(1) $U_{IN} = I_{B1} \cdot R_1 + V_{BE} = 71{,}67 \cdot 20mV + 0{,}7V =$

$= 2{,}13V$ ∴ $U_{IN} \geq 2{,}13V \Rightarrow$ T2 är strypt

B4. $K = \frac{1}{2} \cdot KP \cdot \frac{W}{L} = \frac{1}{2} \cdot 40 \cdot \frac{400}{10} = 0{,}8\ mA/V^2$

$I_D = K(V_{GS} - V_{to})^2$ i konst. strömområdet



$V_{GS} = V_{DS}$

Kirch. spän. lag

$V_{DD} = V_{GS} + I_D \cdot R_S$

$\Rightarrow I_D = \frac{V_{DD} - V_{GS}}{R_S}$

Sätt ekv. lika

$$\frac{V_{DD} - V_{GS}}{R_S} = K(V_{GS} - V_{to})^2 = I_D$$

$$\Rightarrow \frac{15V - V_{GS}}{2{,}5k\Omega} = 0{,}8\ mA/V^2 (V_{GS} - 2V)^2$$

$$\Rightarrow \frac{15V - V_{GS}}{2} = V_{GS}^2 - 4V_{GS} + 4$$

$$\Rightarrow V_{GS}^2 - 3{,}5V_{GS} - 3{,}5 = 0$$

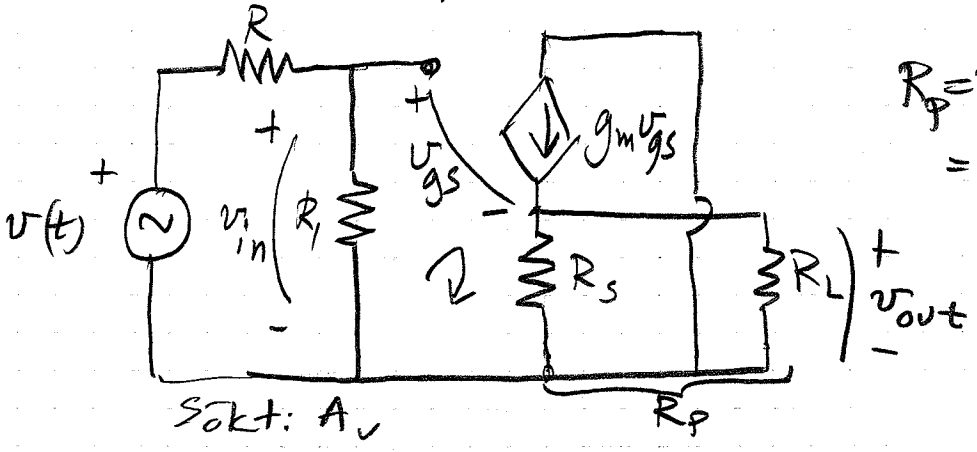
$$\Rightarrow V_{GS} = \frac{3{,}5}{2} \pm \sqrt{\left(\frac{3{,}5}{2}\right)^2 + 3{,}5} = 4{,}31\ V$$

$$\Rightarrow I_{DQ} = \frac{(15 - 4{,}31)\ V}{2{,}5\ k\Omega} = \underline{4{,}28\ mA}$$

$V_{DSQ} = V_{DD} - I_{DQ} \cdot R_S = 15 - 4{,}28 \cdot 2{,}5 = \underline{4{,}31V}$

$g_m = 2\sqrt{I_{DQ} \cdot K} = 2\sqrt{4{,}28 \cdot 0{,}8} = 3{,}7\ mA/V$

Ekvivalent signalschema



$R_P = R_S \| R_L = 2k\Omega$

forts B4/

Kirch. spän. lag

$$v_{in} - v_{gs} - v_{out} = 0 \Rightarrow v_{gs} = v_{in} - v_{out}$$

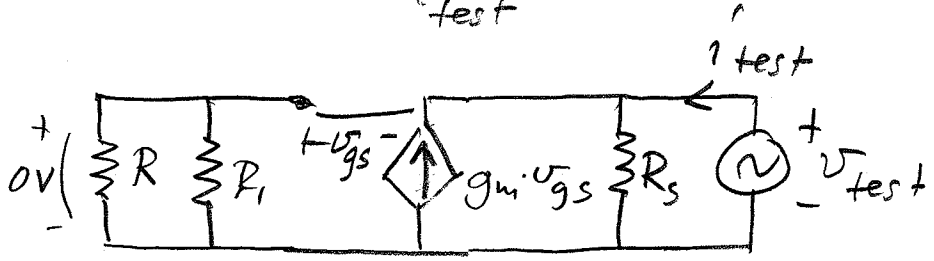
Ohms lag

$$v_{out} = g_m \cdot v_{gs} \cdot R_p = g_m (v_{in} - v_{out}) \cdot R_p$$

$$\Rightarrow v_{out}(1 + g_m R_p) = g_m \cdot v_{in} R_p \Rightarrow A_v = \frac{g_m R_p}{1 + g_m R_p} =$$

$$= \frac{3{,}7 \cdot 2}{1 + 3{,}7 \cdot 2} = \underline{0{,}88\ 99\Omega}$$

Sökt i $R_{out} = \frac{v_{test}}{i'_{test}}$



$$v_{gs} = -v_{test}$$

Kirch. strömlag

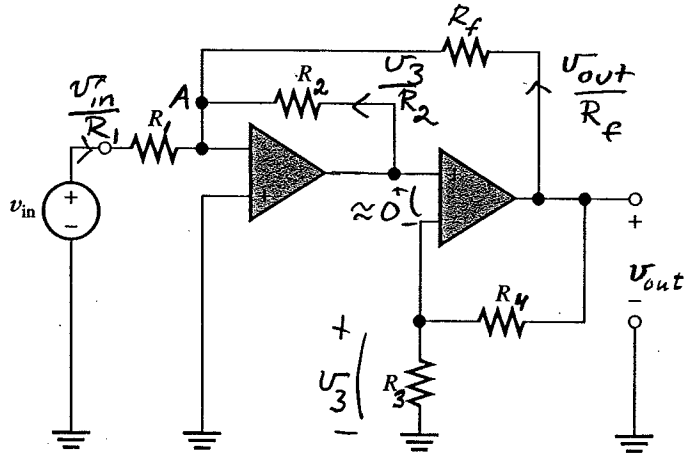
$$g_m \cdot v_{gs} + i'_{test} = \frac{v_{test}}{R_s} \Bigg\} \Rightarrow$$

$$\Rightarrow -g_m \cdot v_{test} + i'_{test} = \frac{v_{test}}{R_s}$$

$$\Rightarrow \frac{1}{R_{out}} = \frac{i'_{test}}{v_{test}} = g_m + \frac{1}{R_s} = 4{,}1\ mA/V$$

$$\Rightarrow R_{out} = \underline{244\Omega}$$

B5.



Kirch. strömlag i A ger

$$\frac{v_{in}}{R_1} + \frac{v_3}{R_2} + \frac{v_{out}}{R_f} = 0$$

Spän. delning på utgången ger

$$v_3 = v_{out} \cdot \frac{R_3}{R_3 + R_4}$$

Insatt i ekv. ovan

$$\frac{v_{in}}{R_1} + v_{out} \frac{R_3}{R_2(R_3+R_4)} + \frac{v_{out}}{R_f} = 0$$

$$\Rightarrow v_{out}\left(\frac{R_3}{R_2(R_3+R_4)} + \frac{1}{R_f}\right) = -\frac{v_{in}}{R_1}$$

$$\Rightarrow A_V = \frac{v_{out}}{v_{in}} = -\frac{1}{R_1\left(\frac{R_3}{R_2(R_3+R_4)} + \frac{1}{R_f}\right)} =$$

$$= -\frac{R_2(R_3+R_4)\cdot R_f}{R_1(R_3R_f + R_2R_3 + R_2R_4)}$$