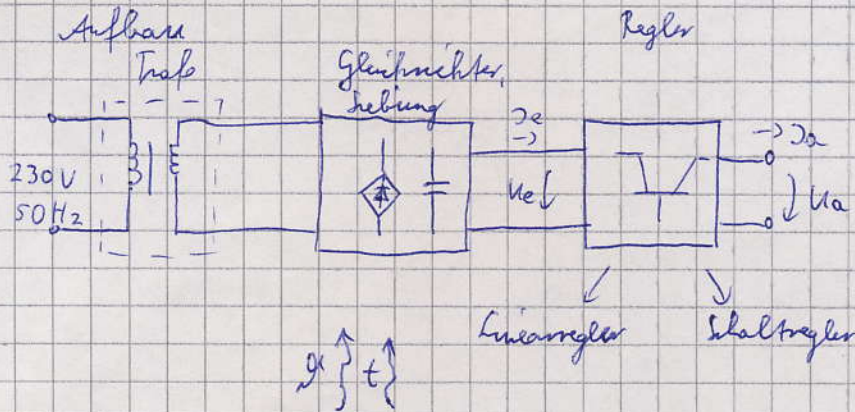


# Stromversorgung

## Kontinuierliche Stromversorgung



$$U_a = f(U_e, I_a, g, t)$$

### Kenngrößen

- ① Empfindlichkeit gegenüber der Eingangsspannung  $S = \left. \frac{\partial U_a}{\partial U_e} \right|_A$
- ② Ausgangswiderstand  $r_i = \left. \frac{\partial U_a}{\partial I_a} \right|_A$
- ③ Temperaturkoeffizient  $\alpha = \left. \frac{\partial U_a}{\partial T} \right|_A$
- ④ zeitliche Konstante (Lagertung)  $\tau = \left. \frac{\partial U_a}{\partial t} \right|_A$
- ⑤ minimale Eingangsspannung (durch Spannungsabfall über Längselement)
- ⑥ maximale Eingangsspannung (durch max. Spannungsabfall über Längselement, Verlustleistung am Längselement)
- ⑦ Wirkungsgrad  $\eta = \frac{P_a}{P_e} = \frac{U_a \cdot I_a}{U_e \cdot I_e}$  (Wärmeabstrahlung)

Folie Parameter

### Aufbau

Folie Blockschaltbild

Folie Schaltung Struktur, Folie Schaltplan bis Spannungsregler mit Längstransistor

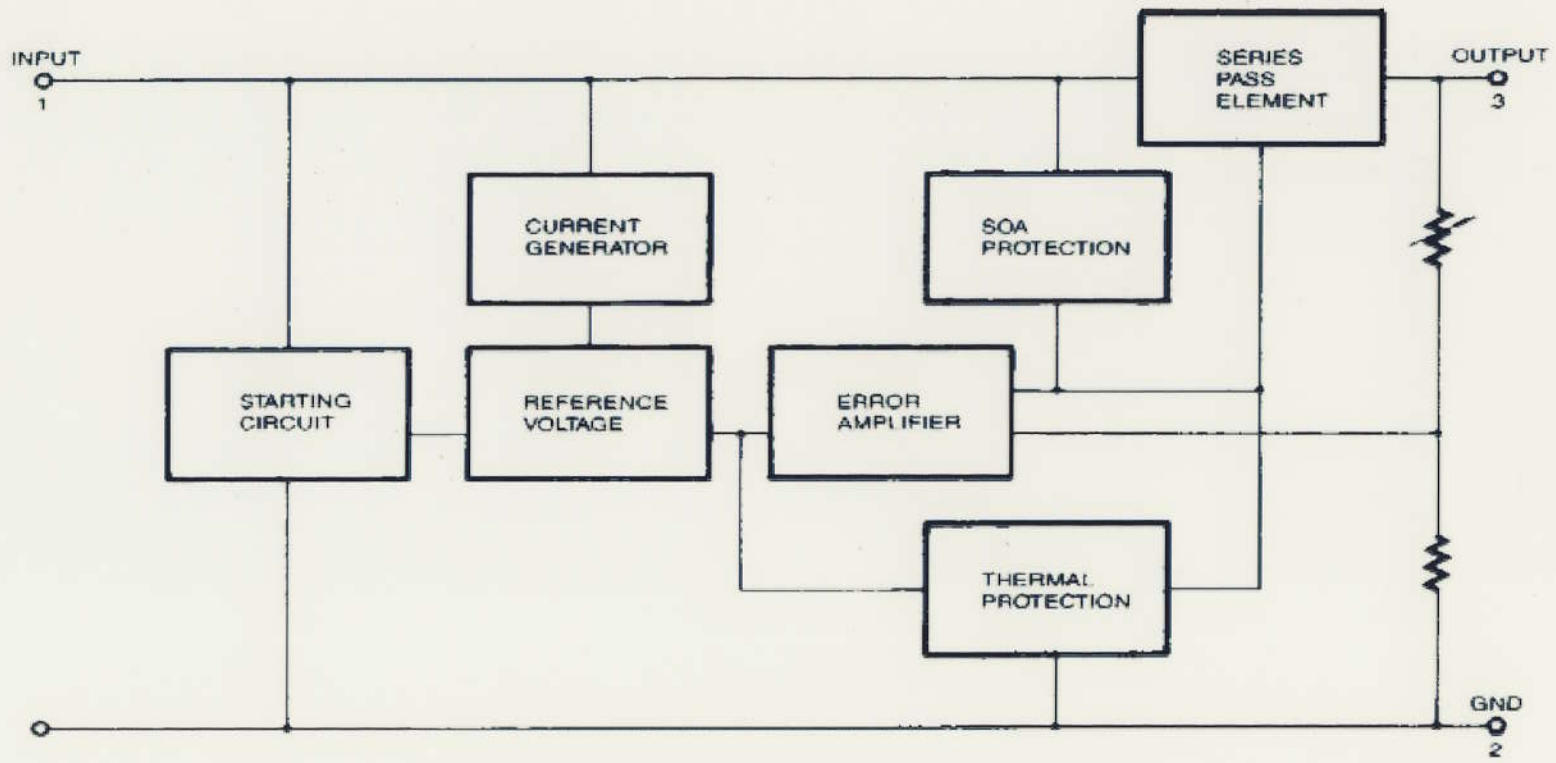
## Electrical Characteristics (MC7806A)

(Refer to the test circuits.  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $I_O = 1\text{A}$ ,  $V_I = 11\text{V}$ ,  $C_I = 0.33\mu\text{F}$ ,  $C_O = 0.1\mu\text{F}$ , unless otherwise specified)

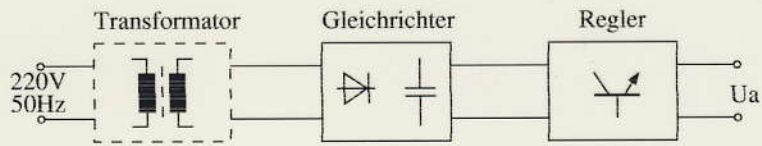
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit	
Output Voltage	$V_O$	$T_J = +25^{\circ}\text{C}$	5.58	6	6.12	V	
		$I_O = 5\text{mA to } 1\text{A}$ , $P_O \leq 15\text{W}$ $V_I = 8.6\text{V to } 21\text{V}$	5.76	6	6.24		
Line Regulation (Note1)	Regline	$V_I = 8.6\text{V to } 25\text{V}$ $I_O = 500\text{mA}$	-	5	60	mV	
		$V_I = 9\text{V to } 13\text{V}$	-	3	60		
		$T_J = +25^{\circ}\text{C}$	$V_I = 8.3\text{V to } 21\text{V}$	-	5		60
			$V_I = 9\text{V to } 13\text{V}$	-	1.5		30
Load Regulation (Note1)	Regload	$T_J = +25^{\circ}\text{C}$ $I_O = 5\text{mA to } 1.5\text{A}$	-	9	100	mV	
		$I_O = 5\text{mA to } 1\text{A}$	-	4	100		
		$I_O = 250\text{mA to } 750\text{mA}$	-	5.0	50		
Quiescent Current	$I_Q$	$T_J = +25^{\circ}\text{C}$	-	4.3	6	mA	
Quiescent Current Change	$\Delta I_Q$	$I_O = 5\text{mA to } 1\text{A}$	-	-	0.5	mA	
		$V_I = 9\text{V to } 25\text{V}$ , $I_O = 500\text{mA}$	-	-	0.8		
		$V_I = 8.5\text{V to } 21\text{V}$ , $T_J = +25^{\circ}\text{C}$	-	-	0.8		
Output Voltage Drift	$\Delta V/\Delta T$	$I_O = 5\text{mA}$	-	-0.8	-	mV/ $^{\circ}\text{C}$	
Output Noise Voltage	$V_N$	$f = 10\text{Hz to } 100\text{KHz}$ $T_A = +25^{\circ}\text{C}$	-	10	-	$\mu\text{V}/V_O$	
Ripple Rejection	RR	$f = 120\text{Hz}$ , $I_O = 500\text{mA}$ $V_I = 9\text{V to } 19\text{V}$	-	65	-	dB	
Dropout Voltage	$V_{\text{Drop}}$	$I_O = 1\text{A}$ , $T_J = +25^{\circ}\text{C}$	-	2	-	V	
Output Resistance	$r_O$	$f = 1\text{KHz}$	-	17	-	$\text{m}\Omega$	
Short Circuit Current	ISC	$V_I = 35\text{V}$ , $T_A = +25^{\circ}\text{C}$	-	250	-	mA	
Peak Current	$I_{\text{PK}}$	$T_J = +25^{\circ}\text{C}$	-	2.2	-	A	

### Note:

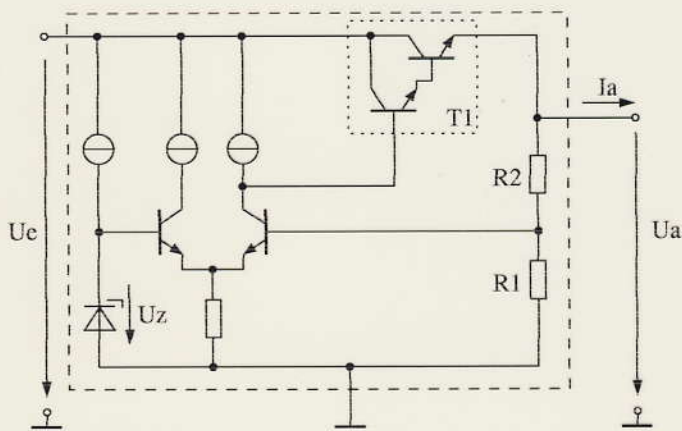
1. Load and line regulation are specified at constant junction temperature. Change in  $V_O$  due to heating effects must be taken into account separately. Pulse testing with low duty is used.



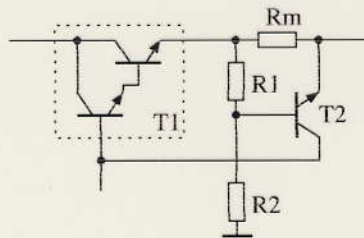
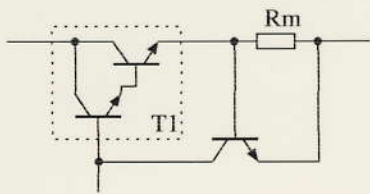
Prinzip



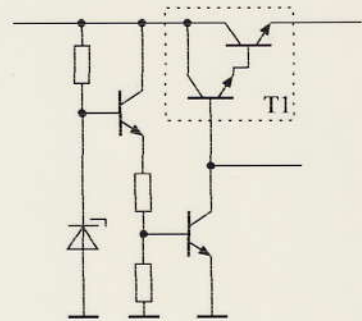
Spannungsregler mit Laengstransistor



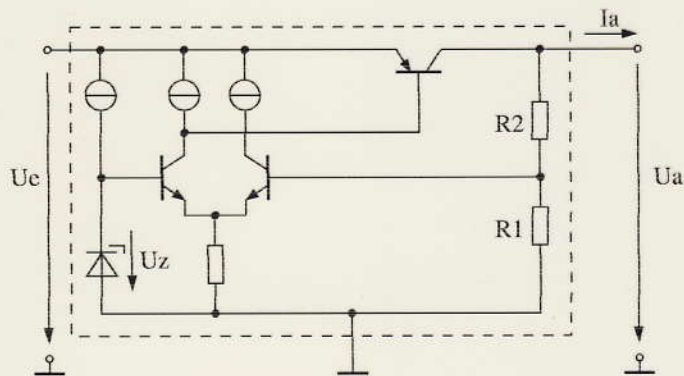
Erweiterungen zur Strombegrenzung



Temperaturbegrenzung



Low-Drop Spannungsregler

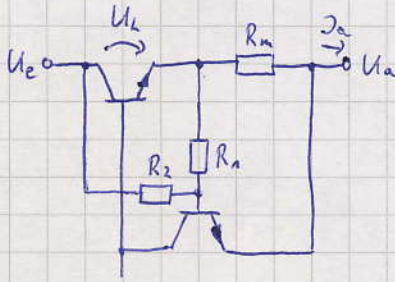


## Schutzschaltungen

- Überstromschutz: (Tabelle links)

$$I_{max} = \frac{U_{BEF}}{R_M}$$

- SOAR - Schutz



$$U_{BE} = I_a R_M \frac{R_2}{R_1 + R_2} + U_L \frac{R_1}{R_1 + R_2}$$

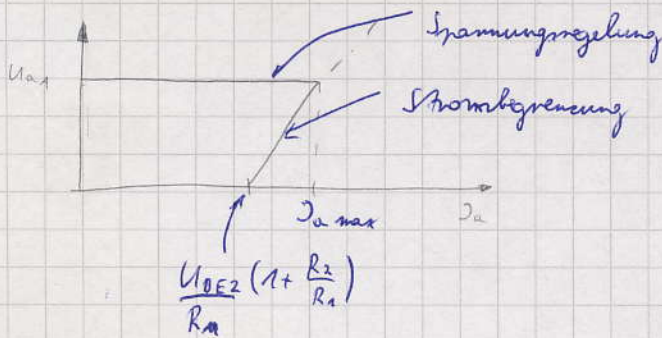
→ Geradengleichung, die unter die Verlustleistungshyperbel gelegt wird

- Überstromschutz mit Fold-Back Strombegrenzung (Tabelle mitte)

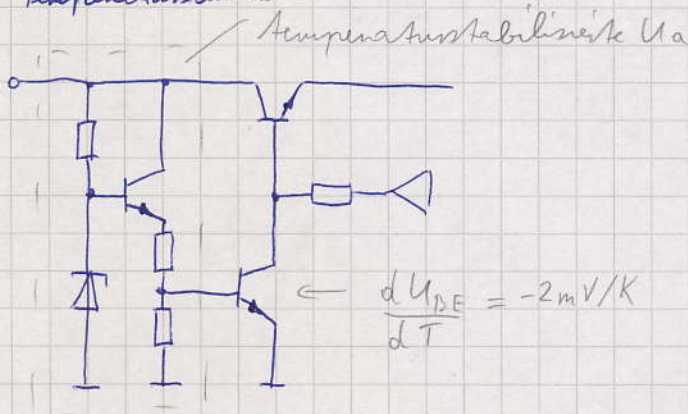
$$U_{BE2} = (U_a + I_a R_M) \frac{R_1}{R_1 + R_2} - U_a$$

$$U_{BE2} = I_a R_M \frac{R_1}{R_1 + R_2} - U_a \frac{R_2}{R_1 + R_2}$$

$$U_a = I_a R_M \frac{R_1}{R_2} - U_{BE2} \left(1 + \frac{R_1}{R_2}\right)$$

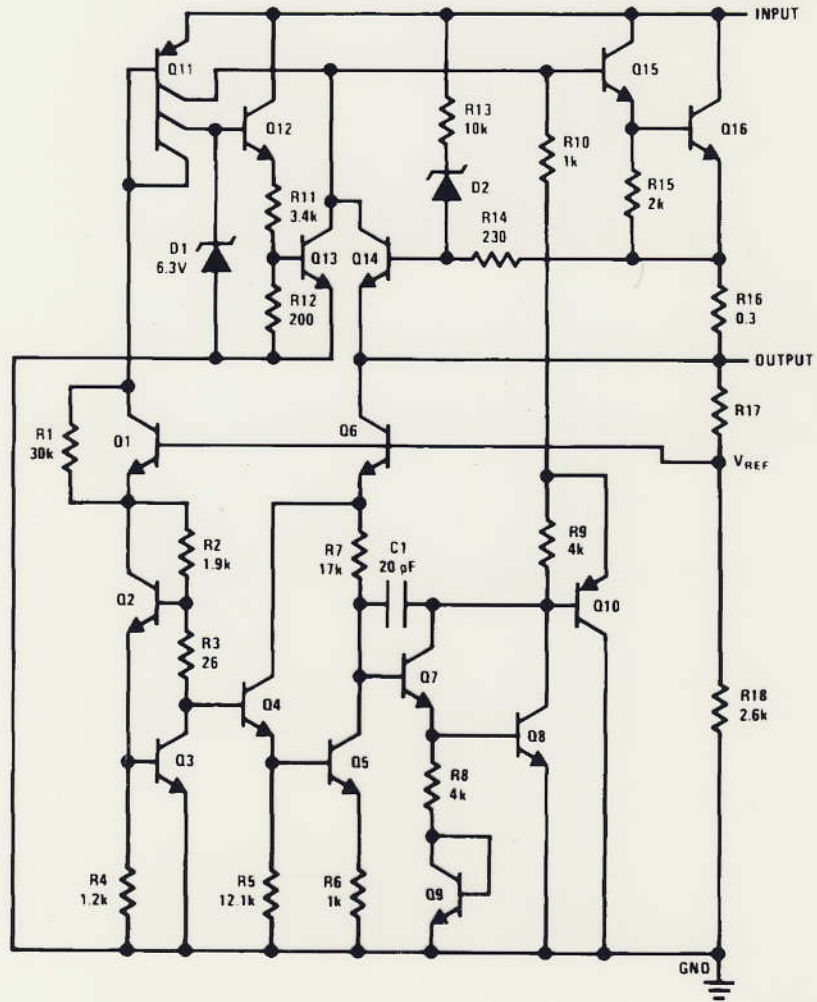


- Temperaturschutz



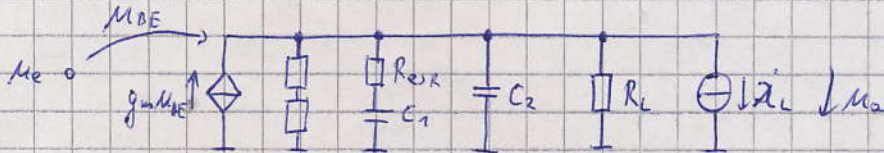
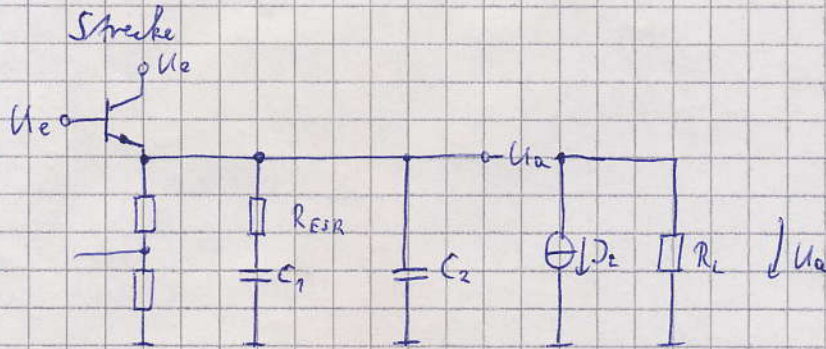
**Du kannst.**  
Trainee bei ABB

Schematic



DS007746-1

# Kleinsignalanalyse



$$U_a = (g_m(U_e - U_a) - I_c) \frac{1}{\frac{1}{R_L} + sC_2 + \frac{1}{R_{ESR} + \frac{1}{sC_1}}}$$

$$U_a = (g_m U_e - I_c) \frac{R_L}{1 + g_m R_L} \cdot \frac{1 + sC_1 R_{ESR}}{1 + s \left( R_L \frac{C_1 + C_2}{1 + g_m R_L} + C_1 R_{ESR} \right) + s^2 \frac{C_1 C_2 R_L R_{ESR}}{1 + g_m R_L}}$$

Nullstelle:  $s_0 = \frac{1}{C_1 R_{ESR}}$

Pole:  $s_{1/2} = -\frac{1}{2} \left( \frac{C_1 + C_2}{C_1 C_2 R_{ESR}} + \frac{1 + g_m R_L}{C_2 R_L} \right) \pm \sqrt{\frac{1}{4} \left( \frac{C_1 + C_2}{C_1 C_2 R_{ESR}} + \frac{1 + g_m R_L}{C_2 R_L} \right)^2 - \frac{1 + g_m R_L}{C_1 C_2 R_{ESR} R_L}}$

Bsp.:  $U_a = 5V$ ,  $R_{ESR} = 20 \Omega$ ,  $C_1 = 10 \mu F$ ,  $R_{ESR} = 0,1 \Omega$ ,  $C_2 = 100 nF$

$f_n = 15,9 kHz$

$f_{p1} = 7,8 kHz$

$f_{p2} = 31 MHz$

$R_L = 200 \Omega$

$f_n = 15,9 kHz$

$f_{p1} = 1,4 kHz$

$f_{p2} = 17 MHz$

**Folie** Frequenzgang der Strecke

Dominanter Pol der Strecke liegt bei mehreren kHz

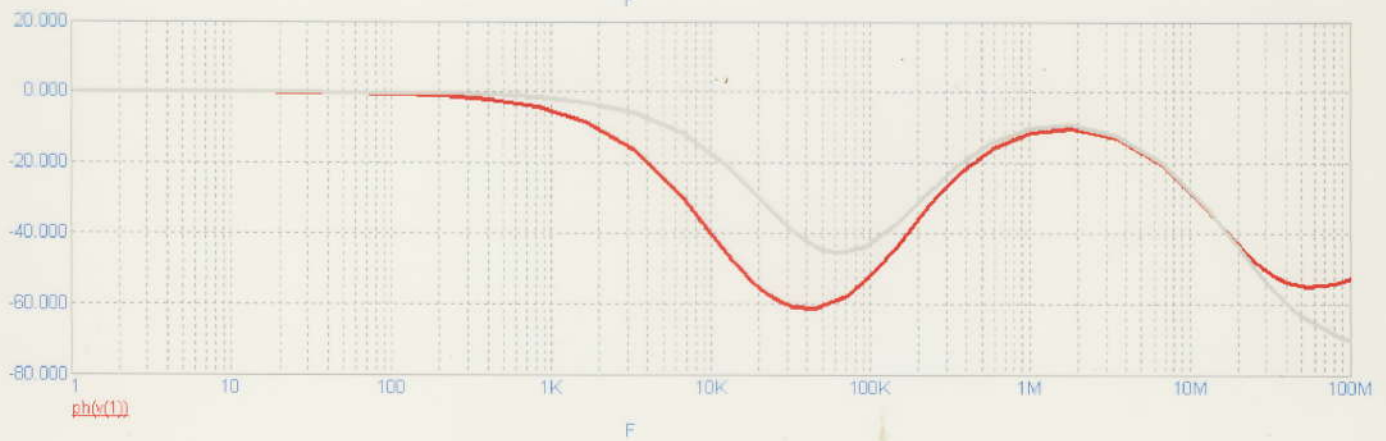
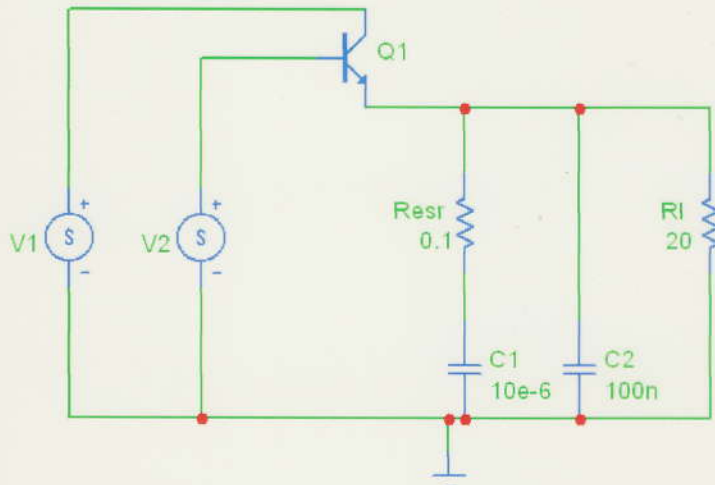
- Einsatz eines OPV als Fehlerverstärker, OPV-Pol liegt bei wenigen 10 Hz
- dominanter Pol des Gesamtsystems ist der dominante Pol des OPV

**Folien** Dimensionierung der Fehlerbestenken, Transientverhalten

- kritischer Fall: hohes  $C_2$ , niedrige Last (2. Pol bei tiefen Frequenzen)

# Linearregler mit npn-Laengstransistor

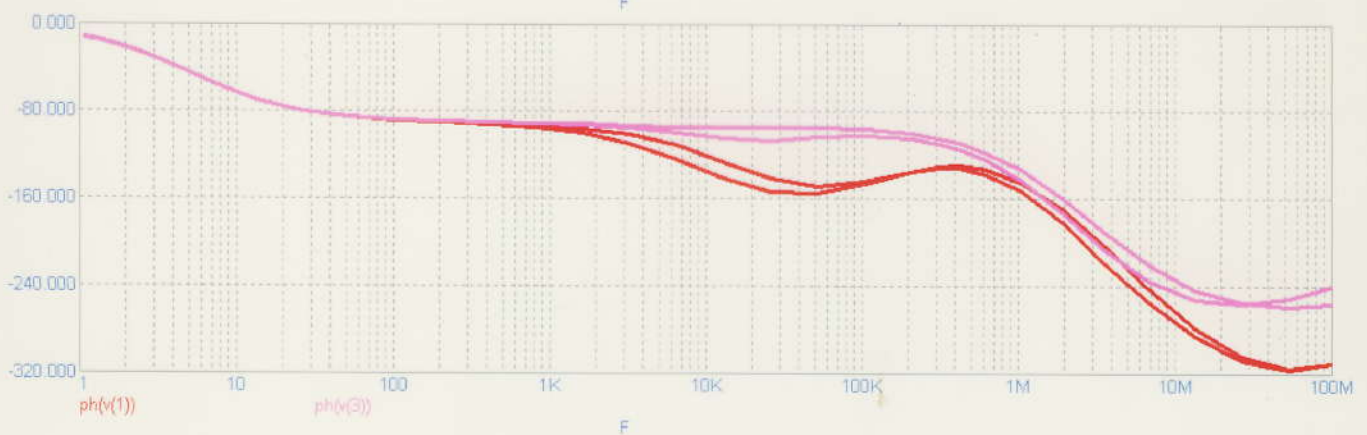
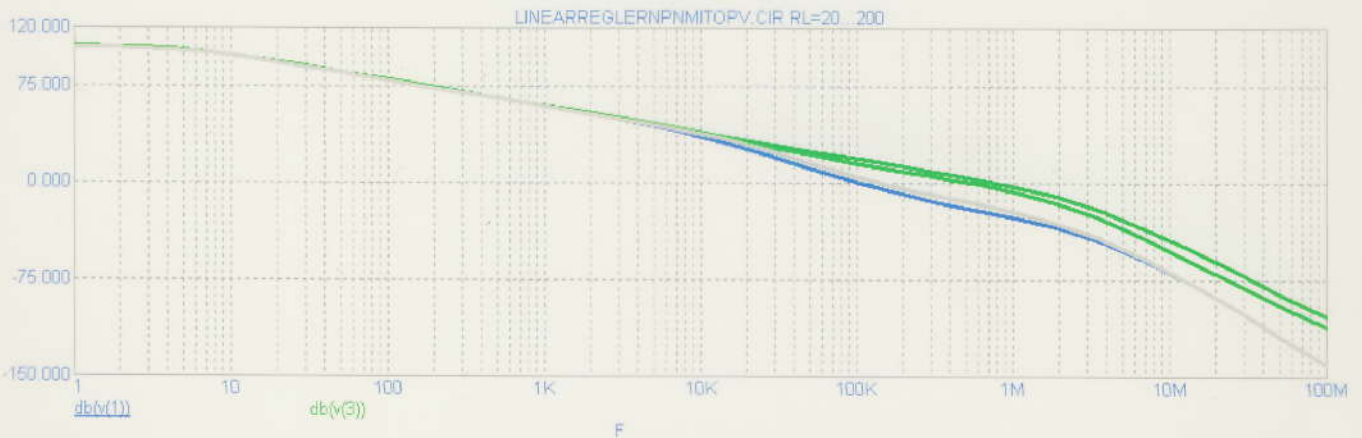
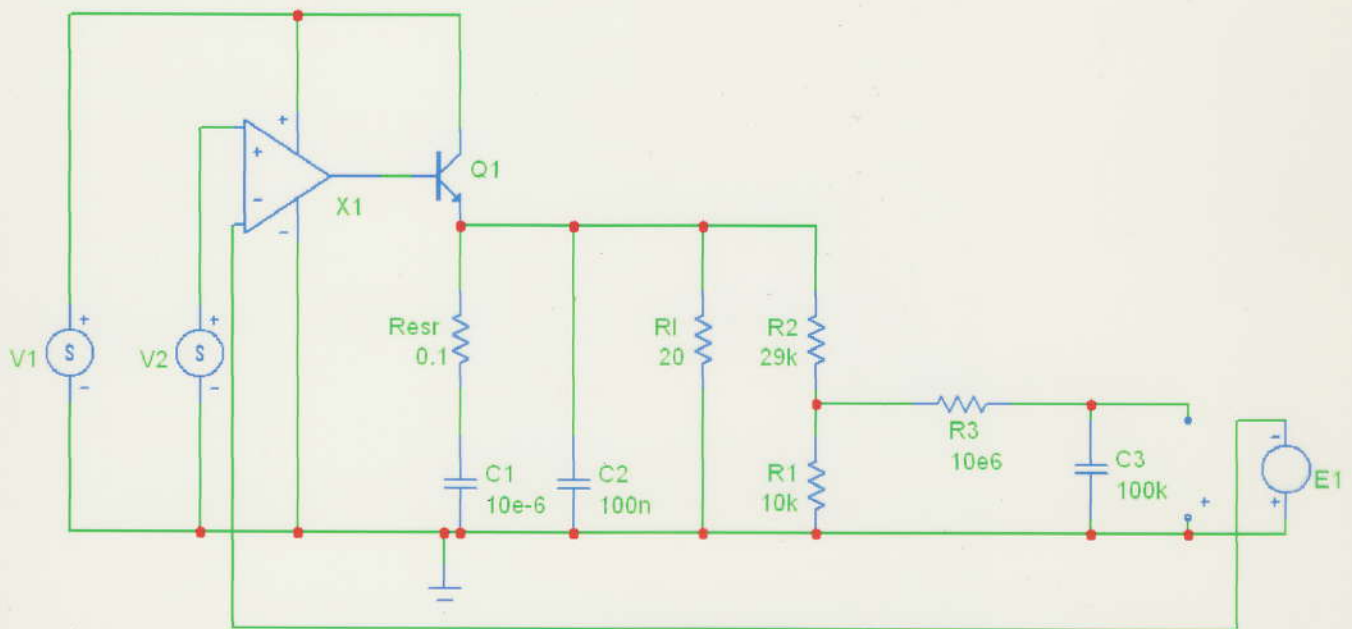
## AC-Verhalten der Strecke





# Linearregler mit npn-Laengstransistor

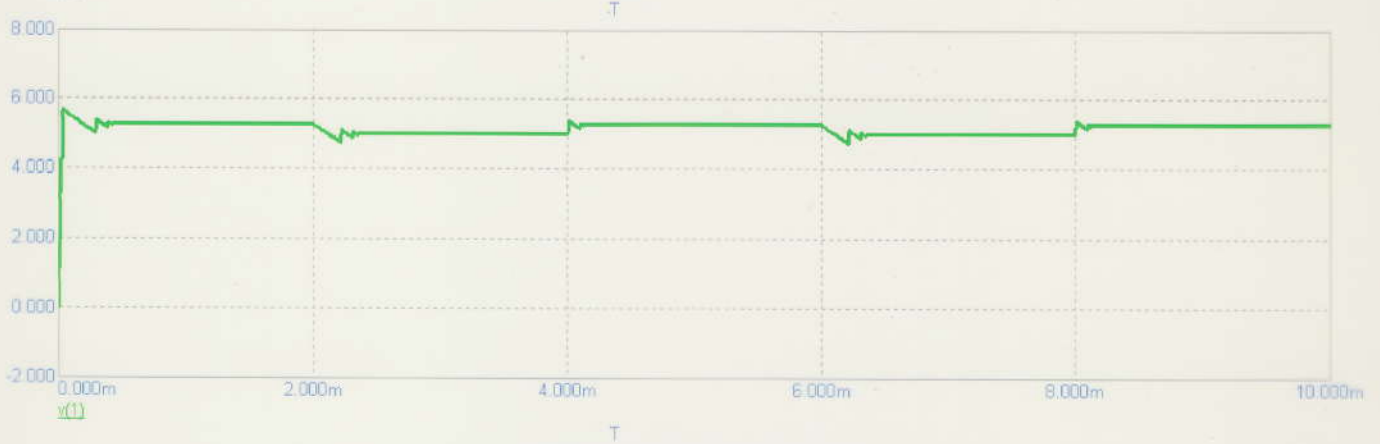
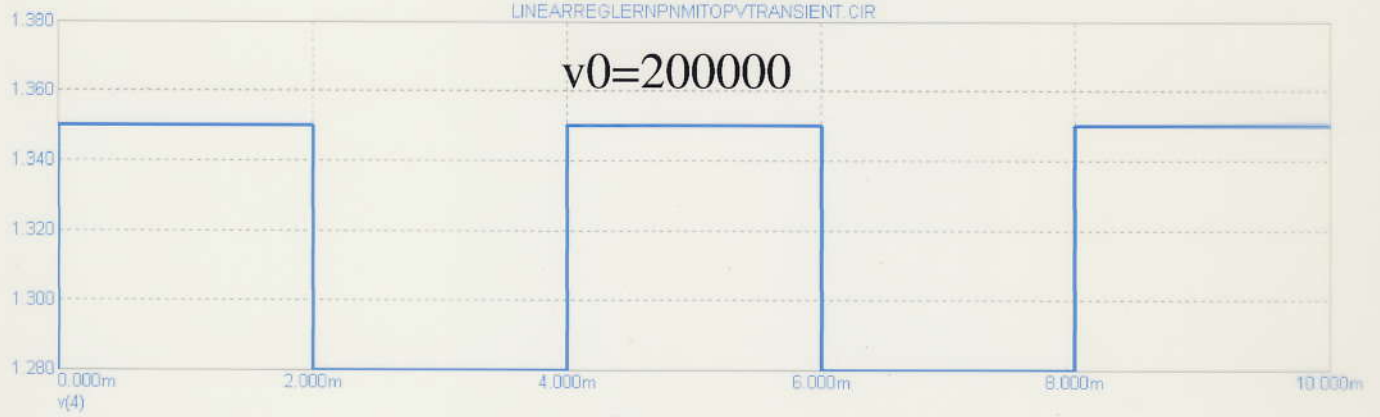
## AC-Verhalten der Strecke mit Fehlererstaerker



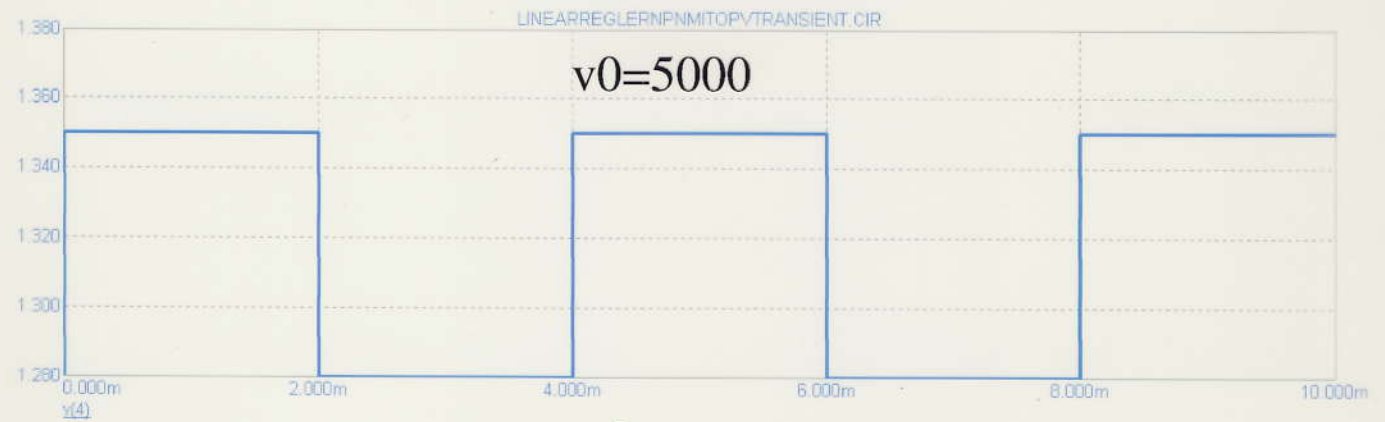
# Transientverhalten

LINEARREGLERNPNMITOPVTRANSIENT.CIR

$v_0=200000$



$v_0=5000$



## Ausgangsimpedanz

$$r_a' = \frac{r_a}{g}$$

$$Z_a = \frac{R_L}{1+g_m R_L} \cdot \frac{1+sC_2 R_{ESR}}{1+s\left(R_L \frac{C_1+C_2}{1+g_m R_L} + C_1 R_{ESR}\right) + s^2 \frac{C_1 C_2 R_L R_{ESR}}{1+g_m R_L}}$$

Verstärker-Modell mit einem Bl:  $V(s) = v_o \frac{1}{1+s\tau_a}$   $k = \frac{R_2}{R_1+R_2}$

$$Z_a' = \frac{R_L}{1+g_m R_L} \cdot \frac{1+s\tau_a}{1+k v_o \frac{1+s\tau_a}{(1+s\tau_{tr})(1+s\tau_{p1})(1+s\tau_{p2})}}$$

$$Z_a = \frac{R_L}{(1+g_m R_L)(1+k v_o)} \cdot \frac{(1+s\tau_a)(1+s\tau_{tr})}{(1+s\tau_{tr})(1+s\tau_{p1})(1+s\tau_{p2}) + k v_o (1+s\tau_a)}$$

Bl des Verstärkers ist Nullstelle in der Ausgangsimpedanz

## Folie 12

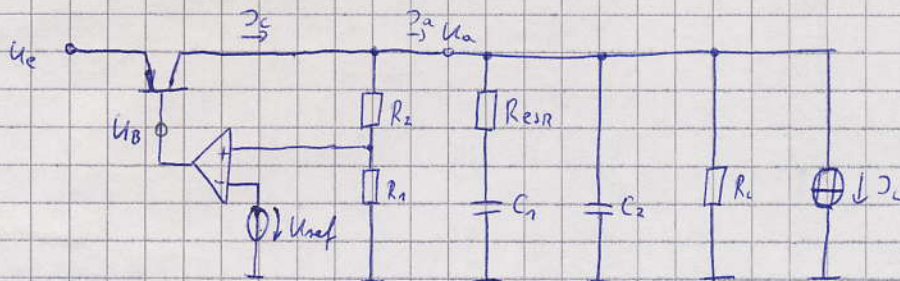
- Nachteil der Reglerstrukturen mit NPN-/NMOS Cingelelement:

hoher Spannungsabfall (>1V) über Cingelement notwendig, da

$U_B$  aus der >  $U_a$  aus der Versorgungsspannung gewonnen wird

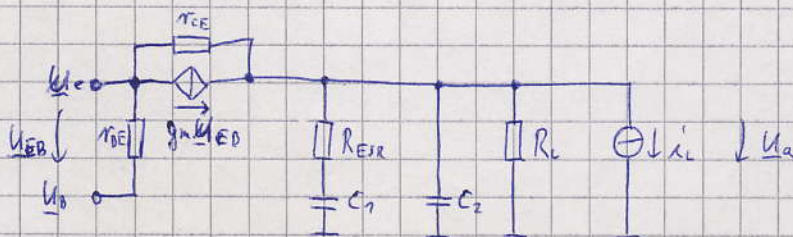
↳

### Low-Drop-Regler



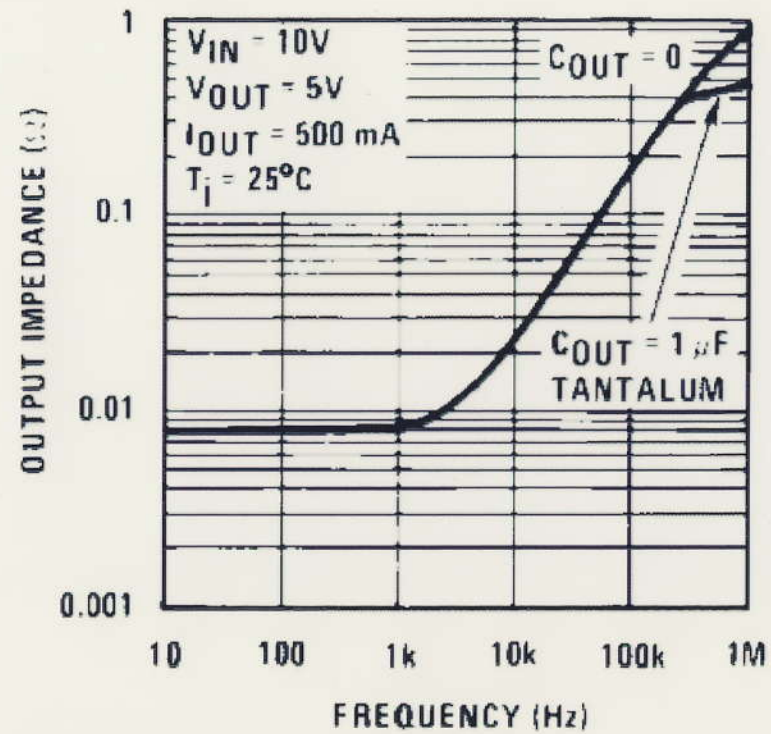
- minimaler Spannungsabfall über Cingelement:  $U_{CEmin} \approx 0,2V$

Verhalten der Strecke:



$$g_m (U_e - U_B) + \frac{(U_e - U_a)}{r_{CE}} = i_L + \frac{U_a}{\frac{1}{R_L} + sC_2 + \frac{sC_1}{1+sC_1 R_{ESR}}}$$

## Output Impedance



$$U_a = \frac{(U_e (g_m + \frac{1}{r_{CE}}) - g_m U_D - \beta_L) R_L (1 + s C_1 R_{ESR})}{\frac{R_L}{r_{CE}} + 1 + s (C_1 (R_L + R_{ESR} (1 + \frac{R_L}{r_{CE}})) + C_2 R_L) + s^2 C_1 C_2 R_L R_{ESR}}$$

$$U_a(0) = \frac{R_L}{1 + \frac{R_L}{r_{CE}}} (g_m r_{CE} - g_m U_D - \beta_L) \rightarrow \text{Spannungsteilerverhalten für } M_B = M_C = 0$$

$$\text{Nullstelle: } s_n = -\frac{1}{C_1 R_{ESR}}$$

$$\text{Pole: } s_{p1/2} = \frac{-1 \left( \frac{1}{C_2 R_{ESR}} + \frac{1}{C_2 R_L} + \frac{1}{C_2 r_{CE}} + \frac{1}{C_1 R_{ESR}} \right) \pm \sqrt{1 \left( \frac{1}{C_2 R_{ESR}} + \frac{1}{C_2 R_L} + \frac{1}{C_2 r_{CE}} + \frac{1}{C_1 R_{ESR}} \right)^2 - \frac{1}{C_1 C_2 R_{ESR} r_{CE}} - \frac{1}{C_1 C_2 R_{ESR} R_L}}}{2}$$

$$\text{Beispiel } U_a = 5V, U_D = 50V, R_L = 20\Omega, C_1 = 10\mu F, R_{ESR} = 0,1\Omega, C_2 = 100nF$$

$$f_n = 15,9 \text{ kHz}$$

$$f_{p1} = 862 \text{ Hz}$$

$$f_{p2} = 16 \text{ MHz}$$

$$R_{L2} = 200\Omega:$$

$$f_n = 15,9 \text{ kHz}$$

$$f_{p1} = 86 \text{ Hz}$$

$$f_{p2} = 16 \text{ MHz}$$

→  $f_{p1}$  bei sehr niedrigen Frequenzen

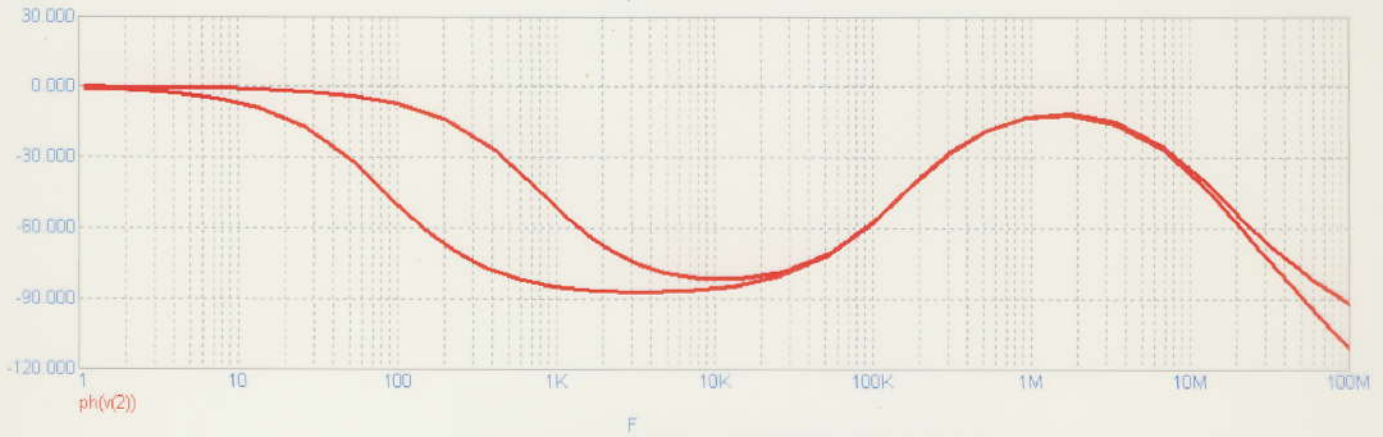
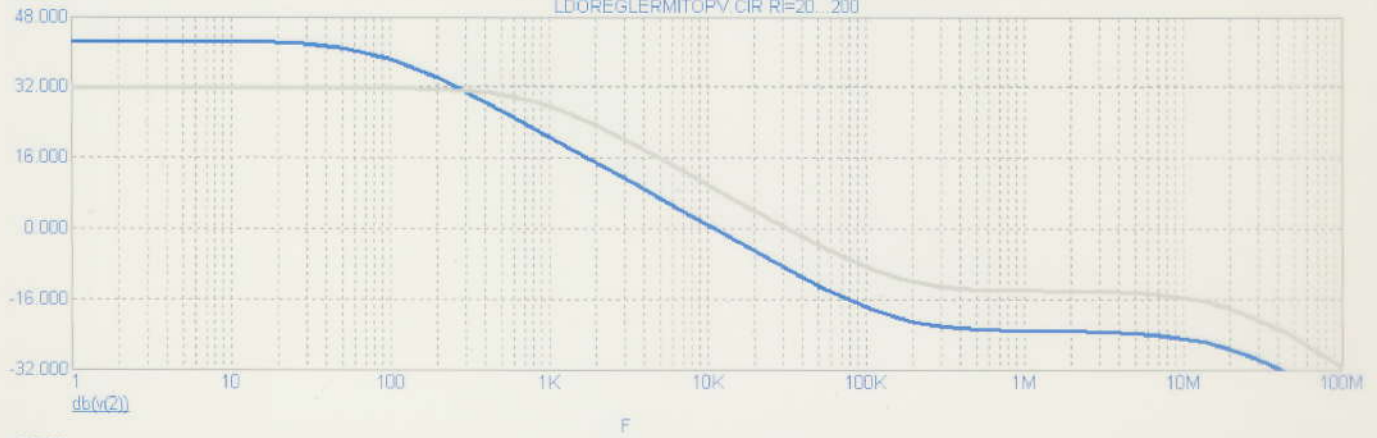
→ muß dominanter Pol der Gesamtstrecke werden, um akzeptable Einschwingzeiten zu erzielen

Folie AC-Verhalten, Strecke, OPV

Folie AC-offen, Lastspannung

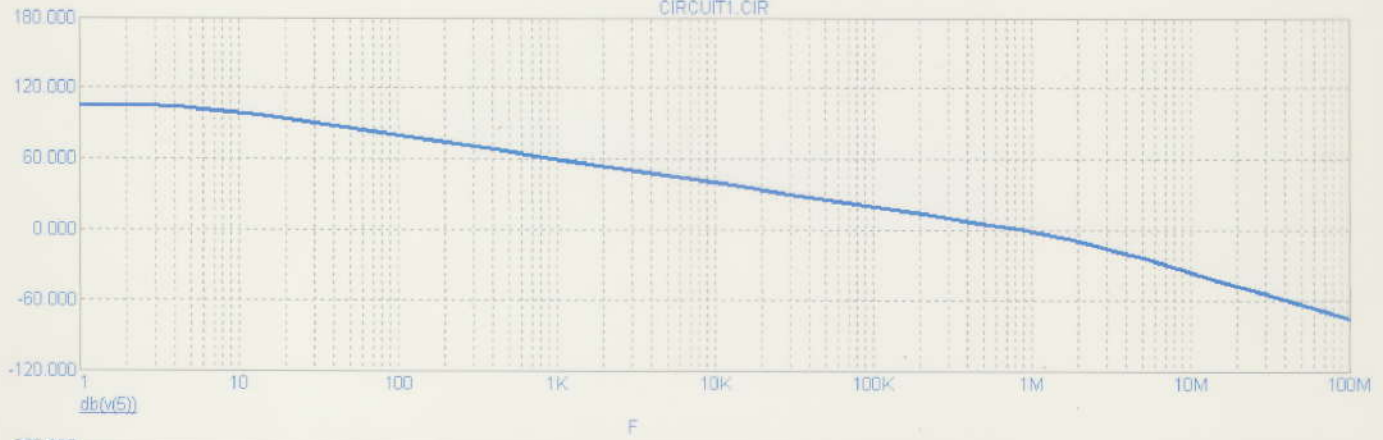
# LDO-Regler, AC-Verhalten, Strecke

LDOEGLERMITOPV.CIR RI=20\_200



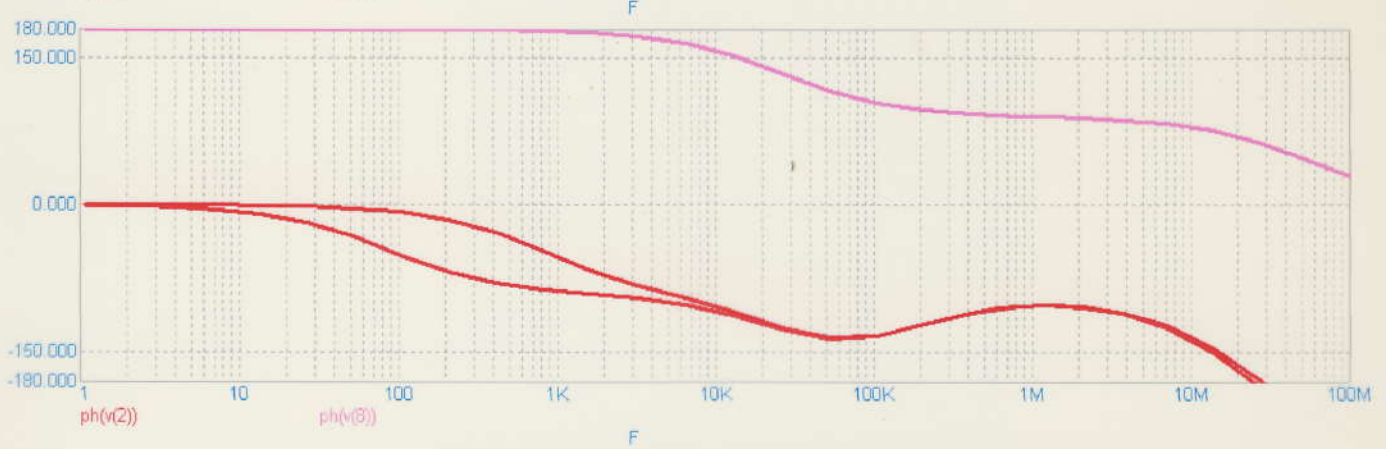
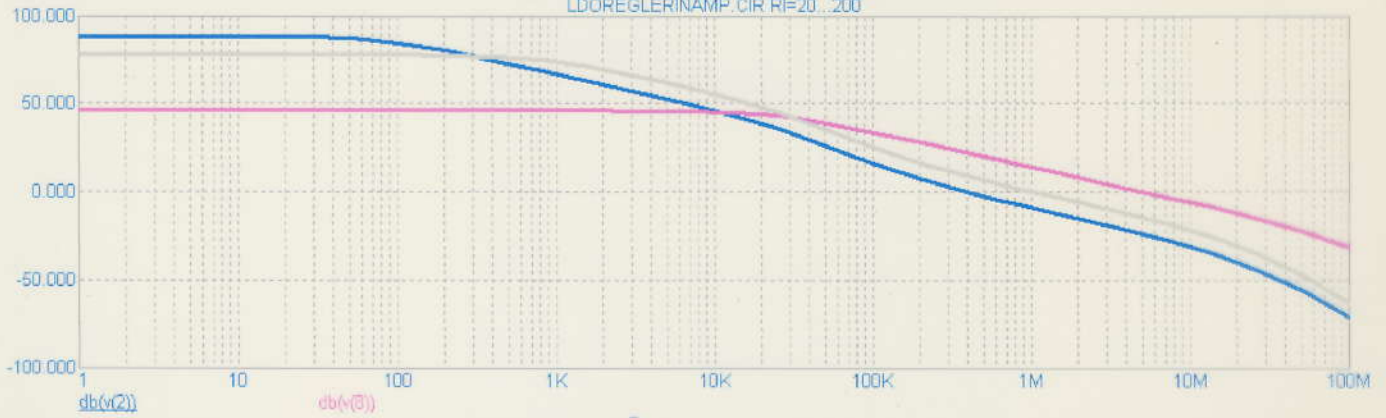
# AC-Verhalten, uA 741

CIRCUIT1.CIR



# LDO-Regler, AC-Verhalten, offene Kette

LDOREGLERINAMP.CIR RI=20..200



# Verhalten bei Lastsprung, LDO-Regler

LDOREGLERLASTSPRUNG.CIR

