

# Musterlösung

Probeklausur ES 2016

## Lösung Aufgabe 1

1.1

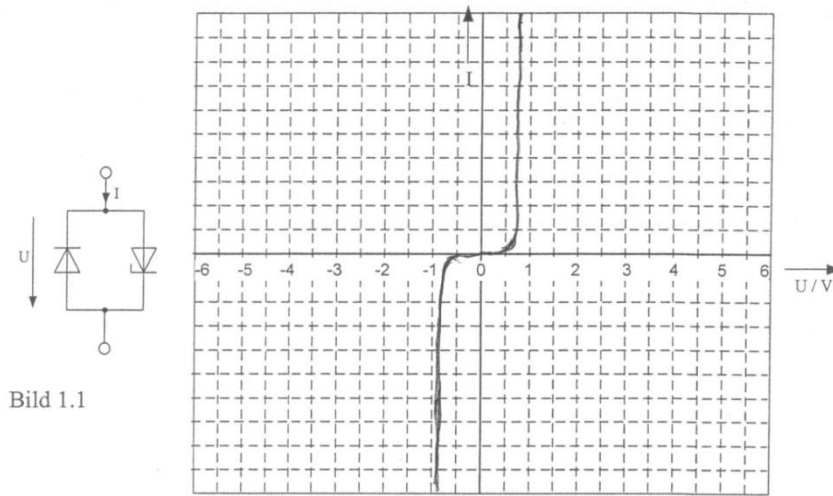
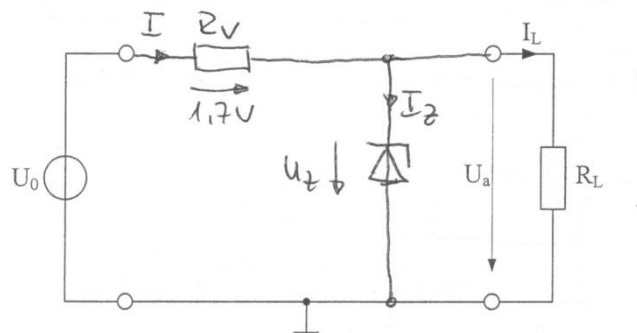


Bild 1.1

1.2



$$R_L = \frac{U_a}{I_L} = 66\Omega \Rightarrow E24: 68\Omega \Rightarrow I_L = 48,5mA$$

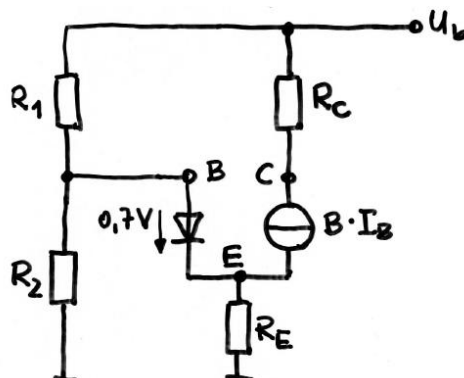
$$I_{\min} = 48,5mA + 2mA \text{ und } I_{\max} = 48,5mA + 6mA$$

$$\frac{1,7V}{54,5mA} < R_V < \frac{1,7V}{50,5mA} \quad 31,2\Omega < R_V < 33,66\Omega \rightarrow E24: R_V = 33\Omega$$

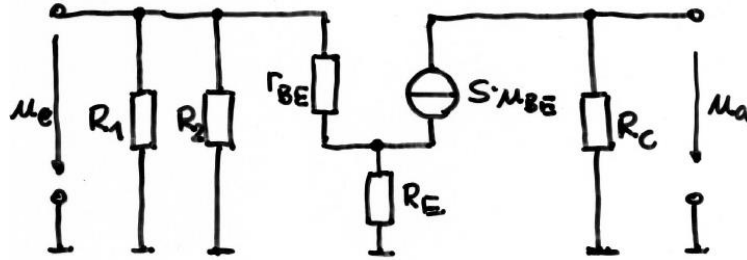
## Lösung Aufgabe 2

2.1 Emitterschaltung mit Stromgegenkopplung

2.2 Großsignalersatzschaltbild



### 2.3 Kleinsignalersatzschaltbild



### 2.4

$$U_B = R_2 \frac{U_b}{R_1 + R_2} = 15V \frac{2,2k\Omega}{2,2k\Omega + 10k\Omega} = 2,7V$$

$$U_E = U_B - 0,7V = 2V$$

$$I_E = \frac{U_E}{R_E} = \frac{2V}{910\Omega} = 2,2mA = I_{C,A}$$

$$U_{CE;A} = U_b - I_{C,A} \cdot (R_C + R_E) = 15V - 2,2mA \cdot (3,9k\Omega + 0,91k\Omega) = 4,42V$$

$$S = \frac{I_{C,A}}{U_T} = \frac{2,2mA}{26mV} = 84,6mS$$

### 2.5

$$r_e = r_{BE} (1 + S \cdot R_E) \parallel (R_1 \parallel R_2)$$

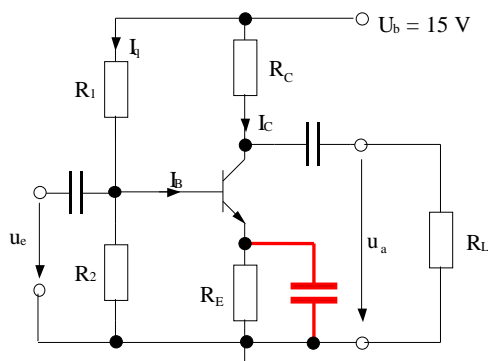
$$r_{BE} = \frac{\beta}{S} = \frac{300}{84,6mS} = 3,55k\Omega \quad , \quad (R_1 \parallel R_2) = 1,82k\Omega$$

$$r_e = (r_{BE} + \beta \cdot R_E) \parallel 1,82k\Omega = 256,5k\Omega \parallel 1,82k\Omega = 1,8k\Omega$$

$$r_a = R_C = 3,9k\Omega$$

$$A \approx -\frac{R_C}{R_E} = -4,28$$

### 2.6



Um eine hohe Verstärkung zu erhalten, muss ein Kondensator parallel zu  $R_E$  geschaltet werden (für Kleinsignalbetrieb erhalten wir dann eine einfache Emitterschaltung)

Damit wird:

$$A \approx -S \cdot r_a \quad (1) \quad \text{mit} \quad r_a = \frac{R_C \cdot R_L}{R_C + R_L}; \quad \text{aus(1):} \quad r_a = -\frac{A}{S} = -\frac{-165}{84,6mS} = 1,95k\Omega$$

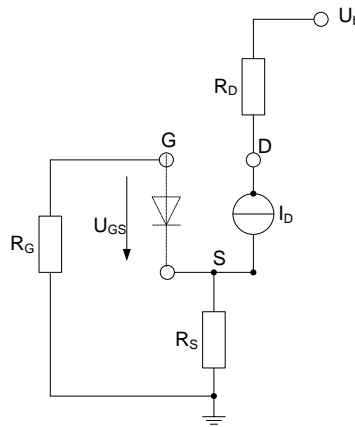
$$\text{mit} \quad r_a = \frac{R_C \cdot R_L}{R_C + R_L} \quad \text{wird:} \quad R_L = \frac{r_a}{R_C} (R_C + R_L) = \frac{1,95k\Omega}{3,9k\Omega} (R_C + R_L) \Rightarrow R_L = 3,9k\Omega$$

### Lösung Aufgabe 3

#### 3.1 Sourceschaltung mit Stromgegenkopplung

3.2  $I_{D0} = 12\text{mA}$

#### 3.3 Großsignalersatzschaltbild



#### 3.4

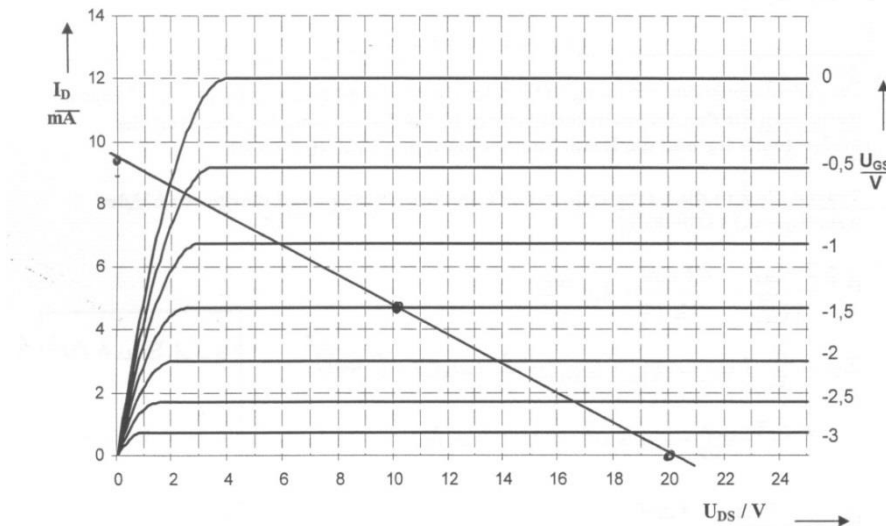
$$\beta = \frac{2I_{D0}}{U_{th}^2} = \frac{24\text{mA}}{16\text{V}^2} = 1,5 \frac{\text{mA}}{\text{V}^2}$$

$$I_D = \frac{\beta}{2}(U_{GS} - U_{th})^2 = 0,75 \frac{\text{mA}}{\text{V}^2} (-1,5\text{V} - (-4\text{V}))^2 = 4,69\text{mA}$$

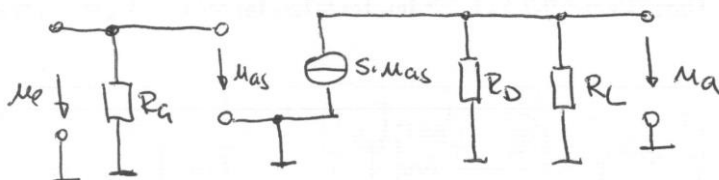
$$R_S = \frac{-U_{GS}}{I_D} = \frac{1,5\text{V}}{4,69\text{mA}} = 320\Omega$$

$$U_{DS} = U_b - (R_S + R_D)I_D = 20\text{V} - 2120\Omega \cdot 4,69\text{mA} = 10,05\text{V}$$

**Lastgerade:**  $I_D = 0 \rightarrow U_{DS} = 20\text{V}$        $U_{DS} = 0 \rightarrow I_D = \frac{U_b}{R_D + R_S} = 9,43\text{mA}$



#### 3.5 Kleinsignalersatzschaltbild



### 3.6

$$r_E = R_G = 1M\Omega$$

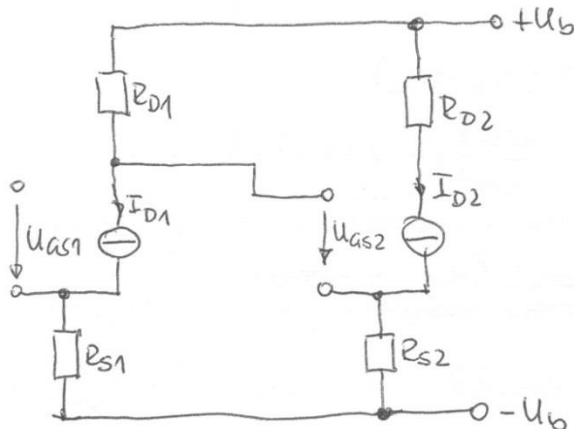
$$S = \frac{\partial I_D}{\partial U_{GS}} = 2 \frac{\beta}{2} (U_{GS} - U_{th}) = 1,5 \frac{mA}{V} \cdot (-1,5V - (-4)) = 3,75mS$$

$$A = -S(R_D \parallel R_L) \approx -S \cdot R_D = -6,75$$

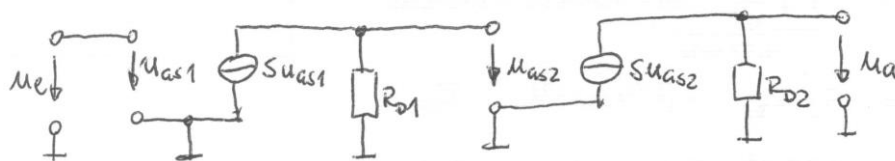
Da  $R_L \gg R_D$

## Lösung Aufgabe 4

### 4.1 Großsignalersatzschaltbild



### 4.2 Kleinsignalersatzschaltbild



### 4.3

$$I_{D1} = \frac{\beta}{2} (U_{GS1} - U_{th})^2 = \frac{1,39mA}{2V^2} (7V - 4V)^2 = 6,255mA$$

$$R_{S1} = \frac{5V}{I_{D1}} = 799,3\Omega \approx 800\Omega$$

$$U_{DS1} = 24V - I_{D1}(R_{D1} + R_{S1}) = 24V - I_{D1}(R_{D1} + R_{S1}) = 9,62V$$

$$I_{D2} = \frac{1,39mA}{2V^2} (9,62V - 4V)^2 = 21,95mA$$

$$R_{S2} = \frac{5V}{21,95mA} = 229\Omega$$

$$R_{D2} = \frac{12V}{21,95mA} = 546\Omega$$

### 4.4

$$A_{ges} = A_1 \cdot A_2$$

$$A_1 = -S_1 R_{D1} = -\beta (U_{GS1} - U_{th}) \cdot R_{D1} = -1,39 \frac{mA}{V^2} \cdot 3V \cdot 1500\Omega = -6,255$$

$$A_2 = -S_2 \cdot R_{D2} = -\beta (U_{GS2} - U_{th}) R_{D2} = -1,39 \frac{mA}{V^2} \cdot 5,62V \cdot 546\Omega = -4,265$$

$$A_{ges} = -6,255 \cdot (-4,265) = 26,7$$

### 4.5

Ja, da  $U_{DS2} = 7V > (U_{GS2} - U_{th}) = 5,62V$  ist

## Lösung Aufgabe 5

### 5.1

Eingangswiderstand gegen unendlich.  
Ausgangswiderstand gegen 0.  
Leerlaufverstärkung gegen unendlich.

### 5.2

OP1: invertierender Integrator  
OP2: nichtinvertierender Verstärker  
OP3: Subtrahierer

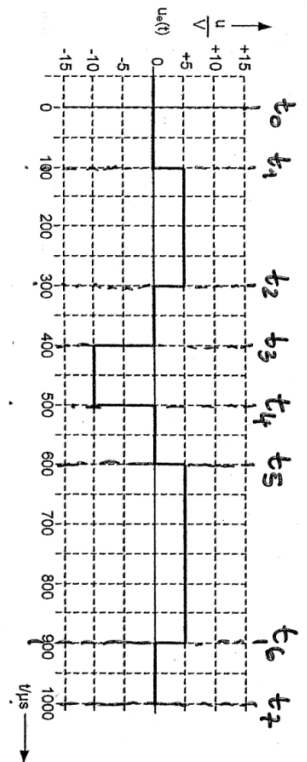
### 5.3

$$u_{a1}(t) = -\frac{1}{R_1 C_1} \int u_e dt + u_{a1}(t=0) \quad \text{Mit } \frac{1}{R_1 C_1} = \frac{1}{200 \mu s}$$

$$u_{a2}(t) = \frac{R_2}{2R_2} \left( \frac{R_2}{R_2} + 1 \right) u_e = \frac{1}{2} \cdot 2 \cdot u_e = u_e$$

$$u_{a3}(t) = \frac{R_4}{R_3} (u_{a2} - u_{a1}) = 1,5(u_{a2} - u_{a1})$$

zu Aufgabe 5 der Probeklausur



$$M_{a1} = -\frac{1}{200 \mu s} \cdot u_e \cdot \Delta t + M_{a1}(t_n)$$

$$t_0 < t < t_1 \quad u_e = 0V \rightarrow M_{a1}(t_1) = 0V$$

$$t_1 < t < t_2 \quad u_e = +5V, \Delta t = 200 \mu s$$

$$M_{a1} = -\frac{1}{200 \mu s} \cdot 5V \cdot 200 \mu s + 0V = -5V = M_{a1}(t_2)$$

$$t_2 < t < t_3 \quad u_e = 0V$$

$$M_{a1} = -[0V] + (-5V) = -5V = M_{a1}(t_3)$$

$$t_3 < t < t_4 \quad u_e = -10V, \Delta t = 100 \mu s$$

$$M_{a1} = -\frac{1}{200 \mu s} \cdot (-10V) \cdot 100 \mu s + (-5V)$$

$$= +5V + (-5V) = 0V = M_{a1}(t_4)$$

$$t_4 < t < t_5 \quad u_e = 0V$$

$$M_{a1} = -[0V] + 0V = 0V = M_{a1}(t_5)$$

$$t_5 < t < t_6 \quad u_e = +5V, \Delta t = 300 \mu s$$

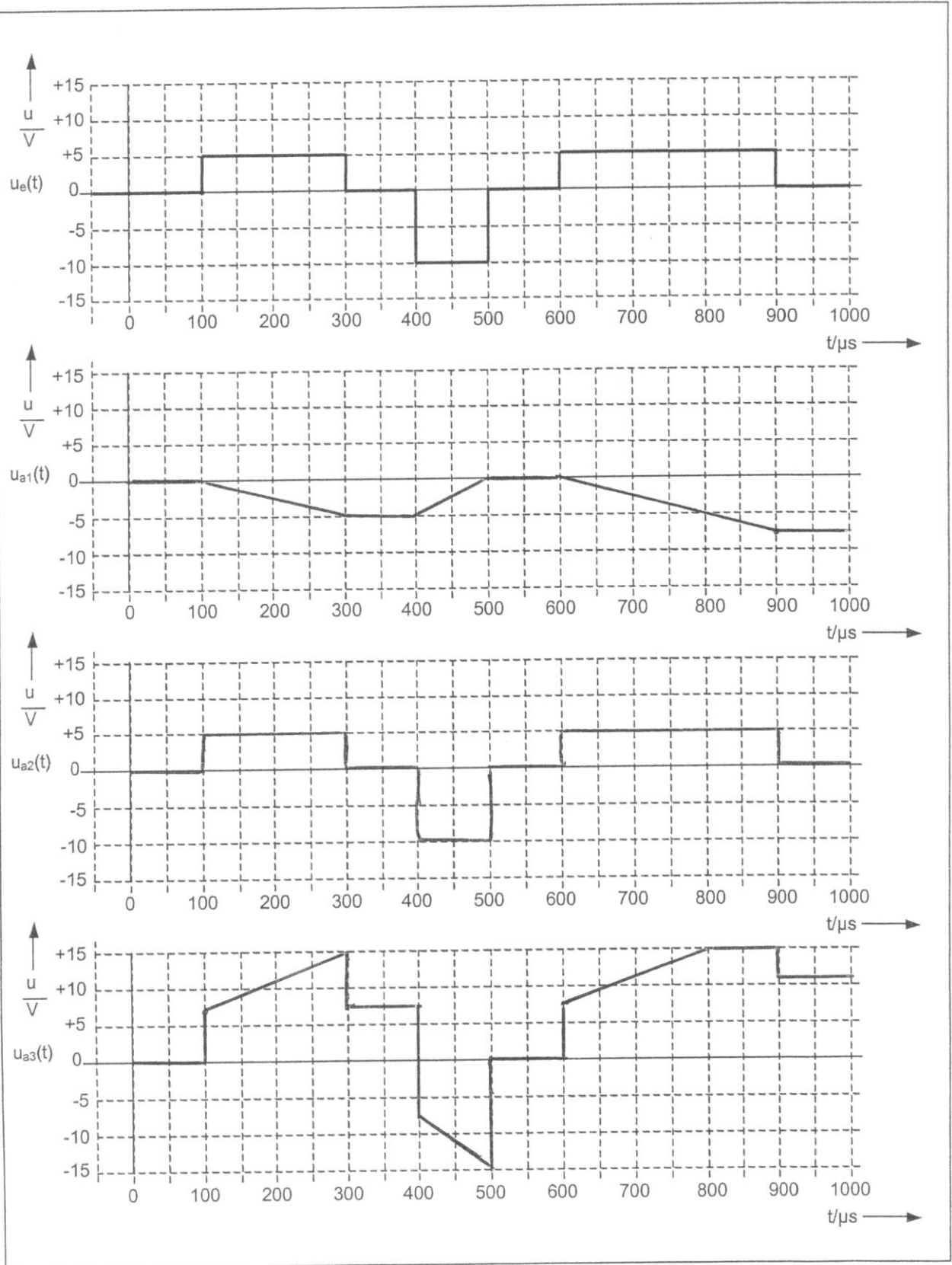
$$M_{a1} = -\frac{1}{200 \mu s} \cdot 5V \cdot 300 \mu s + 0V$$

$$= -7,5V = M_{a1}(t_6)$$

$$t_6 < t < t_7 \quad u_e = 0V$$

$$M_{a1} = -[0V] + (-7,5V) = -7,5V$$

5.4



## Lösung Aufgabe 6

6.1 Nichtinvertierender Schmitt-Trigger

6.2

$$\text{Eingangsseite: } R_1 \cdot I + U_D - u_e = 0 \Rightarrow I = \frac{u_e}{R_1} \Big|_{U_D=0}$$

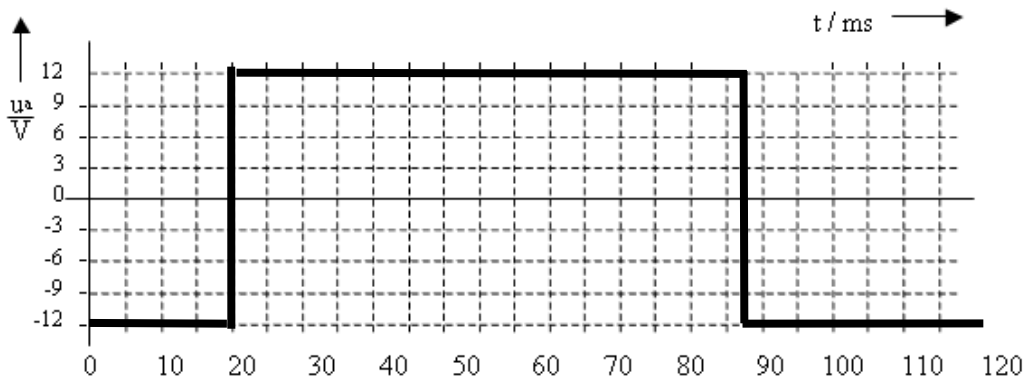
$$\text{Ausgangsseite: } R_2 \cdot I + u_a = 0 \Rightarrow I = -\frac{u_a}{R_2} \quad \text{mit } u_a = \pm 12 \text{ V}$$

$$\Rightarrow \frac{u_e}{R_1} = -\frac{u_a}{R_2} \Rightarrow u_e = -\frac{R_1}{R_2} u_a \Big|_{U_D=0}$$

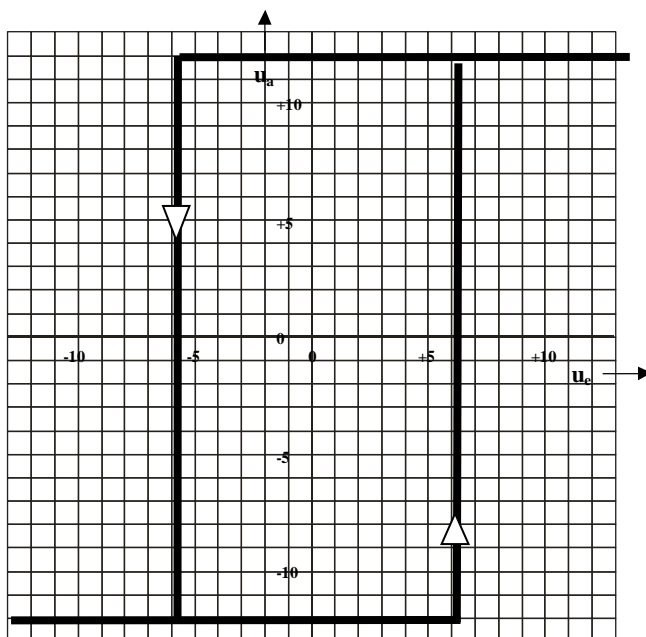
$$u_{e,\text{ein}} = -\frac{R_1}{R_2} \cdot u_{a,\text{min}} = -\frac{1}{2} \cdot (-12 \text{ V}) = +6 \text{ V}$$

$$u_{e,\text{aus}} = -\frac{R_1}{R_2} \cdot u_{a,\text{max}} = -\frac{1}{2} \cdot (+12 \text{ V}) = -6 \text{ V},$$

6.3



6.4

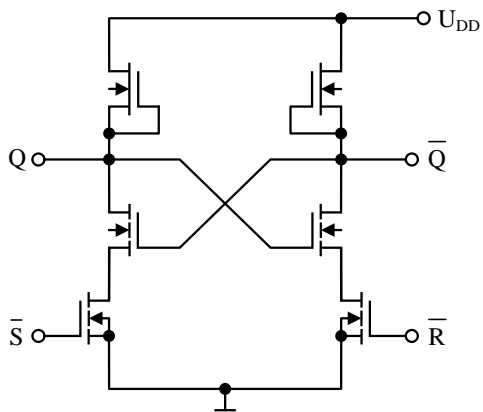


## Lösung Aufgabe 7

### 7.1 Wahrheitstabelle

$\bar{S}$	$\bar{R}$	Q	$\bar{Q}$
0	0	1	1
0	1	1	0
1	0	0	1
1	1	$Q_{-1}$	$\bar{Q}_{-1}$

### 7.2 Schaltung:



### 7.3 Timing

